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EFFECT OF BAFFLE BLOCKS WITH A SLOPING FRONT FACE ON THE LENGTH OF THE JUMP

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ABSTRACT: Stilling basin is a standard design for energy dissipation. Certain structural arrangements and geometry of appurtenances were found to be valuable means of reducing the length of the hydraulic jump. This paper investigates the effect of baffle block with a sloping vertical face on the length of the hydraulic jump. Baffles blocks with different cut ratios were investigated in this study. The results of this study show that baffle blocks with a vertical sloping face are more effective in reducing the length of the jump than blocks with a vertical face or a roughened bed.

INTRODUCTION

Energy dissipation below hydraulic structures has attracted the attention of many researchers. The magnitude of energy dissipated at high dams with large spillways discharges is enormous. The stilling basin is the most common form of energy dissipater. The energy is dissipated by jet diffusion associated with a surface return flow. Baffle blocks increase energy dissipation by the impact phenomenon. They also reduce the length of the jump. USBR basin III that use baffle blocks is much shorter than USBR basin II that does not. Shortening the length of the jump reduces the size and the cost of the stilling basin.

According to Peterka (1978), the important shape feature for baffle blocks is the vertical upstream face. Changing the shape of the front face of the blocks can induce eddies which will cause additional energy dissipation and hence shorten the length of the jump. Eloubaidy et al. (1996) has shown that curved blocks can cause 33% increase in additional residual kinetic energy dissipation, however, no results regarding the length of the jump were presented. Hager (1996) investigated the performance of counter-current type stilling basin. This device induces additional shear layers. It was found that the length of the jump was considerably reduced, the ratio L_j/y_2 was equal to 3.5. For a free hydraulic jump L_j/y_2 is around 6. Ali (1991) has investigated the effect of roughened-bed stilling basin on length of the jump. The blocks used had a vertical face. It was found that a roughened bed could reduce the length of the jump.

The length of the jump is given by different formulas, such as:

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$$- L_j = A h_2 \quad (1)$$

$$- L_j = B(h_2 - h_1) \quad (2)$$

$$- L_j = f(F_1)(h_2 - h_1) \quad (3)$$

where, F_1 is the initial Froude number, h_1 initial depth of the jump and h_2 the sequent depth.

Fujita and Yasuda (1986) proposed the following formula

$$L_j = a\sqrt{h_1 h_L} \quad (4)$$

where, h_L designates the head loss in the jump.

Plotting L_j/h_2 as a function of F_1 is the more common and practical, but plotting L_j/h_1 as a function of F_1 has shown better results (Peterka 1978). Equation (3) is not practical because one has to know the total energy dissipation through the jump.

Ali (1991) based on one-dimensional momentum approach has shown that L_j/h_1 is given by

$$\frac{L_j}{h_1} = K\left(F_1^2 - 1\right) \quad (5)$$

where, K is a parameter depending on the relative length of roughness.

In the present study the hydraulic performance of baffle blocks with sloping front face is investigated. The shape of the blocks will create strong vortices, which will help in reducing the length of the jump, as shown in Fig. 1.

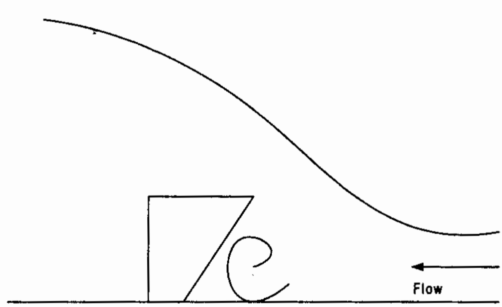

Fig 1. Flow past Baffle block with a slopping front face

EXPERIMENTS

The experiments were conducted in a horizontal channel 4.0-m long and 0.3-m wide. Supercritical flow was generated by a sluice gate positioned upstream of the channel. The tail water depth was controlled by means of a sliding gate positioned at the end of the channel. The discharge was measured by means of a gravimetric tank and the water depth was measured using an electronic point gauge with accuracy ±0.01 mm. The baffle blocks were fastened to the channel floor.

Considering the block size recommended by the US Bureau of Reclamation, the size of the channel and the blockage ratio η=0.5, blocks of 7.5mm x 7.7mm x 7.5mm were used. These blocks were tested under a Froude number ranging from 4.5 to 7.5, different cut ratios and different locations. The geometric characteristics of the blocks tested are shown in table 1. The performance of these blocks was investigated for Froude number ranging from 4.5 to 8.0.

Table 1: Characteristics of the blocks tested

Subgroup	h (mm)	w (mm)	t (mm)	l/w
1	7.5	7.5	7.5	0
2	7.5	7.5	7.5	0.1
3	7.5	7.5	7.5	0.3
4	7.5	7.5	7.5	0.5

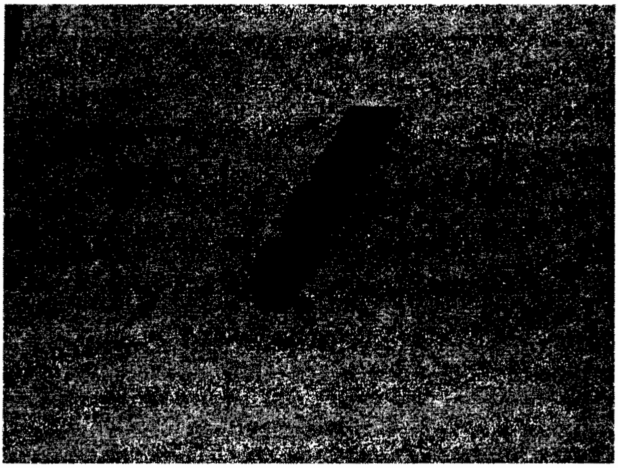

Plate 1. Baffle block

DIMENSIONAL ANALYSES

The flow with baffle blocks with a sloping front face is determined by the following variables:

$y_1, y_2, V_1, l, x, h, s, w, L_j, \rho, \mu$.

The selection of V_1, y_2 and ρ as the basic quantities yield the following dimensionless relationship.

$$\frac{L_j}{y_2} = f\left(F_1, R_e, \frac{y_2}{y_1}, \frac{l}{w}, \frac{x}{y_2}, \frac{s}{h}, \frac{w}{h}\right) \quad (6)$$

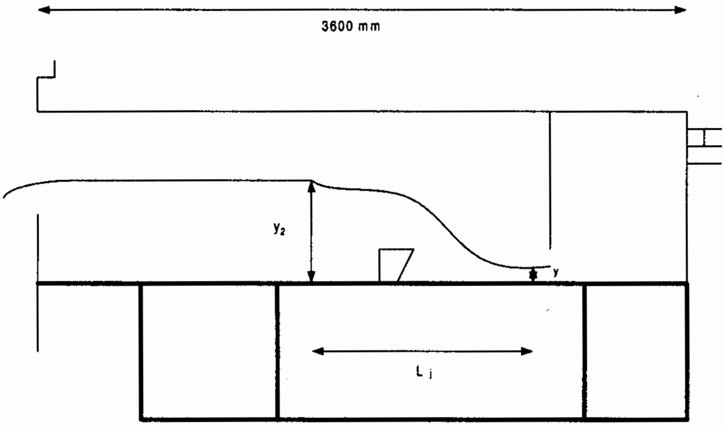

Fig 2. Test rig set up

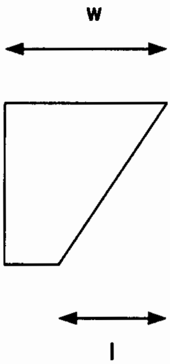

Fig 3. Baffle Block

The viscous force is not significant and hence R_e can be neglected; y_2/y_1 is function of F_1; s/h is a function of the blockage ratio η and w/h. The blockage ratio was kept constant and equal to 0.5, as recommended by Elevatorsky (1959) and w/h was kept equal to 1. Therefore Eq. (6) becomes:

$$\frac{L_j}{y_2} = f\left(F_1, \frac{l}{w}, \frac{x}{y_2}\right) \quad (7)$$

x/y_2 was kept equal to 0.8 as recommended by USBR. So equation (7) becomes:

$$\frac{L_j}{y_2} = f\left(F_1, \frac{l}{w}\right) \tag{8}$$

RESULTS AND ANALYSES

Effect of l/w

Figure 4 shows a plot of the relative length of the jump l_j/y_2 versus F_1 for different values of l/w. It can be seen from this figure that the relative length of the jump decreases as l/w increases. This is explained by the fact that for l/w=0, the energy is dissipated by impact. As l/w increases, a vortex forms in front of the baffle blocks, this vortex becomes stronger as l/w increases and F_1 increases. The extra turbulence created by these eddies induce a decrease in the length of the hydraulic jump. Analyses of the experimental data showed that the relative length of jump could be expressed as:

$$\frac{L_j}{h_2} = aF_1^2 + bF_1 + c \tag{9}$$

where, a,b, and c are parameters depending on l/w.

For the best configuration l/w=0.5, it was found that:

$$\frac{L_j}{y_2} = 0.025F_1^2 - 0.051F_1 + 2.17 \tag{10}$$

with a coefficient of correlation r^2=0.973.

The linear plot has shown a lower coefficient of correlation.

The plot L_j/h_1 presented in Fig. 5 has shown better result with a coefficient of correlation r^2=0.992. The resulting equation for the case w/l=0.5 is

$$\frac{L_j}{y_2} = 6.32F_1 - 16.7 \tag{11}$$

Effect of a second row of blocks

Experiment was conducted with two rows of blocks. The second row was placed at a distance 2w from the first row as shown in Fig. 6. The second row produced only 5% decrease in the relative length of jump, as shown in Fig. 7.

Comparison with other types of Control

A comparison with other type of controls is shown in figure 8. This figure shows that baffle blocks with a sloping vertical face are more efficient in reducing the length of the jump than the stilling basin I, basin II, or the roughened bed proposed by Ali (1991). In addition to the impact effect, sloping vertical face blocks create strong vortices, which dissipate more energy and hence reduce the length of the jump.

Figure 9 shows that baffle blocks reduce the length of the jump by 60 to 50% relative to smooth bed. Roughened bet proposed by Ali (1991) reduces length of jump by 50 to 30%, whereas basin II by 35% to 30%. Thus, baffle blocks with a sloping face are more effective in reducing the length of the jump than a roughened bed or Baffle blocks with a vertical face.

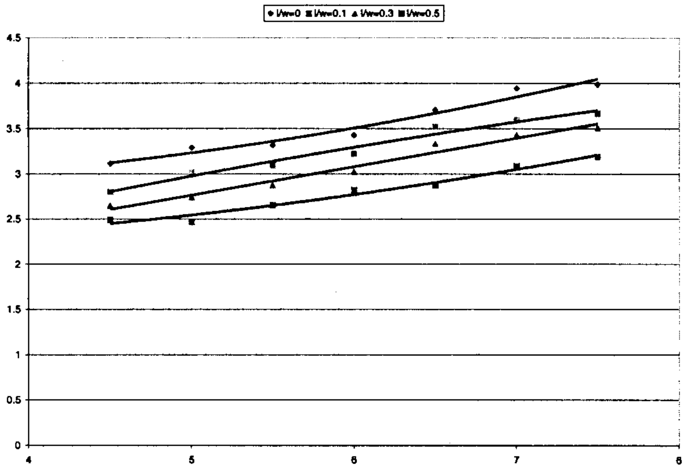

Fig 4. L_j/y_2 *versus* F_1

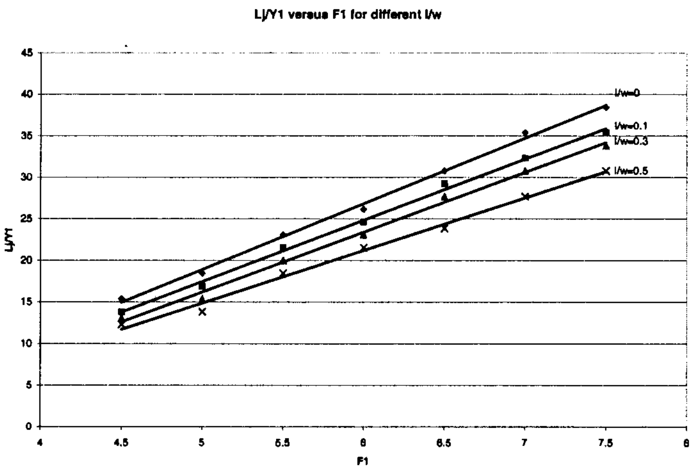

Fig 5. L_j/y_1 *versus* F_1

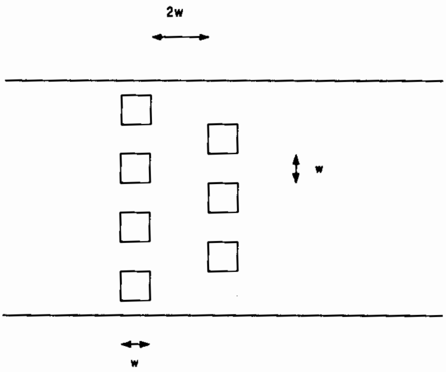

Fig 6. Two rows of blocks

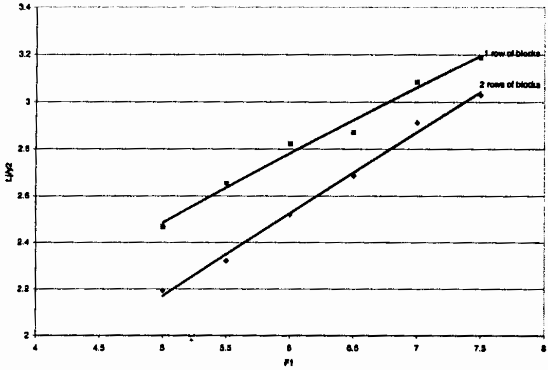

Fig 7. Effect of a second row of blocks

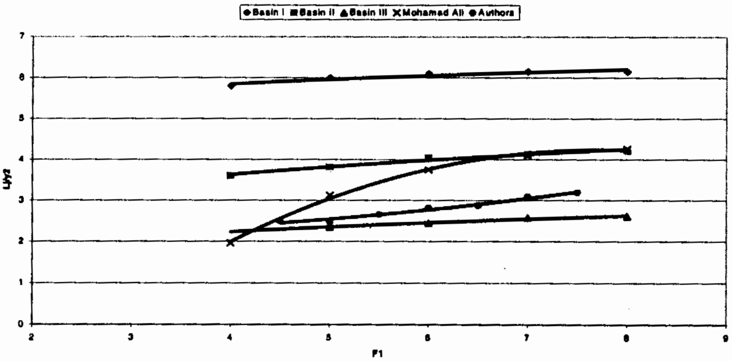

Fig 8. Comparison with other types of control

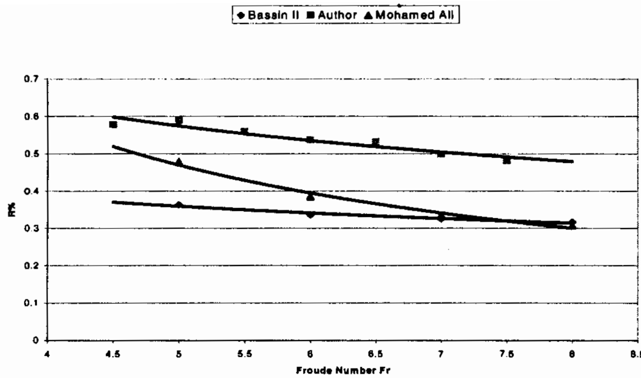

Fig 9. Percentage Reduction in Length of Jump

CONCLUSION

Baffle block with a sloping face reduces the length of a hydraulic jump. The results show the reduction increases with increasing l/w. The shape of the blocks will create strong vortices, which will help in reducing the length of the jump. The results of this study show baffle blocks with a sloping front face can reduce the length of the jump by 48% relatively to the free jump and 18% relatively to basin II and the roughened bed proposed by Ali (1991). A second row of baffle block was not very effective in reducing the length of the jump. Only 5% increase in the reduction of the relative length Lj/y_2 was observed.

ACKNOWLEDGMENT

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