UNIT-II-

FLOW THROUGH PIPES

[13 MARKS]

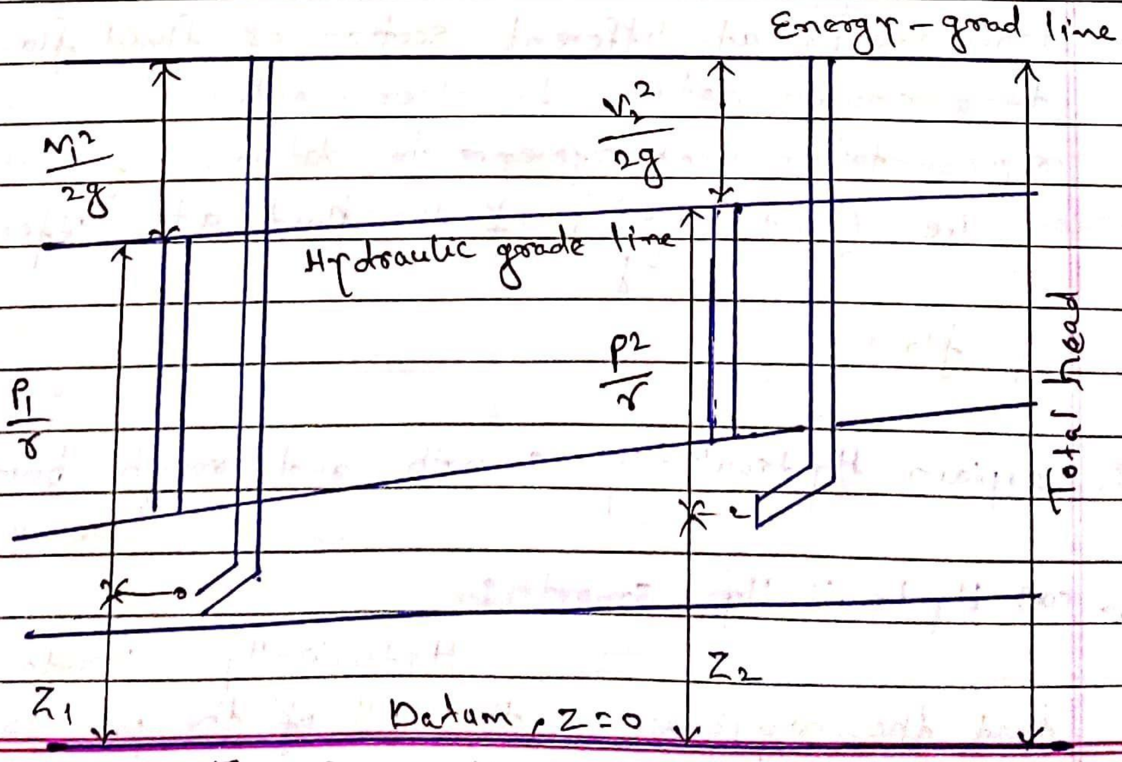
THEORIES :- 06 Marks
NUMERICALS :- 07 Marks

THEORY :-

01. Explain Total energy line and Hydraulic Grade line. (Compulsary)

ANS→ (a) Total energy line :- (TEL)

The term 'energy grade line, Energy line' as it applies to the area of reclamation can be defined as 'The line showing the total energy at any point in a pipe. The total energy in the flow of the section with reference to a datum line is the sum of the elevation of the pipe centreline, the piezometric height (or pressure head) and the velocity head.



(Fig. Energy line and hydraulic Grade line)

[HGL = Hydraulic grade line]
[TEL = Total Energy line]

(b) Hydraulic Grade line :- (HGL)

The term Hydraulic grade line as it applies to the area of reclamation can be defined as the hydraulic grade line lies below the energy grade line by an amount equal to the velocity head at the section. The two lines are parallel for all sections of equal cross-sectional area. The distance between the pipe centerline and the hydraulic grade line is the pressure head, or piezometric height at the section.

OR

Hydraulic Grade line :- It is an imaginary line indicating with reference to a datum, the piezometric head at different section. It is infact a graphical representation of the piezometric head i.e piezometric head is sum of datum head and pressure head $\left(z+\frac{P}{\gamma}\right)$ at different sections.

Total Energy line :- It is an imaginary line showing the total energy at different section of fluid flow wrt to a chosen datum. In other words, it is a graphical representation with reference to datum, of total energy i.e $\left(z+\frac{P}{\gamma}+\frac{V^2}{2g}\right)$ of the fluid at different sections of flow.

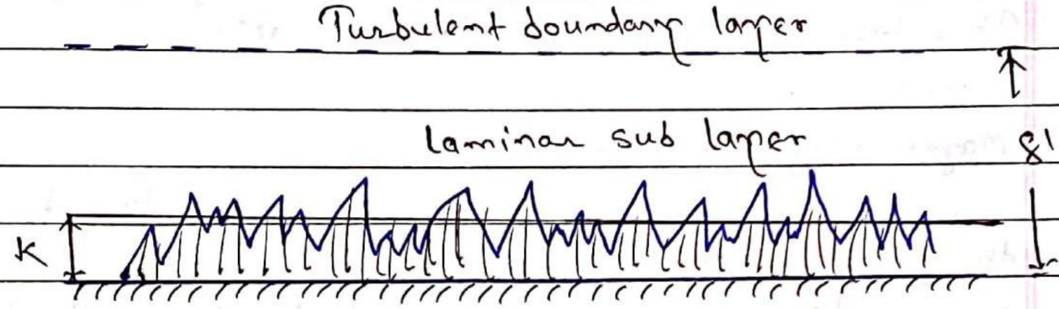
02. Explain Hydraulically smooth and rough boundaries.

[Semi-compulsary]

Ans> (a) Hydraulically smooth :-

Hydraulically Smooth means that the roughness on the wall of the pipe is less the thickness of the laminar sub layer of the turbulent flow. A hydraulically smooth pipe has excellent hydraulic properties that allow fluids to be flow with a minimum head loss. The high abrasion resistance of PP also helps minimize any increase in surface roughness due to abrasion by particles being carried in the fluid.

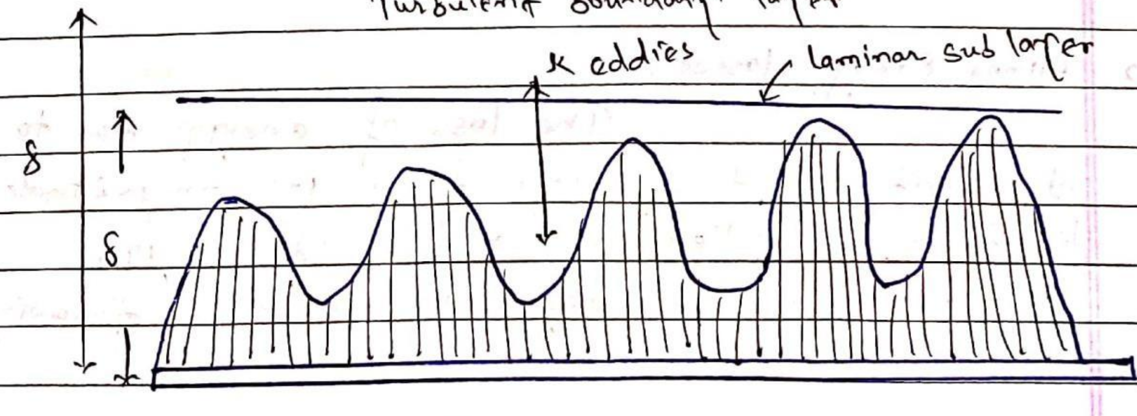
$K/\delta' < 0.25$



(Fig. Hydraulically smooth pipe)

(b) Hydraulically rough boundaries :-

When the average depth K of the surfaces irregularities is greater than laminar sub-layer of surface δ is called as hydrodynamically rough boundary. The eddy which is formed outside of the laminar sub layer penetrates into the laminar sub layer. Such boundary is called as rough boundary.



(Fig. Rough Boundary layer)

Q3. Explain various losses in pipes. Write the assumptions expressions for the same. (Compulsary)

ANS> Various Losses in pipes :-

When a fluid is flowing through a pipe, the fluid experiences some resistances due to which some of the energy of the fluid is lost. This loss of energy is classified as:-

(a) Major energy losses :-

The viscosity causes loss of energy in the flows; which is known as frictional loss or major energy loss and it is calculated by the following formula.

(a) Darcy - weisbach formula :-

The loss of head can be measured by the following equations.

$$\therefore \boxed{h_f = 4fLV^2/(2gD)}$$

where h_f = loss of head due to friction

f = coefficient of friction

L = Length of pipe

V = mean velocity of flow

D = diameter of pipe

(b) Minor Energy losses :-

The loss of energy due to change of velocity of the flowing fluid in magnitude or direction is called minor loss of energy.

The minor loss of energy includes the following cases

(a) loss of energy due to sudden enlargement,

$$\boxed{\therefore h_L = \frac{(v_1 - v_2)^2}{2g}}$$

(b) Loss of energy due to sudden contraction,

$$\boxed{\therefore h_L = 0.5\frac{v^2}{2g}}$$

(c) Loss of energy at the entrance to a pipe,

$$\boxed{\therefore h_L = 0.5\frac{v^2}{2g}}$$

(d) loss of energy at the exist from a pipe,

$$\boxed{\therefore h_L = \frac{v^2}{2g}}$$

(e) Loss of energy due to gradual contraction or enlargement,

$$\boxed{\therefore h_L = k\frac{(v_1 - v_2)^2}{2g}}$$

(f) loss of energy in bends,

$$\boxed{\therefore h_L = \frac{kv^2}{2g}}$$

(g) Loss of energy in various pipe fittings,

$$\boxed{\therefore h_L = \frac{kv^2}{2g}}$$

04. Derive an expression for Darcy-Weisbach formula to determine the head loss due to friction.

[FUTURE]

ANS⇒ Derive :-

Consider a horizontal pipe of cross-sectional area A carrying a fluid with a mean velocity v.

By Bernoulli's equation ; we get

$$\frac{p_1}{w} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{v_2^2}{2g} + z_2 + h_f$$

Since $v_1 = v_2 = v$ and $z_1 = z_2$

$$\text{Loss of head} = h_f = \frac{p_1}{w} - \frac{p_2}{w}$$

Let f' be the frictional resistance per unit area at unit velocity ; then frictional resistance

$$= f' \times \text{area} \times v^n$$

$$= f' \times PL \times v^n$$

where P is the wetted perimeter of the pipe.

The pressure forces at the sections 1 and 2 are $(p_1 A)$ and $(p_2 A)$ respectively. Thus resolving all the forces horizontally ; we have

$$p_1 A = p_2 A + \text{frictional resistance}$$

$$(p_1 - p_2) A = f' \times PL \times v^n$$

$$(p_1 - p_2) = f' \times \frac{P}{A} \times L v^n$$

Dividing both sides by the specific weight w of the following fluid

$$\frac{p_1 - p_2}{w} = \frac{f'}{w} \times \frac{P}{A} L v^n$$

But $h_f = \dfrac{p_1 - p_2}{w}$, then

$$h_f = \frac{f_1}{w} \times \frac{P}{A} \times L v^n$$

$$\left(\because \frac{A}{P} = m \text{ ...... hydraulic radius} \right)$$

$$h_f = \frac{f_1}{w} \times \frac{L v^n}{m}$$

for pipes running full

$$m = \frac{A}{P} = \frac{\left(\frac{\pi D^2}{4}\right)}{(\pi D)} = \frac{D}{4}$$

Substituting this in the eqn for h_f and assuming $n = 2$

$$h_f = \frac{4 f_1}{w} \frac{L v^2}{D}$$

putting $\frac{4 f_1}{w} = \frac{f}{2g}$

$$\boxed{\therefore h_f = \frac{f L v^2}{2 g D}}$$

where,

f = friction factor
L = length of pipe
v = mean velocity of pipe
D = diameter of pipe
g = 9.8 or 10 Const value
h_f = head loss of pipe

NUMERICALS :-

TYPE-I- [Compulsory]

[Based on Three Reservoir Problems] [7 MARKS]

W 2016 Q1. Three pipes are connected in parallel between two reservoirs having water level difference of 15m. The details regarding pipes are as given below.

Pipe 1

$L = 1.2km$ $D = 0.8m$ $f = 0.03$

Pipe 2

$L = 1.0 km$ $D = 0.65m$ $f = 0.03$

Pipe 3

$L = 1.5km$ $D = 1.0m$ $f = 0.02$

(a) Determine discharge through each pipe and total discharge.

(b) Also calculate the diameter of single pipe required to replace the three pipes with length $= 1.2km$ & $f = 0.03$.

Soln Part (A)

$$hf_1 = hf_2 = hf_3 = 15m$$

$$hf_1 = \frac{f_1 \times L_1 \times Q_1^2}{12.1 D_1^5}$$

$$\Rightarrow 15 = \frac{0.03 \times 1.2 \times 1000 \times Q_1^2}{12.1 \times 0.8^5}$$

$$Q_1 = 1.28 \ m^3/sec$$

$$hf_2 = \frac{f_2 \times L_2 \times Q_2^2}{12.1 D_2^5}$$

$$\Rightarrow 15 = \frac{0.03 \times 1 \times 10^3 \times Q_2^2}{12.1 \times 0.65^5}$$

$$\therefore Q_2 = 0.83 m^3/sec$$

$$hf_3 = \frac{f_3 \times L_2 \times Q_3^2}{12.1 D_3^5}$$

$$\Rightarrow 15 = \frac{0.02 \times 1.5 \times 10^3 \times Q_3^2}{12.1 \times 1^5}$$

$\therefore Q_3 = 2.45 \, m^3/sec$

Total discharge,

$$Q = Q_1 + Q_2 + Q_3$$

$$\boxed{\therefore Q = 4.56 \, m^3/sec}$$

Part, B

$$h_{f1} = \frac{f L Q^2}{12.1 \times D^5}$$

$$\Rightarrow 15 = \frac{0.03 \times 4.56^2}{12.1 \times D^5}$$

$$\boxed{\therefore D = 1.32 m}$$

02. Two reservoir having water level difference of 50 m are connected by two pipes in series. Pipe 1 having 100 m length, 100 mm dia and $f = 0.04$. Pipe 2 having 200 m length, 200 mm ϕ, $f = 0.04$. Determine discharges considering all losses.

Solⁿ→ $H = H_L\ entry + h_{f1} + h_L\ exp + h_{f2} + h_L\ exist$

$$50 = \frac{0.5v^2}{2g} + \frac{f_1 L_1 v_1^2}{2g D_1} + \frac{(v_1 - v_2)^2}{2g} + \frac{f_2 l_2 v_2^2}{2g D_2} + \frac{v_2^2}{2g}$$

Applying conitinuity eqⁿ (continuity)

$$Q_1 = Q_2$$

$$A v_1 = A v_2$$

$$\frac{\pi}{4} \times (0.1)^2 \times v_1 = \frac{\pi}{4} \times (0.2)^2 \times v_2$$

$$v_1 = 4 v_2$$

$$50 = \frac{0.5 \times (4v_2)^2}{2 \times 9.81} + \frac{0.001 \times 100 \times (4v_2)^2}{2 \times 9.81 \times 0.1} + \frac{(4v_2 - v_2)^2}{2g}$$

$$+ \frac{0.04 \times 200 \times v_2^2}{2 \times 9.81 \times 0.2} + \frac{v_2^2}{2g}$$

$\therefore v_2 = 1.06$ m/sec

& $v_1 = 4.24$ m/sec

$Q = A_1 \times v_1 = A_2 \times v_2$

$\boxed{Q = 0.033 \text{ m}^3/\text{sec}}$

03. Three pipes connected in parallel between two reservoir having WL difference = 10 m with given details.

Pipe	Length	Diameter	F
1	1000 m	0.9 m	0.02
2	500 m	0.75 m	0.02
3	750 m	0.5 m	0.02

Considering all losses, deto dischage flowing through each pipe. Also calculate the diameter of single equivalent pipe to replace above three pipes having length = 1200 m and $f = 0.03$.

Solⁿ→ $H = h_f = 10$ m

Part (A)

Considering pipe I →

$H = h_L$ entry $+ h_L$ pipe $+ h_L$ exist

$$10 = \frac{0.5 v_1^2}{2g} + \frac{f_1 L v_1^2}{2g D_1} + \frac{v_1^2}{2g}$$

$$10 = \frac{0.5 \times v_1^2}{2 \times 9.81} + \frac{0.02 \times 1000 \times v_1^2}{2 \times 9.81 \times 0.9} + \frac{v_1^2}{2g}$$

$v_1 = 2.67$ m/sec

$\therefore Q_1 = A_1 \times v_1$

$$Q_1 = \frac{\pi}{4} \times (0.9)^2 \times 2.87$$

$$Q_1 = 1.83 \ m^3/sec$$

Considering pipe (2)

$$10 = \frac{0.5 v_2^2}{2g} + \frac{0.02 \times 500 \times v_2^2}{2g \times 0.75} + \frac{v_2^2}{2g}$$

$$\therefore v_2 = 3.63 \ m/s$$

$$Q_2 = A_2 \times v_2$$

$$Q_2 = \frac{\pi}{4} \times (0.75)^2 \times 3.63$$

$$\therefore Q_2 = 1.60 \ m^3/sec$$

Considering pipe 3 –

$$10 = \frac{0.5 v_3^2}{2g} + \frac{0.02 \times 700 \times v_3^2}{2g} + \frac{v_3^2}{2g}$$

$$v_3 = 2.49 \ m/s$$

$$Q_3 = A_3 \times v_3$$

$$Q_3 = \frac{\pi}{4} \times (0.5)^2 \times 2.49$$

$$\therefore Q_3 = 0.5 \ m^3/sec$$

$$\therefore Q = Q_1 + Q_2 + Q_3$$

$$Q = 1.83 + 1.60 + 0.5$$

$$\boxed{\therefore Q = 3.93 \ m^3/sec}$$

Part. B

$$H = \frac{0.5 v^2}{2g} + \frac{fLv^2}{2gD} + \frac{v^2}{2g}$$

$$\Rightarrow 10 = \frac{0.5 \times v^2}{2 \times 9.81} + \frac{0.03 \times 1200 \times v^2}{2 \times 9.81 D} + \frac{v^2}{2 \times 9.81}$$

$$Q = A \times v$$

$$3.93 = \frac{\pi}{4} \times D^2 \times v$$

$$v = \frac{5}{D^2}$$

$$\Rightarrow 10 = 0.025 \left(\frac{5}{D^2}\right)^2 + \frac{1.83 \left(\frac{5}{D^2}\right)^2}{D} + 0.051 \left(\frac{5}{D^2}\right)^2$$

$$\therefore D = 1.37 \ m$$