Q 6th sem - civil $\boxed{\text{Pdf - 3}}$ Subject - Environmental Engineering
Topic - Filtration

Design the approximate dimensions of a set of rapid gravity filters for treating water required for a population of 50,000. The rate of supply being 180 litres per day per person. The filters are rated to work 5000 litres per hour per m². Assume ~~Assuming~~ whatever data are necessary, and not given.

Soln

Assume, maximum daily demand is 1.8 times the average daily demand.

→ The maxm. water demand per day

$= \text{population} \times \text{Max}^m \text{ daily rate of supply}$

$= 50{,}000 \times 1.8 \times (180)$

$= 16.2 \times 10^6$ litres $= 16.2$ million litres.

→ water demand per hour

$= \dfrac{16.2 \times 10^6}{24}$ litres/hour

$= 675 \times 10^3$ litres/hour

→ Rate of filtration = 5000 litres/hour/m²

∴ Area of filter beds required $= \dfrac{\text{water demand}}{\text{Rate of filters}}$

$= \dfrac{675 \times 10^3}{5000} \, m^2 = 135 \, m^2$

∴ $\boxed{A = 135 \, m^2}$

→ Since two unit are required to be designed

∴ Area of each unit $= \dfrac{135}{2} = 67.5 \, m^2$

→ Assuming $L = 1.5B$ ∴ $1.5B \times B = 67.5$

∴ $B = \sqrt{\dfrac{67.5}{1.5}} = 6.7 \, m$

6th Sem. civil Subject - Environmental engineering
Topic - Filtration

* Problem associated with failure

1. Air binding
2. cracking of filter
(3) Mud ball formation
(4) sand incrastation in filter
(5) sand boiling leakage of sand.

1. Air binding → Initial head loss in filter is 15-30 m loss goes in increasing as more and more impurities are trapped. A storage comes when the frictional resistance by the media exceeds the static head of water over filter head.

→ the bottom sand then acts like vacuum. Hence water gets sauced in filter media without getting filtered, the negative pressure so, developed release dissolved gases. this making bubbles which sticks to sand grains there by seriously affecting the operation. this phenomene is ~~to~~ known as Airbinding. To avoid it filter is cleaned when the head loss is more than the static head of water over sand bed.

2. cracking of filter → fine sand in top layer shrinks forming shrinkage cracks. the crack is widened by pressure applied on filter. thus ~~flocs~~ flocs, mud other impurities penetraters deep into the filter there by reducing the efficiency.

(3) Mud ball formation → Mud from the atmosphere gets deposited on the sand surface and during inadequate washing the mud may sink down in sand bed this mud sticks to sand grain and other arrasted impurities there by forming mude balls.

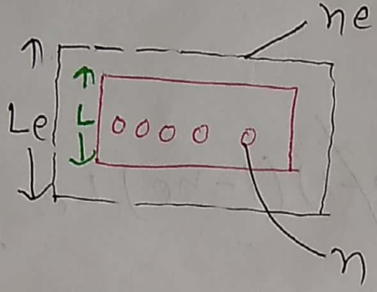
→ The mud balls go on increasing in size and may sink down in gravel layers this interfers with upward movement of water during backwashing, causing turbulence around them and gravels are displaced thus improper washing leads to accumulation of mud. once mud ball formation starts, it goes on increasing in numbers and entire space is filled with them. To avoid it scouring with compressed air along with backwashing for 4 minutes supported by manual surface racking and surface washing with caustic soda is adopted.

(4) Sand incrustation in filters →

→ in the incoming water, if carbonate ions, are present, then it will lead to the formation of white deposited on the sand particles present in filter bed known as incrustation of sand. which will lead to increasing the diameter of sand particle thus reduce the efficiency of filter bed.

⑤ sand boiling and leakage of sand →

→ Due to backwashing the Effective Stress gets reduce, thickness of sand bed increase porosity also increases, leading to sand boiling and finally leakage of sand takes place to overcome this Problem filter bed should not be washed frequently.



Where L = original Thickness of filter bed.

Le = expanded Thickness of filter bed.

n = original porosity

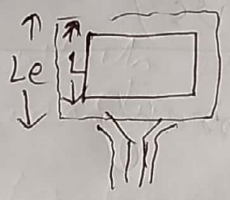
ne = expanded porosity.

$$\therefore \boxed{L(1-n) = Le(1-ne)}$$

* Expression for backwashing of rapid sand gravity

$$\boxed{L(1-n) = Le(1-ne)}$$

* for unit area



$$h_{Le} \cdot \gamma_w = \gamma_{sub} \times L$$

Where γ_w = unit weight of water in kN/m3.

γ_{sub} = Submerged unit weight of sand immerged. in depth 'L'

$$\rightarrow \boxed{\gamma_{sub} = \frac{(G-1)}{(1+e)} \times \gamma_w}$$

$$\rightarrow \underset{\text{porosity}}{n} = \frac{e}{1+e}, \quad 1-n = 1-\frac{e}{1+e} = \frac{1+\cancel{e}-\cancel{e}}{1+e} = \frac{1}{1+e}$$

$\rightarrow \boxed{\gamma_{sub} = (G-1)(1-n)\gamma_w}$

$\rightarrow h_{Le} \times \gamma_w = \gamma_{sub} \times L$

$\rightarrow h_{Le} \times \cancel{\gamma_w} = (G-1)(1-n)\cancel{\gamma_w} \times L$

$\therefore \boxed{h_{Le} = (G-1)(1-n) \times L}$

Head loss.

* During backwashing →

$n \rightarrow n_e$

$L \rightarrow L_e$

$\rightarrow \underbrace{(\cancel{G-1})(1-n)}_{\text{initial head loss}} L = (\cancel{G-1})(1-n_e) L_e$

$\rightarrow (1-n) \times L = (1-n_e) L_e$

$\therefore \boxed{L_e = \frac{(1-n)L}{(1-n_e)}}$

→ where L_e = expanded Thickness of filter bed in 'm'

L = original Thickness of filter bed in 'm'

$\therefore \boxed{n_e = \left(\frac{v_b}{v_s}\right)^{0.22}}$

~~Expend~~ extended porosity

Where -

v_b = backwashing velocity (m/s)

(Quantity of water required for backwashing divided by the filter bed area)

v_s = settling velocity (m/s)

$$\boxed{v_s = \left[\frac{\frac{4}{3} g d (G-1)}{C_d}\right]^{\frac{1}{2}}}$$

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* Design criteria of filter bed

Step ① let 'Q' be the design discharge

f_r = rate filtration in L/hour/m²

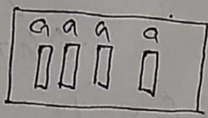
$\therefore \quad Q = A \times f_r$

Area: $\therefore \quad \boxed{A = \dfrac{Q}{f_r}}$

A = area of crosssectional of filter bed.

Step-②

Area = A



$\therefore \quad \boxed{A = n \cdot a}$

where n = no. of filter unit

a = Surface area per filter unit

* Step-③ : volume of water filtered out

$= Q \times t$

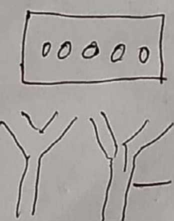
$\therefore \quad \boxed{V = A \times f_r \times t}$

V → volume

t → total time out filter

Step-④

for backwashing



→ volume of water used for backwashing

$= \boxed{A \cdot f_{br} \cdot t_b}$

t_b → time taken by back washing

f_{br} = Rate of backwashing

* Step⑤ If n = no. of troughs Quantity of water used by each troughs = $\boxed{\dfrac{\text{Quantity of water required for backwashing}}{\text{No. of troughs used}}}$

~~Step-6 percentage of water used for backwashing~~

~~backwashing = total quantity of water used for backwashing / Q~~

Step-6 - percentage of water used for back washing

$$= \frac{\text{total quantity of water used for backwashing}}{\text{total quantity of water filter out per day}} \times 100$$

$$= \frac{A \times f_b \times t_b}{Q} \times 100$$

$= 0.471 < 0.5$

Since $R_e < 0.5$, the coefficient of drag force (C_D) can be calculated by using Eq. (9.5) as :

$$C_D = \left[\frac{24}{R_e}\right] = \frac{24}{0.471} = 50.92$$

Now, $$h_L = \frac{1.067 \,.\, (1.389 \times 10^{-3})^2 \times (0.67)}{0.85 \times 9.81 \times (0.4)^4}\left[\frac{50.92}{0.4 \times 10^{-3}}\right]$$

$$= 822.5 \times \frac{10^{-6}}{10^{-3}} = \mathbf{0.822\ m.}\quad \textbf{Ans.}$$

Example 9.26. *A rapid sand filter is to be provided in a water treatment plant, to process the water for a town with a population of 2,75,000. The water demand is 200 litres/capita/day. The rate of filtration is 15 $m^3/m^2/hour$. Allow 5% of filtered water for storage to meet the backwash requirements. Each backwashing period is of 30 min. Determine the number of filters required allowing one as a standby unit. The available surface area configuration of filter unit is 10 m × 4 m. Also compute the up-flow velocity and headloss to expand the bed to 0.66 m from its original undisturbed depth of 0.6 m. The porosity of the bed is 0.50. Specific gravity is 2.5. The average particle size is 0.6 mm. The drag coefficient is 5.02. The flow is assumed to be transitional flow.*

Solution. Water required daily

= Population × Per capita demand

= 2,75,000 × 200 L/c/d

= 55×10^6 L/d = 55 MLD ...(*i*)

Filtered water required for backwashing

= 5%

= 5% × 55 MLD = 2.75 MDL ...(*ii*)

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$\therefore$ Daily water demand of filtered water

$= (i) + (ii) = 55 + 2.75$

$=$ **57.75 MLD.**

Since 30 minutes (*i.e,* 0.5 hr) is lost daily in back washing the filters, the effective time left for working of filter units

$= 24 - 0.5 =$ **23.5 hr.**

$\therefore$ Filtered water required per hour $= \dfrac{57.75}{23.5} =$ **2.457 ML/h**

Now, filtration rate = 15 $m^3/m^2.h$ (given)

$\therefore$ Area of filter required

$$= \frac{\left[\dfrac{2.457 \times 10^6}{10^3}\right] m^3/h}{15\ m^3/m^2.h}$$

$$= 163.83\ m^2$$

Size of filter (given) = 10 m × 4 m

Area of one filter unit = 40 m^2

No. of units required $= \dfrac{163.83}{40} = 4.01$; say 4.

(*i*) Using one filter unit as stand by unit, total number of filters required $\simeq$ **5. Ans.**

Use eqn. (9.2) for settling velocity (v_s) as

$$v_s = \sqrt{\frac{\frac{4}{3} . g . d . (G-1)}{C_D}}$$

$$= \sqrt{\frac{\frac{4}{3} \times 9.81 \times (0.6 \times 10^{-3})(2.5-1)}{5.02}}$$

$=$ **0.048 m/s**

Now, use Eq. (9.39) as :

$$\frac{D_e}{D} = \left(\frac{1-n}{1-n_e}\right)$$

where $n = 0.5$ (given)

$$\therefore \quad \frac{0.66\ m}{0.60\ m} = \frac{1-0.5}{1-n_e}$$

or $\quad (1-n_e) = \dfrac{0.5 \times 0.6}{0.66} = 0.455$

or $\quad n_e =$ **0.545**

Now, use Eq. (9.40) as :

$$n_e = \left(\frac{v_b}{v_s}\right)^{0.22}$$

$$0.545 = \left(\frac{v_b}{0.048}\right)^{0.22}$$

or $$v_b = 3.04 \times 10^{-3} \text{ m/s}$$
$$= 0.304 \text{ cm/s}$$
$$= 18.2 \text{ cm/min.}$$

Hence, the backwash upflow velocity = 18.2 cm/min. **Ans.**

Head loss through the expanded medium is given by Eq. (9.38) as :

$$h_{Le} = (1 - n_e)D_e \,.\, (G - 1)$$
$$= (1 - 0.545)\ 0.66\ (2.5 - 1)$$
$$= 0.455 \times 0.66 \times 1.5$$
$$= \mathbf{0.45\ m.}\ \ \textbf{Ans.}$$

9.20. Slow Sand Filters *versus* Rapid Gravity Filters

The differences between these two types of filters are brought out in Table 9.5.

Table 9.5. Comparison of Slow Sand and Rapid Gravity filters

S.No. (1)	*Item* (2)	*Slow Sand filters* (3)	*Rapid Gravity filters* (4)
1.	Pre-treatment requirements	Effluents either from plain sedimentation tanks or raw waters without any treatment are generally fed into them ; and coagulation is not at all required.	Coagulation, flocculation, and sedimentation is a must.
2.	Base material	The gravel base supports the sand. It varies from 3 to 65 mm in size and 30 to 75 cm in depth.	The gravel base supports the sand and also distributes the wash water uniformly on the surface of sand. It varies from 3 to 40 mm in size and its depth is slightly more, *i.e.* about 60 to 90 cm.

Table 9.5 continues

S.No. (1)	*Item* (2)	*Slow Sand filters* (3)	*Rapid Gravity filters* (4)
3.	Filter sand	The effective size of filter sand ranges between 0.2 to 0.4 mm and uniformity coefficient between 1.8 to 2.5 or 3.0.	The effective size of the filter sand ranges between 0.35 to 0.55 and uniformity coefficient between 1.2 to 1.8.
		The grain size distribution is generally uniform throughout the depth of filter media, except that top 10 to 15 cm may be laid of finer variety.	The sand is laid in layers with smallest grain size at top and coarsest grain size at the bottom.
4.	Under-drainage System	Laid in order to receive filtered water.	Laid in order to receive filtered water and also to pass water for back washing at a very high rate.
		Open jointed pipes or drains covered with blocks may be used.	Perforated pipe laterals discharging into mains or diffuser plate bottom may be used.
5.	Size of each unit	Large, such as (30 m × 60 m). The area varying from 100 to 2000 sq m or more.	Small, such as 5 m × 8 m. The area varying from 10 to 80 sq. m.
6.	Rate of filtration	Small, such as 100 to 200 litres per hour per sq. m of filter area.	Large, such as 3000 to 6000 litres per hour per sq. m of filter area.
7.	Economy	High initial cost of both land and materials, but low cost of operation and maintenance.	Low initial cost, but higher cost of operation and maintenance. Overall, it is cheaper and economical.
8.	Depreciation Cost	Relatively low.	Relatively high.
9.	Efficiency	Very efficient in removing bacteria (98 to 99 par cent) but less efficient in removing colour. Overall turbidity removal in these filters using plain sedimentation is also low. They cannot handle turbid waters containing turbidities more than 50 mg/l.	Less efficient in removing bacteria (80 to 90 per cent) but vary efficient in removing colour. The overall turbidity removal in these filters using coagulation sedimentation, is also high. They can, therefore, handle very turbid waters.

Table 9.5 continues

S.No. (1)	*Item* (2)	*Slow Sand filters* (3)	*Rapid Gravity filters* (4)
10.	Flexibility	Not flexible for meeting variations in demand.	Quite flexible for meeting reasonable variations in demand.
11.	Suitability and adaptability	May be adopted for treating smaller village supplies or for individual industrial supplies, especially at hotter places where no covers are required to protect the filters from freezing. They are however, becoming obsolete.	They are widely and almost universally adopted for treating public supplies, especially at all major cities and towns.
12.	Post treatment, required, if any	Almost pure water is obtained. However, it *may be disinfected slightly* to make it completely safe. Other miscellaneous treatments may or may not be reqd.	*Disinfection is a must* and some other miscellaneous treatments may be given, if needed.
13.	Ease in construction	Simple	Complicated, as underdrainage is to be properly designed.
14.	Skilled supervision, if reqd.	Not required.	Essential.
15.	Loss of head	Approximately 10 cm is the initial loss, and 0.8 to 1.2 m is the final limit when cleaning is required.	Approximately 0.3 m is the initial loss, and 2.5 to 3.5 m is the final limit when cleaning is required.
16.	Method of cleaning	(*a*) Scrapping and removing the top 1.5 to 3 cm thick layer, and washing down by hoses. (*b*) Laborious method.	(*a*) Agitating the sand grains and back washing with or without compressed air. (*b*) Short and easy method.
17.	Qty. of wash water required	Very small amount of wash water, varying from 0.2 to 0.6 per cent of the total water filtered is generally needed.	Large amount of wash water varying from 1 to 5 per cent of the total water filtered, is generally required.
18.	Period of cleaning	Cleaned at intervals of 1 to 3 months.	Cleaned frequently at intervals of 1 to 3 days.

③ pressure filters

→ Smallest rapid sand gravity placed in closed vessel.

→ pressure applied is greater than the atmospheric pressure.

→ 300 to 700 kN/m² → pressure is applied.

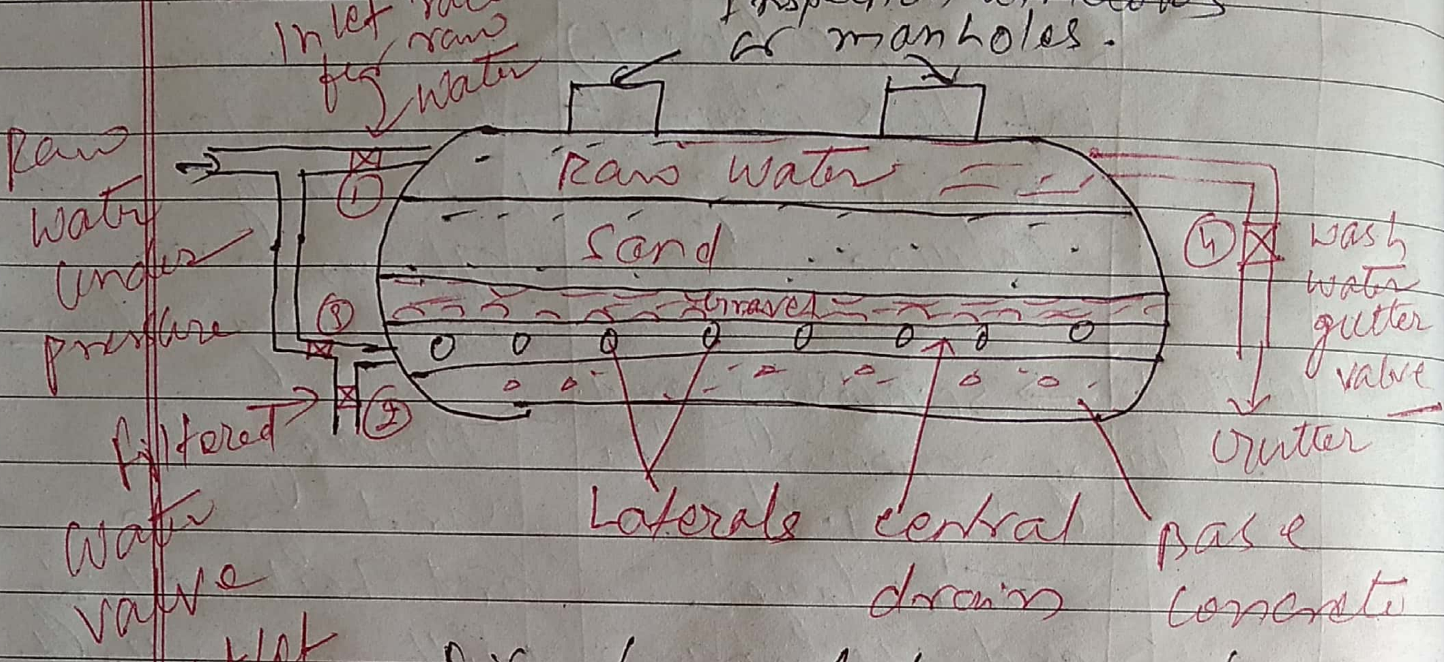
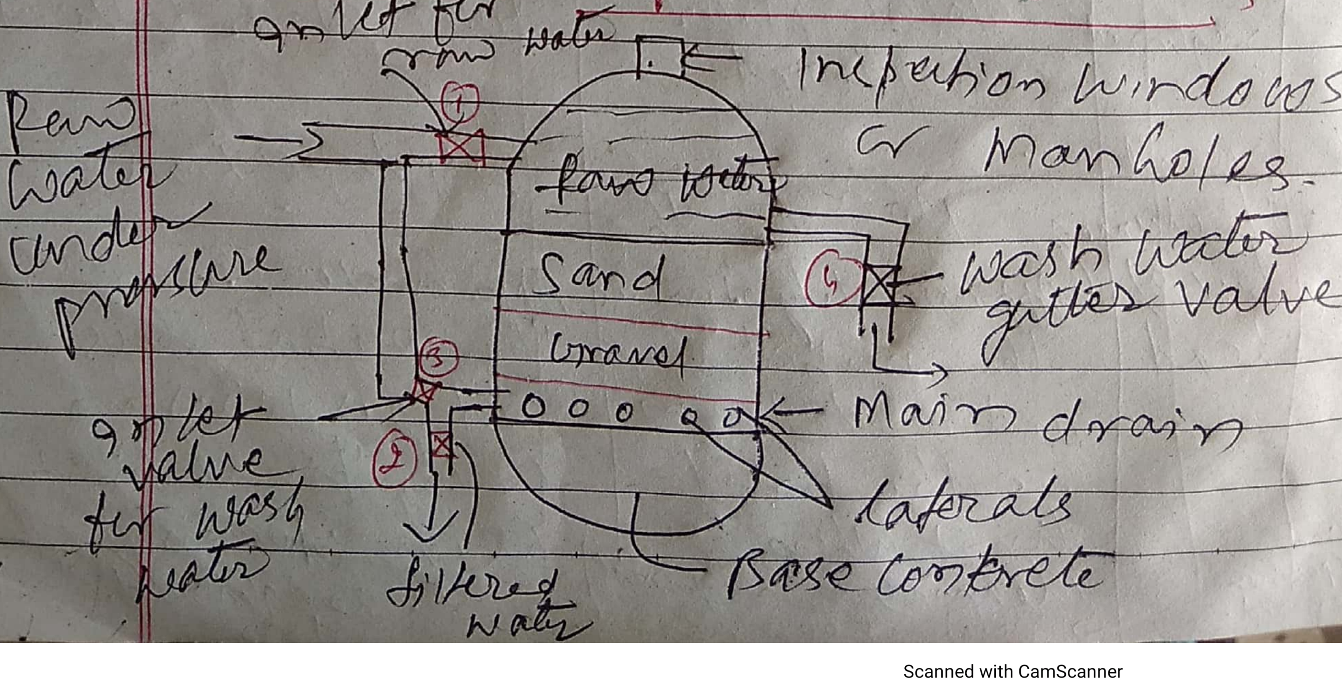


Fig- horizontal pressure filters

* vertical pressure filters



→ Rate of filteration → 6000 to 15000 litres/m²

* Advantages
① Coagulation, flocculation takes place ~~Hable~~ inside the pressure filters.

② Small & compact
(3) Rate of filtration is high.

* Disadvantages → ① Not ~~for~~ fit for drinking purposes

② Bacterial removal Efficiency is less

(3) Uneconomically.

Used → Small industries
→ Swimming pools.