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Experimental investigating effect of Froude number on hydraulic parameters of vertical drop with supercritical flow upstream

Rasoul Daneshfaraz[1,*] , Sina Sadeghfam[1], Vadoud Hasanniya[2]

[1] Department of Civil Engineering, Faculty of Engineering, University of Maragheh, Maragheh, Iran
[2] Graduate Student, University of Maragheh, Maragheh, Iran

ABSTRACT: The supercritical flow as the inflow at upstream of the vertical drops can produce a considerable impact, destruction and erosion at the downstream of drops influence by fall and collision. Therefore in this study, with the aim of evaluation and prediction of the general behavior of hydraulic parameters in vertical drops with the supercritical flow at upstream, 55 experiments were carried out with various discharges and Froude numbers. The experimental results indicated that in the supercritical flows, by increasing the relative critical depth and Froude numbers, the relative length of drop, the relative length of splashing and the relative total length of the drop were increased. However, by increasing the relative critical depth and Froude number, the relative depth of the pool initially increases and then decreases, and the relative energy loss is initially reduced and then increased. By increasing the Froude number at a constant relative critical depth, the relative length of the drop, the relative length of splashing, the relative total length of drop and the relative energy loss increases, and relative depth of the pool decreases. Also, in a constant Froude number, by increasing the relative critical depth, the relative length of drop, the relative length of splashing, the relative total length of the drop and relative depth of the pool increase, and the relative energy loss decreases. Meanwhile, the results of the present study with the larger range of Froude number were compared with the previous studies and were studied the reasons for the agreement or disagreement.

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1. INTRODUCTION

A vertical drop is a hydraulic structure that reduces the longitudinal slope to the level of the design slope. This structure is used in areas with mountainous topography to transfer water from the upstream to the downstream of a canal. The inflow, as an important design parameter, is usually sub-critical in the upstream of the vertical drops. However, in some cases due to the topographical conditions of an area, installation of a gate before the drop, or construction of drops with short longitudinal distances, the flow pass through the upstream of this structure with a supercritical regime.

The most of the studies on vertical drops by researchers such as Gill [1], Rajaratnam and Chamani [2], Chamani et al [3] focused on the hydraulic parameters of the vertical drops with a subcritical inflow at upstream. But there are also some studies on investigating hydraulic parameters of vertical drops with the supercritical flow at upstream such as Chamani and Beirami [4], Tokyay and Yildiz [5], and Liu et al [6]. An overview of these studies indicates the differences in the results presented for the vertical drops with supercritical flows. Therefore, the current research was carried out with the purpose of studying the behavior of hydraulic parameters in a vertical drop with an upstream supercritical flow and comparing the results with the former research.

*Corresponding author's email: daneshfaraz@yahoo.com

2. MATERIALS AND METHODS

Experiments on vertical drops with supercritical flow were carried out in a laboratory flume with a length of 5 m, a width of 0.3 m and a height of 0.45 m. In the Table (1) the main characteristics of the vertical drop with a supercritical flow are presented.

3. RESULTS AND DISCUSSION

3.1. The total length of the drop

The distance between the splash point to the brink of the drop, which is known as the total length of the drop in the supercritical free overflow, is calculated as the sum of the impinging jet distance to the bottom from the brink and the length of a splash. Fig (1) depicts the relative total length of the drop with respect to relative critical depth and Froude number.

The results show that the behavior of total length of drop with respect to the changes in relative critical depth and Froude number are similar to the parameters of the length of drop and the length of the splash. With an increase in relative critical depth and Froude number, the values of these parameters also increased. Moreover, for a constant relative critical depth, the relative total length of the drop increased with an increase in Froude number. For a constant Froude number, increasing the relative critical depth leads to an

Table 2. Characteristics of the experimental model

Model's description						
Supercritical flow generator gate				vertical drop		
Opening's Height (cm)	Thickness (cm)	Height (cm)	Width(cm)	Height (cm)	Width (cm)	Length (cm)
1.3-1.7-2.1	0.3	65	30	15	30	120

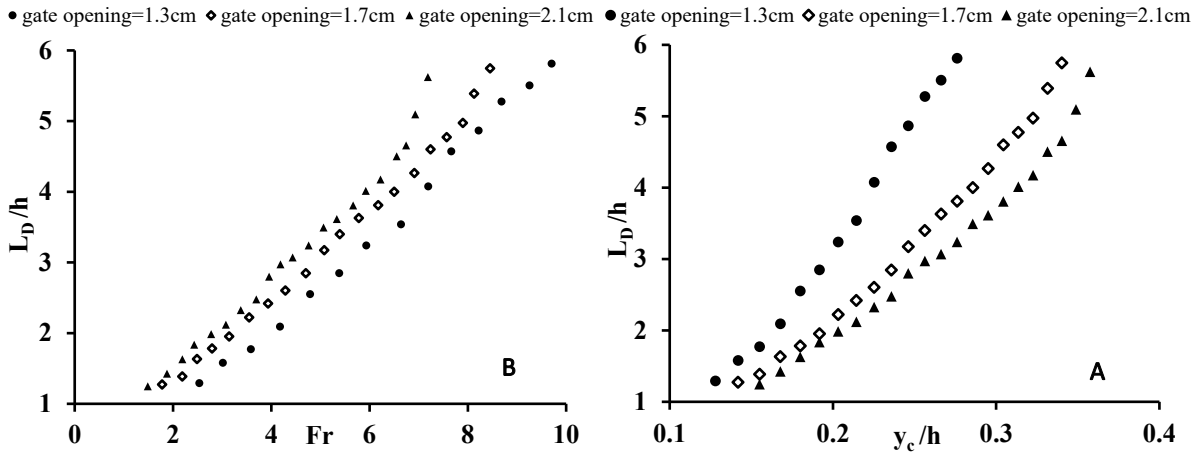

Fig. 1. Variation of the total relative length of drop to a) Relative critical depth and b) Froude number

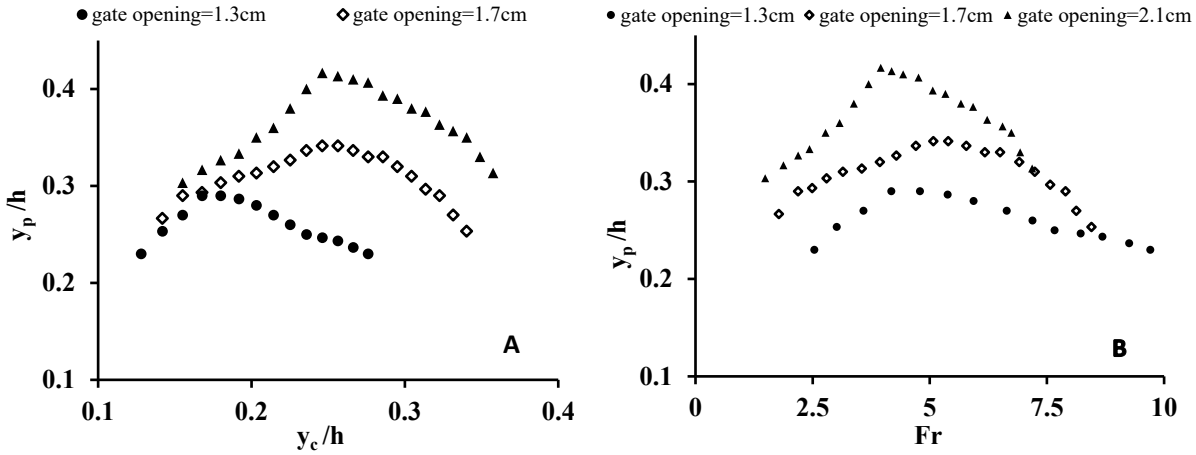

Fig. 2. Variation of relative depth of pool versus: a) Relative critical depth; b) Froude number

increase in the value of this parameter.

3.2. Pool depth

Fig. (2-a-b) represents the relative changes in pool depth below the falling jet with respect to relative critical depth and Froude number. According to Fig. (2-a), it can be observed that for a constant gate opening, by increasing in the relative critical depth and Froude number, the relative pool depth increases initially and then decreases.

The results show that by increasing Froude number for a constant critical depth, the relative depth of the pool decreases. Also, for a constant Froude number, increasing the relative critical depth leads to an increase in the relative pool depth.

3.3. Relative energy loss

Relative energy loss, which is the main function of vertical drops, usually occurs as a result of jet impact to the bottom of the pool and turbulent flow in the pool below the jet. In vertical drops with the upstream supercritical flow, the strike to the bottom happens with a higher intensity as a result of the higher velocity of flow, which leads to a splash of water after the jet strikes the bottom of the pool. The splash in the downstream section, can increase the energy loss by

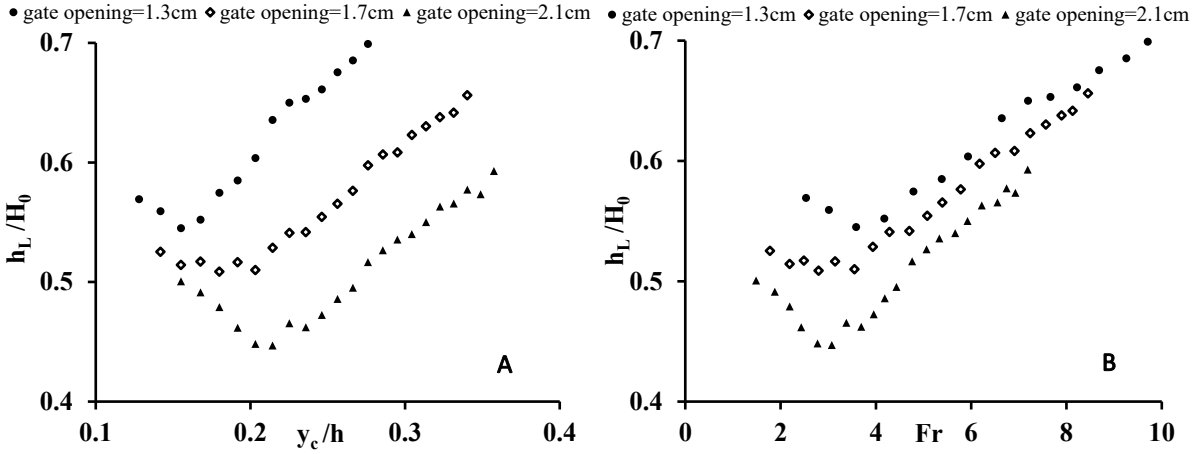

Fig. 3. Variation of relative energy loss versus: a) Relative critical depth; b) Froude number

increasing the turbulence and the air-water contact surface. Fig. (3-a-b) shows the changes in relative energy loss with respect to relative critical depth and Froude number.

According to Fig. (3-a-b) with an increase in the relative critical depth and upstream Froude number for a constant gate opening, the amount of energy loss decreases initially, then increases. Also, the results show that in a constant relative critical depth, with a decrease in the gate opening and the increase in Froude number, the amount of relative energy loss increases. Also, for a constant Froude number, increasing the opening of the gate, which has a direct relationship with the relative critical depth, leads to a decrease in the amount of relative energy loss. The reason for the increased energy loss after an increase in Froude number is the increased amount of flow splash.

By comparing the behavior of relative energy loss of the present research to the research by Chamani and Beirami [4] it is found that the results of the present research are in no way consistent with the results obtained by Chamani and Beirami [4]. Apparently, the reason for the great inconsistency between the results obtained by the two studies is that the effect of the flow splash after the jet strikes the bottom was not accounted for in the research by Chamani and Beirami [4]. Also, the comparison between the energy dissipation behavior of the present study and Tokyay and Yildiz [5] indicates a similarity in the decreasing energy loss with the increase in Froude number up to 4. However, the amounts of relative energy loss obtained by Tokyay and Yildiz [5] are bigger than the laboratory results of the present study.

4. CONCLUSION

The following results were obtained for hydraulic parameters of vertical drop using the laboratory model of the present research:

1- The relative length of drop, relative length of the splash, and the relative total length of drop increased with an increase in the relative critical depth and Froude number.

2. Increasing the relative critical depth and Froude number, the depth of pool initially increased and then decreased. At the same time, the relative energy loss initially increased and then decreased by increasing the relative critical depth and Froude number.

3. The results of the present study with respect to the effects of the upstream Froude number on the behavior of relative energy loss were in no way consistent with the research by Chamani and Beirami [4] and the only similarities with the results of the study by Tokyay and Yildiz [5] were the overall behavior of energy loss for Froude numbers smaller than 4.

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