CE 4353/5360 September 25, 2019

Homework 4, Due October 2

1. Problem 3.10 modified. A spillway chute and the hydraulic jump stilling basin at the end of the chute are rectangular in shape with a width of 80 ft. The incoming flow has a depth of 2.60 ft at a design discharge of 10000 cfs. Within the basin are 20 baffle blocks that are each 3.0 ft high and 3.0 ft wide.
(a) Assuming an effective coefficient of drag of 0.6 for the baffle blocks, based on the upstream velocity and combined frontal area of the blocks, calculate the sequent depth (ft) and compare with the sequent depth (ft) without baffle blocks.
(b) What is the energy loss in ft in the basin with and without the blocks?

2. Problem 3.17 modified. For a river flow between bridge piers 3 m in diameter with a spacing of 15 m, determine the backwater h_1^* in cm using the momentum method if the downstream depth is 4.0 m and the downstream velocity is 2.5 m/s. Assume a coefficient of drag of 2.0 for the bridge piers.

3. Problem 3.19 modified. A straight-walled contraction connects two rectangular channels 12 ft and 7.2 ft wide. The discharge through the contraction is 300 cfs, and the depth of the approach flow is 0.815 ft. Calculate the downstream depth (ft), Froude number, and the length (ft) of the contraction that will minimize standing waves. Will choking be a problem?

1. 3.60 modified Given: Spillway chute & Stilling basin, rectangular, $b = 80\,ft$
$y_1 = 2.6\,ft$ at $Q = 10000\,cfs$
20 baffle blocks, each 3 ft high by 3 ft wide

Find: (a) $C_D = 0.6$ for blocks, Find y_2 with blocks & without blocks
(b) Find energy loss (ft) with & without blocks.

(a)(i) without blocks

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8 Fr_1^2}\right]$$

$$V_1 = \frac{Q}{b y_1} = \frac{10000\,cfs}{(80\,ft)(2.6\,ft)} = 48.1\,ft/s$$

30 total

10

$$Fr_1 = \frac{V}{\sqrt{g y_1}} = \frac{48.1\,ft/s}{[(32.2\,ft/s^2)(2.6\,ft)]^{1/2}} = 5.26$$

$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1 + \sqrt{1 + 8(5.26)^2}\right] = 6.96$$

$$y_2 = 6.96(2.6\,ft)$$

$$\boxed{y_2 = 18.1\,ft}$$

(ii) with blocks

$$M_1 = M_2 + \frac{D}{\gamma}$$

$$D = \frac{C_D \rho A_p V_1^2}{2} \quad \text{for each block}$$

$$A_p = (3\,ft)(3\,ft) = 9\,ft^2$$

10

$$D = (20)\,\frac{0.6\,(1.94\,\frac{slugs}{ft^3})(9\,ft^2)(48.1\,ft/s)^2}{2}\left(\frac{1\,lb}{1\,slug\,ft/s^2}\right)$$

$$= 20\,(12120\,lb) = \underline{2.42 \times 10^5\,lb}$$

$$A_1 h_{c_1} + \frac{Q^2}{g A_1} = A_2 h_{c_2} + \frac{Q^2}{g A_2} + \frac{D}{\gamma}$$

$$\frac{b y_1^2}{2} + \frac{Q^2}{g b y_1} = \frac{b y_2^2}{2} + \frac{Q^2}{g b y_2} + \frac{D}{\gamma}$$

$$\frac{(80\,ft)(2.6\,ft)^2}{2} + \frac{(10000\,cfs)^2}{(32.2\,ft/s^2)(80\,ft)(2.6\,ft)} = \frac{(80\,ft)\,y_2^2}{2} + \frac{(10000\,cfs)^2}{(32.2\,ft/s^2)(80\,ft)\,y_2} + \frac{2.42 \times 10^5\,lb}{62.4\,lb/ft^3}$$

2704   14930.7   38819.9   3878.2

$$270 + 14930 = 40 y_2^2 + \frac{3.88 \times 10^4}{y_2} + 3880$$

11322.9

$$40 y_2^2 + \frac{3.88 \times 10^4}{y_2} - 11320 = 0$$

283.07   970.5

$$y_2^3 - 283\,y_2 + 970 = 0$$

Goal Seek

$y_2 = -18.3,\ 3.59,\ \underline{14.74}$ probably the high y_2

Can Check $y_c = \left[\frac{q^2}{g}\right]^{1/3} = \left[\frac{\left(\frac{10000\,cfs}{80\,ft}\right)^2}{32.2\,ft/s^2}\right]^{1/3} = 7.8\,ft$

So $\boxed{y_2 = 14.7\,ft}$

(b) $E_1 = y_1 + \frac{V_1^2}{2g}$

$= 2.6\,ft + \frac{(48.1\,ft/s)^2}{2(32.2\,ft/s^2)}$

$\boxed{E_1 = 38.5\,ft}$

w/o blocks

$V_2 = \frac{Q}{A_2} = \frac{Q}{by_2} = \frac{10000\,cfs}{(80\,ft)(18.1\,ft)} = 6.91\,ft/sec$

10

$E_2 = y_2 + \frac{V_2^2}{2g} = 18.1\,ft + \frac{(6.91\,ft/s)^2}{2(32.2\,ft/s^2)}$

$\boxed{E_2 = 18.8\,ft}$

$E_L = E_1 - E_2 = 36.5\,ft - 18.8\,ft$

$\boxed{E_L = 19.7\,ft}$

w/ blocks

$V_2 = \frac{Q}{A_2} = \frac{Q}{by_2} = \frac{(10000\,cfs)}{(80\,ft)(14.7\,ft)} = 8.50\,ft/sec$

$E_2 = y_2 + \frac{V_2^2}{2g} = 14.7\,ft + \frac{(8.50\,ft/s)^2}{2(32.2\,ft/s^2)}$

$\boxed{E_2 = 15.8\,ft}$

$E_L = E_1 - E_2 = 36.5\,ft - 15.8\,ft$

$\boxed{E_L = 22.7\,ft}$

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3.17 modified Given: River flow between bridge piers

$a = 3\,m$, $s = 15\,m$

$C_D = 2.0$, $y_4 = 4.0\,m$, $V_4 = 2.5\,m/s$

Find: y_1, h_1^* (cm)

$$M_1 = M_4 + \frac{D}{\gamma} \Longrightarrow$$

$$\frac{y_1^2}{2} + \frac{q^2}{g y_1} = \frac{y_4^2}{2} + \frac{q^2}{g y_4} + \frac{C_D a y_1 V_1^2}{2 g s}$$

$$V = \frac{Q}{A} = \frac{Q}{by} = \frac{q}{y}$$

$$q = Vy = V_1 y_1 = V_4 y_4 \Longrightarrow V_1 = \frac{q}{y_1}$$

$$\frac{y_1^2}{2} + \frac{q^2}{g y_1} = \frac{y_4^2}{2} + \frac{q^2}{g y_4} + \frac{C_D a y_1}{2 g s}\left(\frac{q}{y_1}\right)^2$$

$$= \frac{y_4^2}{2} + \frac{q^2}{g y_4} + \frac{C_D a q^2}{2 g s y_1}$$

$$\frac{y_1^2}{2} + \frac{q^2}{g y_1}\left[1 - \frac{C_D a}{2 s}\right] = \frac{y_4^2}{2} + \frac{q^2}{g y_4}$$

$$q = V_4 y_4 = (2.5\,m/s)(4.0\,m) = 10\,m^2/s$$

$$\frac{y_1^2}{2} + \frac{(10\,m^2/s)^2}{(9.81\,m/s^2)\,y_1}\left[1 - \frac{(2.0)(3\,m)}{2(15\,m)}\right] = \frac{(4.0\,m)^2}{2} + \frac{(10\,m^2/s)^2}{(9.81\,m/s^2)(4\,m)}$$

$$\frac{y_1^2}{2} + \frac{8.15}{y_1} = 8.0 + 2.55 = 10.55$$

$$y_1^3 - 21.10\,y_1 + 16.30 = 0$$

$y_1 = 0.80,\ 4.14,\ -4.94$ w/Goal Seek

$$\boxed{y_1 = 4.14\,m}$$

$$h_1^* = y_1 - y_4 = 4.14\,m - 4.0\,m$$

$$h_1^* = 0.14\,m\left(\frac{100\,cm}{m}\right)$$

$$\boxed{h_1^* = 14\,cm}$$

Can also use Fig 3.17 w/ Π_{4}, $\frac{C_D a}{s}$

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20 total

3.19 modified | Given: Straight-walled contraction

$b_1 = 12$ ft $b_2 = 7.2$ ft

$Q = 300$ cfs $y_1 = 0.815$

Find: y_3, $\mathbb{F}_{r3}$, L to minimize standing waves

Will choking be a concern?

(i) $\mathbb{F}r_1 = \dfrac{V}{\sqrt{g y_1}}$

$V_1 = \dfrac{Q}{A_1} = \dfrac{300 \text{ cfs}}{(12\text{ft})(0.815\text{ft})}$

$V_1 = 30.7$ ft/sec

$\mathbb{F}r_1 = \dfrac{30.7 \text{ ft/sec}}{[(32.2\text{ ft/s}^2)(0.815\text{ ft})]^{1/2}}$

$\mathbb{F}r_1 = 6.00$

$r = \dfrac{b_3}{b_1} = \dfrac{7.2\text{ ft}}{12\text{ ft}} = 0.60 \Rightarrow$ Fig 3.20 (b) $\Rightarrow \theta = 3.0°$

$\theta = 3°$, $\mathbb{F}r_1 = 6 \Rightarrow$ Fig 3.20(a) $\Rightarrow \dfrac{y_3}{y_1} = 1.9$

$y_3 = 1.9\, y_1 = 1.9(0.815\text{ft})$

$\boxed{y_3 = 1.55 \text{ ft}}$

(ii) $\mathbb{F}r_3 = \dfrac{V_3}{\sqrt{g y_3}}$

$V_3 = \dfrac{Q}{b_3 y_3} = \dfrac{300 \text{ cfs}}{(7.2\text{ft})(1.55\text{ ft/sec})} = 26.9$ ft/sec

$\mathbb{F}r_3 = \dfrac{26.9 \text{ ft/sec}}{[(32.2\text{ ft/s}^2)(1.55\text{ ft})]^{1/2}} = \boxed{3.8}$

$L = \dfrac{b_1 - b_3}{2\tan\theta} = \dfrac{12\text{ ft} - 7.2\text{ ft}}{2\tan 3°}$

$\boxed{L = 45.8 \text{ ft}}$

$\theta < 5°$, so choking is not a problem