ENERGY DISSIPATORS - Design of different types (1-7) of energy dissipation arrangements as Per USBR guidelines

As per USBR (UNITED STATES BUREAU OF RECLAMATON) various energy dissipation arrangements guidelines have been given.

A tremoandous amount of experimental as well as theoritical work has been perfomed in connection with the hydraullic jump on a horizontal apron.

General Investigation of the hydraullic jump on Horizontal Apron (Basin I).

The objectives of the study were

1. to determine the applicability of the hydraullic jump formula for the entire range of conditions experienced in design.
2. To determine the length of the jump over the entire practical range
3. To observe catalog & evaluate the various forms of the jump.

① The Froude number

$$F_1 = \frac{V_1}{\sqrt{gD_1}}$$

F_1 = is a dimensionless parameter
V_1 = velocity of flow
D_1 = depth of flow
g = acceleration due to gravity

② Application of hydraulic Jump formula

The expression for the hydraulic jump based on pressure-momentum may be written as

$$D_2 = -\frac{D_1}{2} + \sqrt{\frac{D_1^2}{4} + \frac{2V_1^2 D_1}{g}}$$

or

$$D_2 = -\frac{D_1}{2} + \sqrt{\frac{D_1^2}{4} + \frac{2V_1^2 D_1^2}{gD_1}}$$

where D_1 & D_2 are the depths before & after the jump. These depths are often called Conjugate or sequent depths.

③ Length of the Jump

The length of the jump is plotted in two ways
The first method can got from the table ① page ⑧ of USBR code.

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Forms of Hydraulic Jump

When the froude no is unity, the water is flowing at critical depth, then a jump cannot form. This corresponds to point 0 on the specific energy diagram. For the value of Froude no b/w 1 to 1.7 there is a slight difference in D_1 & D_2.

① Water flowing under a sluice gate discharges into a rectangular stilling basin the same width as the gate. The average velocity & the depth of the flow after contraction of jet is $V_1 = 85$ ft per sec., $D_1 = 5.6$ feet. Determine the conjugate tail water depth (i.e D_2), length of basin required to confine the jump.

Soln

$$F_1 = \frac{V_1}{\sqrt{g D_1}} = \frac{85}{\sqrt{9.8 \times 5.6}} = 11.46$$

With the value of Froud no 11.46 in table ① pg ⑧ USBR

$$\frac{D_2}{D_1} = 9.45$$

$$D_2 = 9.45 \times 5.6 = 52.92 \text{ feet}$$

in column ⑪ $\frac{L}{D_2}$ for Froude no 11.46

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$$\frac{L}{D_2} = 6.05$$

$$L = 6.05 \times D_2$$

$$= 6.05 \times 52.92$$

$$L = \underline{320} \text{ feet}$$

length of basin necessary is $L = 320$ feet

II. Stilling basin for High dam & Earth dam spillways & large canal structures (Basin II)

It is possible to reduce the jump length by the installation of accessories such as baffles & sills in the stilling basin. These accessories exert a stabilising effect & also increase factor of safety. These type of stilling basins have been used on high dams, & earth dams spillways & large canal structures. This basin contains ① Chute blocks at the upstream end &

② A dentated sill at the downstream end.

The following rules are recommended for generalization of Basin II

① An additional factor of safety is advisable for both low & high values of froude no. A minimum margin of factor of safety of 5% of D_2 is recommended.

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(2) Basin II may be effective down to a froud no of 4 but the lower values should not be taken for granted.

(3) The length of basin can be obtained from the interrelated curve.

(4) The height of chute blocks is equal to the depth of flow entering the basin or D_1.

(5) The width & spacing should be equal to approximately D_1.

(6) The height of the dentated sill is equal to $0.2D_2$, & the maximum width & spacing recommended is approximately $0.15 D_2$.

III Stilling basin for canal structures, small outlet works & small spillways (Basin-III)

A shorter basin having a simpler end sill may be used if baffle piers are placed downstream from the chute blocks. The most effective way to shorten a stilling basin is to modify the jump by the addition of appurtenances in the basin.

(1) Basin-III has a large factor of safety against jump sweepout & operates equally well for all values

of the froude no above 4.

② Basin III should not be used where baffle piers will be exposed to velocities above the 50 to 60 feet per second.

③ The height, width & spacing of the chute blocks are equal to D_1, the same as Basin-II.

④ The height of baffle piers increases with the froude no as can be observed from column 22 Table ④ - pg 36, USBR code

⑤ The most effective position of the baffle piers is $0.8\ D_2$ downstream from the chute blocks.

⑥ The height of the solid end sill is also shown to vary with the froude No although there is nothing critical about this dimension.

⑦ Stilling Basin III may be effective for value of the froude No as low as 4.

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IV Stilling Basin design for Canal structures & Diversion Dams (Basin IV)

The characteristics of the hydraulic jump for Froude no b/w 2.5 & 4.5 and the design of an adequate stilling basin designated as Basin - IV. Low dams & outlet works fall in this category.

1. The length of basin IV is relatively short and can be obtained by upper curve.
2. No baffle piers are needed in the basin as these will prove a greater detriment than aid.
3. The addition of small triangular sill placed at the end of the apron for scour control is desirable.
4. The following expression can be used for computing the length of beams:-

$$L = \frac{Q}{CSN\sqrt{2gy}}$$

Q = total discharge in c.f.s

C = experimental co-efficient

S = width of a space in feet

N = Number of spaces

g = acceleration due to gravity

y = is the depth of the flow