Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/02/jls.htm
2015 Vol. 5 (S2), pp. 319-323/Ghamari and Nekoufar
Research Article

OPTIMUM DESIGN OF TYPE I STILLING BASINS

***Ammar Ghamari and Kouros Nekoufar**
Islamic Azad University, Chalous Branch, Chalous, Iran
**Author for Correspondence*

ABSTRACT
Stilling basins are one of the most commonly used structures for the energy dissipation of downstream flow in dams. Stilling basin is one of the elements that cause reduction in flow velocity and also energy. The purpose of designing and constructing these structures is to control and dissipate energy, and to reduce sequent depth in a way that avoid submerged jump but also avoid drawing hydraulic jump into potential. In this paper, we sought to reduce the severe pressure fluctuations in order to minimize damage to the stilling basin. In this project we used FLUENT software, which is one of the most powerful soft wares in this field. In this paper, we simulated the hydraulic jump index for type I stilling basin which included investigating the impact of Froude number, spillway length and width on the hydraulic characteristics and the water surface profile.

Keywords: *Hydraulic Jump, Hydrostatic Pressure, Slope of the Channel Bed, Stilling Basins*

INTRODUCTION
When flooding occurs, the downstream flow develops a risk of scouring and consequently put the downstream structures into the risk of damages. Stilling basin is one of the most widely used energy dissipation structures, by which energy is reduced before reaching the downstream structures. The water which is overflowing downstream over the spillway has a potential energy caused by its altitude, and after it starts flowing down this potential energy converts to kinetic energy (Shojaeian and Hasanzadeh, 2011). The high velocity of downstream flow is the reason behind the formation of this kinetic energy. This energy must get reduced or dissipated; otherwise it will cause scouring and erosion in the outlet structures. This erosion in some cases may even appear in the form of small tunnels below the dam body and lead to its destruction (Shafahianbajestan, 2004). Hydraulic jump is always associated with severe energy loss. During sudden hydraulic jump that is supercritical, the water depth significantly increases and after this increase in depth, supercritical flow becomes sub critical flow. In such cases, if were duce the flow velocity by the help of facilities such as stilling basin, the natural river bed downstream will be less affected by erosion. Construction of stilling basin is one of the possible and normal measures for controlling the downstream flow of hydraulic structures (Stevens, 1944). The purpose of this paper is to reduce the severe pressure fluctuations in order to minimize damage to the stilling basin.

Literature Review
Stilling basin is one of the most commonly used structures for the energy dissipation of downstream flow in dams. It is a short section of a floored channel (Shafahianbajesta, 2009). It is worth mentioning that the dimensions of the chute block in stilling basin play an important role in the type and size of these structures. The elements such as central blocks in stilling basin dissipate more energy and reduce the sequent depth of the hydraulic jump. The impact of these blocks depends on their position, height, and the opening space between them (Varjav and Peyman, 2008). As we know, water flows down over the spillway and this water has a considerable amount of potential energy. This potential energy in the water which is flowing downstream will be converted into kinetic energy. The high velocity of downstream flow is the reason behind the formation of this kinetic energy. This energy must get reduced or dissipated; otherwise it will cause scouring and erosion in the outlet structures. This erosion in some cases may even appear in the form of small tunnels below the dam body and lead to its destruction. So we reduce the flow velocity by the help of facilities such as stilling basin to reduce the erosion in the river bed. As mentioned before, stilling basin is one of the elements that can reduce the flow velocity and energy. The purpose of designing and constructing these structures is to control and dissipate energy, and to reduce sequent depth in a way that avoid submerged jump but also avoid drawing hydraulic jump into potential (Shafai, 2009).

Types of the stilling basins:
These basins are built in a way that first cause an increase in their throw length and second, cause the throw to be in the form of…. There are several types stilling basins which are mentioned below:

- Stilling basin Type I
- Stilling basin Type II
- Stilling basin Type III
- Stilling basin Type IV
- Stilling basin Type V
- SAF Stilling basin
- USBR Stilling basin

MATERIALS AND METHODS

Methodology

We studied the pressure fluctuations in the stilling basin by the use of fluent software.
In this simulation, the water inlet boundary condition was considered in the form of (mass flow rate), the basin roof was considered as (pressure-inlet), and the output was considered as (pressure outlet). Hypotheses of this study are as follows:

- Hydraulic jump is a phenomenon which is accompanied with energy loss.
- The maximum pressure starts on the chute and continues until the beginning of the basin.
- Does the reduced pressure and velocity fluctuations causer educed damaging to the stilling basin?
- Does the rotation and displacement of hydraulic jump location affect the pressure fluctuations?

Using the Froude number equation (equation 1-4), we can determine the incoming fluid velocity for different Froude numbers:

$$\mathbf{Fr}=\frac{V}{\sqrt{gy_1}} \qquad (1)$$

V: flow velocity
G: acceleration of gravity
Y: flow depth
The output rate can also be obtained from the equation (2-4).

$$\dot{m} = \rho_{water} V A_{water.in} \qquad (2)$$

Rngk_4 method was used to model the turbulent flow and (enhanced wall treatment) was used to model the behavior of the fluid near the wall.
Froude number has a decisive role in the length of hydraulic jump and the extent of energy dissipation. It must to be noted that several factors such as channel bed slope, roughness height, flow rate and velocity in sequent depth, etc. are all effective on hydraulic jump, but the Froude number plays a greater role. It must be mentioned that Type II, III, IV, V basins cover the full range of Froude number, but Type I stilling basin is limited to a range of Froude number or flow velocity.
Studies have shown that this type of basin, is only effective up to the Froude number of 3, and does not cover a larger Froude number (Arabhabhirama, 2009).
As shown in Figures3-1, 4-4, and 5, for the Froude number of 2 the length of jump is 10 meters, and for the Froude number of 4 the length of jump is 35 meters, and for the Froude number of 6 the length of jump is over 50 meters; this means that an increase in Froude number causes an increase in the length of jump.
According to the following formula:

$$E_1 = \mathrm{E}_2 + \mathrm{h}_{\mathrm{L}_{12}} \qquad (3)$$

$$\frac{v_1^2}{2g} + y_1 = \frac{v_2^2}{2g} + y_2 + \mathrm{h}_{\mathrm{L}_{12}}$$

In this equation:

Y_1: water depth in the supercritical state
Y_2: water depth in the subcritical state
Therefore, efforts should be made to reduce the effect of length of jump and to control the effect of fluid kinetic energy to dissipate it as soon as possible.
This energy dissipation will be accompanied by sudden change in depth (increasing depth), followed by increasing turbulence in the flow, which not only will cause significant energy loss but It will also significantly reduce the amount of flow velocity (Posey & Hsing, 2010).

RESULTS AND DISCUSSION

Results Analysis

Impact of the Froude Number on the Hydraulic Jump in the Basin
In this study, basin length is 50 meters, its width is 3 meters and its height is4.28284.Thecontours of water volume fraction for different Froude numbers in Z=-1.5 are shown below (Khadar and Rajagopals, 2008).

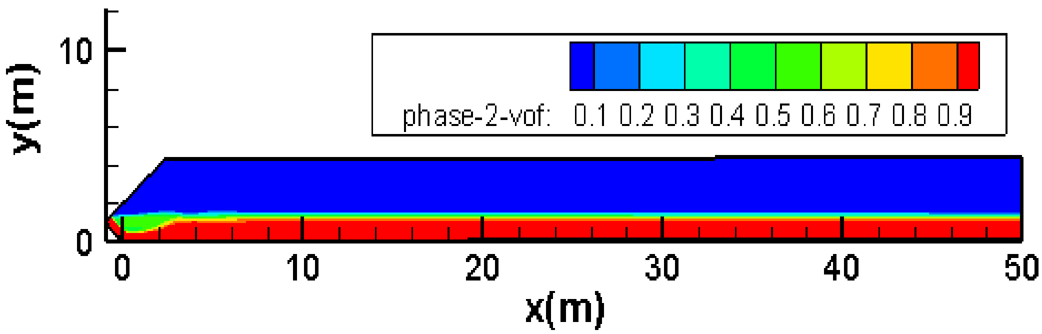

Figure 1: Contour of water volume fraction for the Froude number of 2

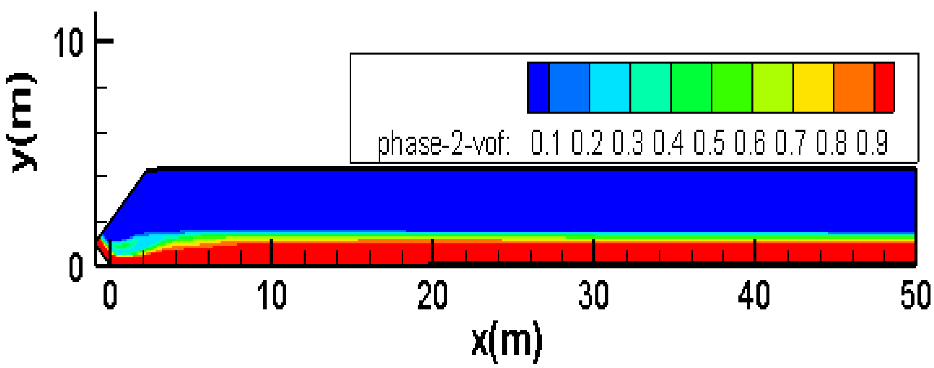

Figure 2: Contour of water volume fraction for the Froude number of 3

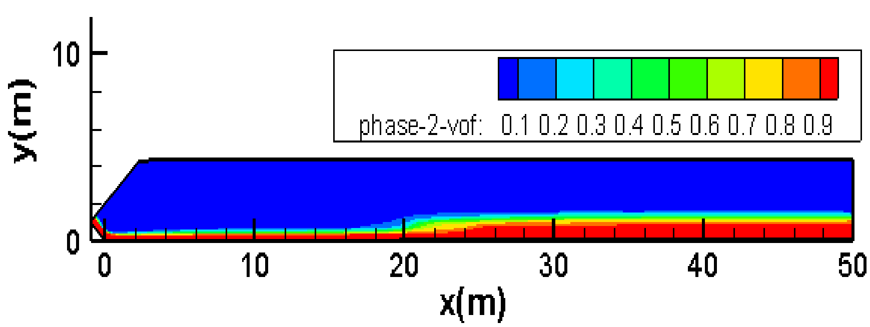

Figure 3: Contour of water volume fraction for the Froude number of 4

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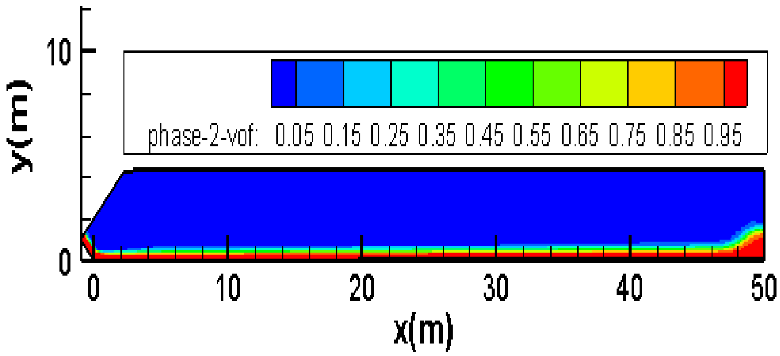

Figure 4: Contour of water volume fraction for the Froude number of 5

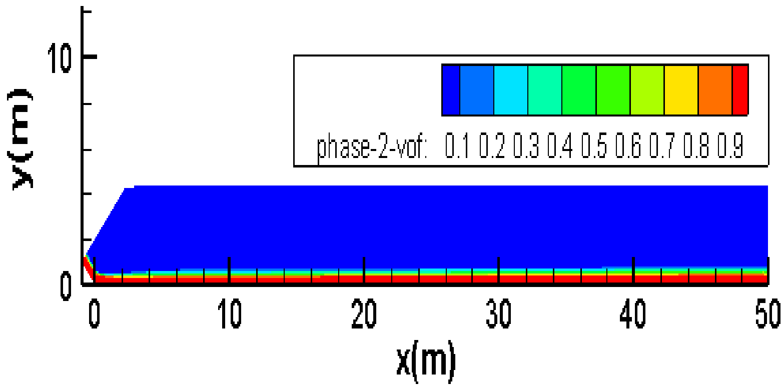

Figure 5: Contour of water volume fraction for the Froude number of 6

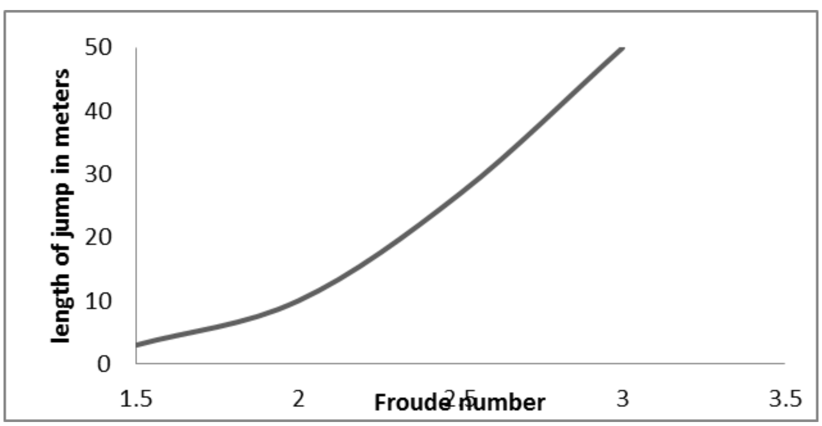

Chart 1: Analysis of length of jump in terms of Froude number

Conclusion

In this study, length of jump was analyzed in different conditions. Figures 1, 3 and 5 showed that higher value of The Froude number results in increased length of jump. In Figure 1, it was observed that for the Froude number of 2 the length of jump was 10 meters, and for the Froude number of 4 the length of jump was 35 meters, and for the Froude number of 6 the length of jump was over 50 meters. In other words, the higher length of jump results in increased kinetic energy in the fluid and consequently it takes much longer to dissipate this energy. As we know, When the Froude number is Fr<3, the wave form incomplete and weak jumps will occur. With lower values of Froude number hydraulic jump will happen near the overflow toe which will cause higher energy dissipation and lower extent of erosion for the basin body. But if the hydraulic jump occurs in greater distance, lower amounts of energy will be dissipated, and basin body will be under greater risk of damage, which won't be economical and efficient. Type I stilling basin is more compatible with Froude numbers of 1<Fr< 2.5. In these basins, no barriers are used for energy dissipation, so basin length must be four times the sequent depth of hydraulic jump ($4Y_2$) in order to prevent the damage to basin body. If 1.7 <Fr<2.5 then basin length must be equal to the length of jump. Therefore, for optimal and economical design of type I stilling basins, we should avoid large Froude numbers because this type of basin is effective up to the Froude number of 3, and barely covers the larger values.

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