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Experimental study of Energy Dissipation at Vertical Drops Equipped to Vertical Screen with Gradually Expanding at the Downstream

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ABSTRACT: In the present study, the effect of vertical drop, gradually expanding and vertical screens are investigated to increase the energy dissipation efficiency of the flow. The experiments were carried out in a horizontal laboratory flume with a rectangular cross section, two vertical drop heights, and the wall expanding ratios of 0.5 to 1, the porosity ratio of the screens of 40% and 50%, and the range of Froude number of 0.86-0.92. The results showed that the use of screens and the expansion of the walls would increase energy dissipation and decrease the pool and downstream depths. The application of expanding wall, screens and the effect of simultaneous use of screens and expanding walls increases the efficiency of energy dissipation by 25, 44 and 48 percent, respectively. The porosity ratio of the screens is not much efficient in energy dissipation, but it reduces the pool depth and increases the downstream depth. Under the same hydraulic conditions, with increasing drop height, the energy dissipation rate due to the higher impact intensity of the jet passing through the drop or its downstream floor increases and the pool depth decreases. By increasing the discharge, the hydraulic jump formed in the upstream of the screens with a porosity ratio of 40% is submerged and moves upstream. However, in screens, 50% of the jump is free and moves downstream.

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1. INTRODUCTION

The design of energy dissipator in downstream hydraulic structures to reduce deterioration and erosion effects is always an important issue for hydraulic engineers. Vertical drops are the energy dissipators structures used in irrigation and drainage networks. Screens are a porous plate, which is placed vertically in the flow at a specified distance from the supercritical flow generator. Many studies have been carried out on vertical drops [1-3]. Recently, the screens are proposed as energy dissipators in the downstream of hydraulic structures [4-7].

One of the topics studied by various researchers has been to propose methods to increase energy dissipation efficiency in energy dissipator structures such as drops. In recent years, alternative methods of hydraulic jump and stilling basin have been explored, including the use of vertical screens along the flow path. In the present study, the effect of a vertical drop, gradually expanding and vertical screens to increase the energy dissipation are investigated.

2. DIMENSIONAL ANALYSIS

Various parameters affect energy dissipation in a vertical drop with a vertical screen and gradually expanding. Some of which are more important than other parameters. Sections zero and 2 are considered for the energy relationship. Fig. 1

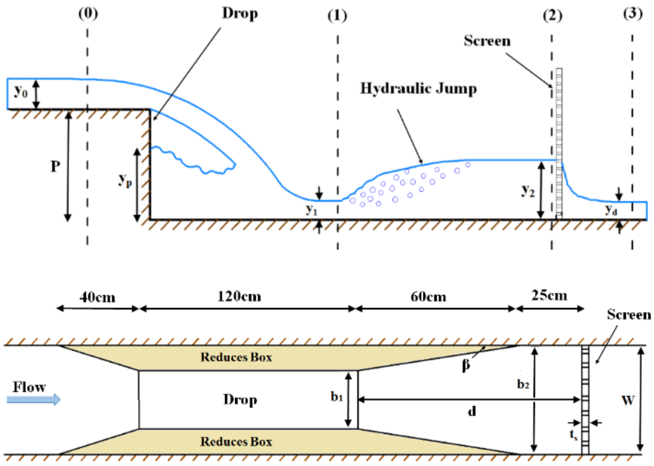

Fig. 1. Vertical drop equipped to vertical screen with gradually expanding

shows the important parameters of the present study. Important parameters on energy dissipation can be written as:

$$\Delta E = f_1(\rho, \mu, g, Q, W, P, N, t, d, y_c, y_0, B, y_d, y_p) \quad (1)$$

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Where, ΔE energy dissipation, ρ Mass density, μ Dynamic viscosity, g Gravitational acceleration, Q flow discharge, W channel width, P drop height, N porosity ratio, t screen thickness, d Distance between screen and drop, y_c critical depth, y_0 upstream depth, B = b1/ b2; gradual divergence ratio, y_d downstream depth, and y_p pool depth.

Finally, According to the Buckingham- π theorem, the relative energy dissipation can be defined as:

$$\frac{\Delta E}{E_0} = f_2(N, B, \frac{y_c}{P}) \tag{2}$$

Also, the relative depths of the pool and downstream the screen are expressed defined as:

$$\frac{y_p}{P} = f_3(N, B, \frac{y_c}{P}) \tag{3}$$

$$\frac{y_d}{P} = f_4(N, B, \frac{y_c}{P}) \tag{4}$$

3. METHODS AND MATERIALS

3.1. Experimental Facilities

Tests were carried out at the rectangular flume with length, width and height 5, 0.3, 0.45m, respectively. The flume's bed and walls are plexiglass to improve flow visibility and reduce friction. The flow in the flume is generated with two pumps with a maximum flow discharge of 450 lit/min connected to two rotameters with ±2% accuracy. Fig. 2 is a schematic that displays the experimental setup.

The vertical drops and gradually expanding were created from glass and vertical screen created from dense polyethylene. Table 1 illustrate dimensional and hydraulic experimental parameters of the experiment.

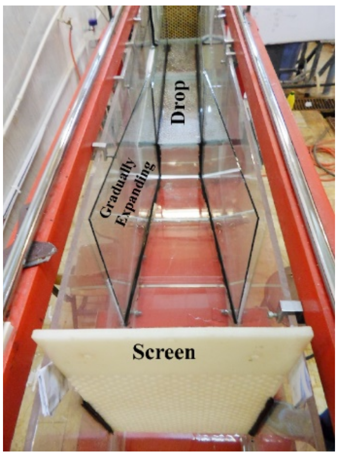

Fig. 2. Illustration of the vertical drop equipped to vertical screen with gradually expanding

Table 1. Dimensional and hydraulic experimental parameters

$B=b_1/b_2$	N(%)	P(m)	y_0(m)	y_c(m)	Fr_0	Q(L/min)
1, 0.8, 0.68, 0.5	40, 50	0.15-0.2	0.021-0.068	0.092-0.058	0.68-0.92	150-800

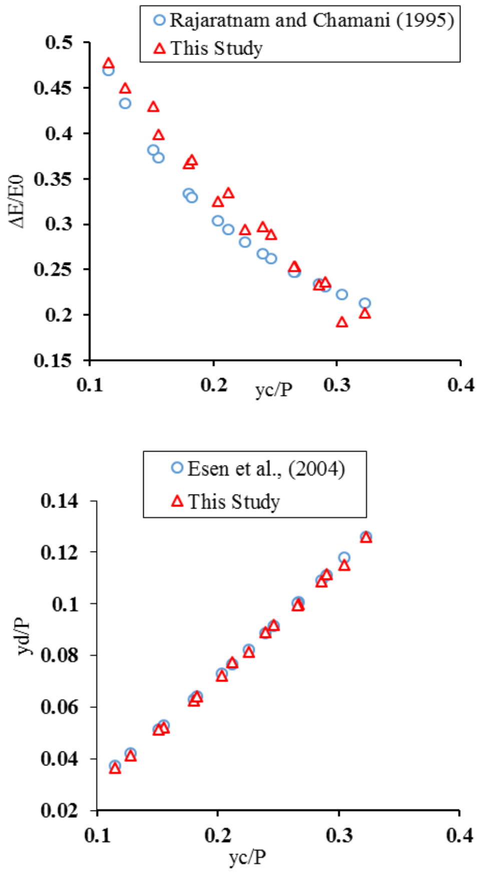

Fig. 3. Comparison of results of vertical drop with previous researchers

4. RESULTS AND DISCUSSION

In the present study, experiments were carried out on a vertical drop with two heights of 15 and 20 cm in the discharge range of 150 to 800 lit/min. The results of this experiment were compared with Rajaratnam and Chamani (1995) and Esen et al. (2004) results. Fig. 3 shows the relative depth downstream and energy dissipation parameters with the researcher's results.

As can be seen in Fig. 3, the results are in good agreement with the studies of Rajaratnam and Chamani (1995) and Esen et al. (2004).

4.1. Influence of vertical screen with gradually expanding on vertical drop energy dissipation

Creating a gradually expanding at the cross section can be a suitable solution to reduce the depth required for the hydraulic jump. On the other hand, the application of gradually expanding coupled with a vertical screen can also reduce the cost of stilling basins. Fig. 4 shows the combined effect of the vertical screen with gradually expanding on the pool depth, downstream depth and the amount of energy dissipation passing through the vertical drops.

It is observed that the application of gradually expanding the wall and place the vertical screen at downstream of the vertical drop increases the energy dissipation and decreases

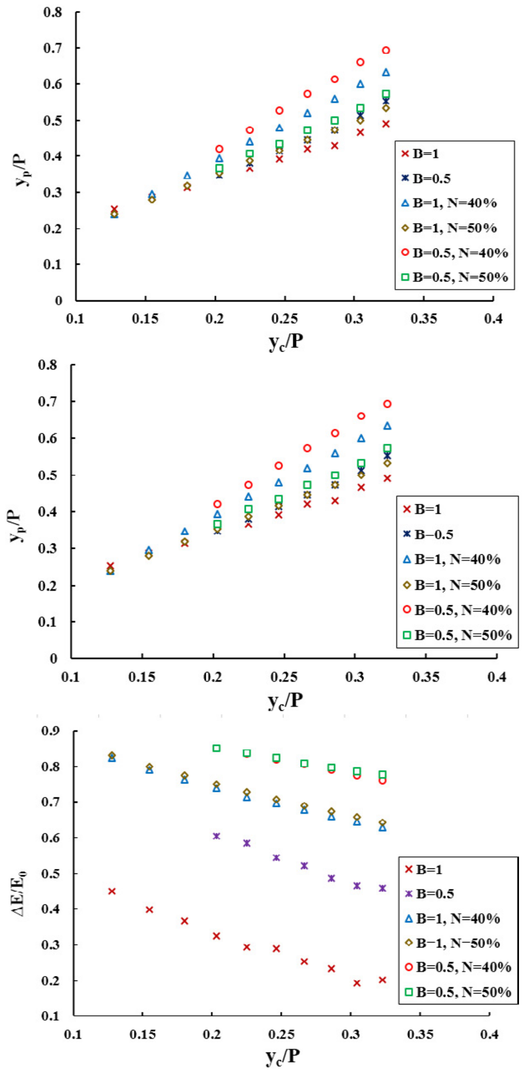

Fig. 4. The combined effect of vertical screen with gradually expanding on downstream hydraulic parameters

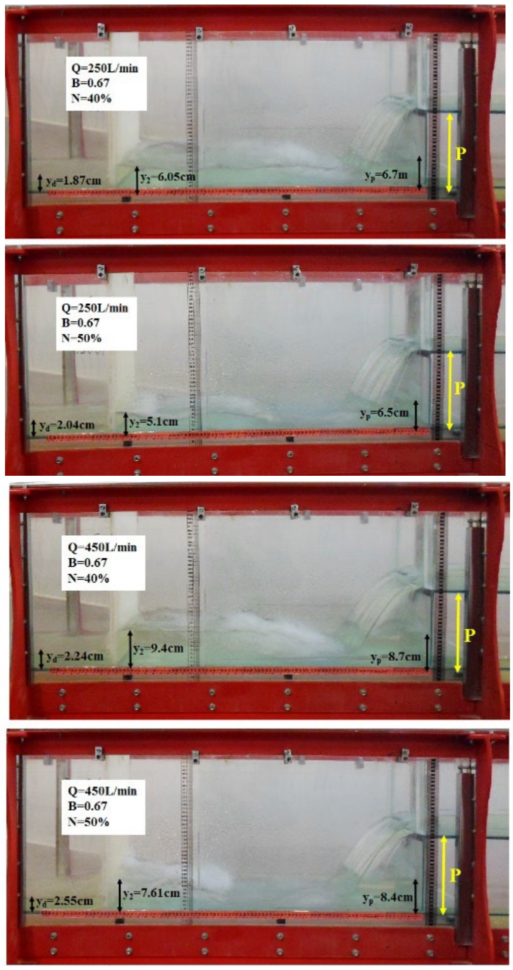

Fig. 5. The flow through the vertical drop in the presence of screen plates and gradually expanding wall

Fig. 6. Jump V-shaped formed after the drop with screens and gradually expanding wall

the pool and the downstream depths. By comparing the porosity ratio of the vertical screen with gradually expanding, it can be seen that increasing the porosity ratio in fixed gradually expanding wall has little effect on each other in energy dissipation, but decreases the pool depth and increases the downstream depth. At constant screen plate porosity ratio, increasing the gradually expanding wall case that increases energy dissipation and the pool depth and decreases downstream depth. Applying the gradually expanding wall and screen, on average, increases 48% of the current energy dissipation efficiency downstream of the vertical drop. Fig. 5 shows the flow through the vertical drop in the presence of the screen and gradually expanding wall beneath it.

As the discharge increases, with the constant gradually expanding wall, the hydraulic jump in the screen plates with a porosity ratio of 40% upstream tends, while in the screen with a porosity ratio of 50%, the hydraulic jump moves downstream. The jump formed after the drop is V-shaped despite the screen plates. The reason for this is the uniform distribution of velocity and depth in the transverse section of the channel due to gradually expanding wall (Fig. 6).

5. CONCLUSIONS

1-The gradually expanding wall created downstream of the vertical drop causes turbulence on the jet sides, the uniform distribution of depth in downstream it, increases the pool depth and By increasing the pool and the downstream depths of the drop, it increases the energy dissipation efficiency by 25%. As the discharge increases (y_c/P increase) the amount of energy dissipation due to the submergence of the flow decreases in downstream.

2-Increase the height of the vertical drop at a constant ratio of screen plate porosity, the energy dissipation increases, but this increase is negligible and results in an average 4% increase in energy dissipation efficiency.

3-The downstream depth in the screen plates with a porosity ratio of 50% increases due to more flow pass than the porosity of 40%.

4-Simultaneous application gradually expanding wall and screen plates, on average, increases 48% the flow energy dissipation efficiency in downstream of the vertical drop.

5-Based on the results and observations of the present study, it can be concluded that the application of gradually expanding wall with screen plates can reduce the cost of construction of stilling basins.

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