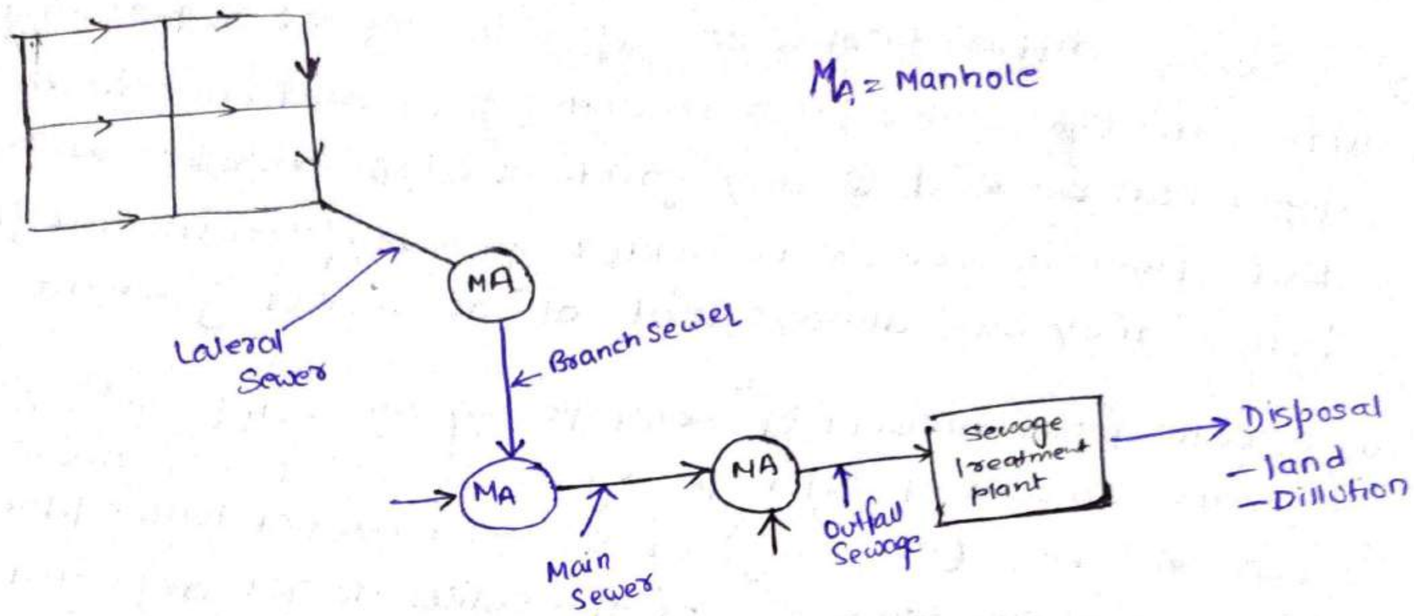
Design of Sewers



Type of component structure.	Properties for deciding design period	Design life
→ Lateral sewer	Requirement may changes faster in limited area.	full development.
→ Branch, Main, outfall sewer	These are difficult & costly to enlarge.	40-50
→ Treatment plant	Interest rate being high/moderate.	15-20
→ Pumping plant	Technological advancement	5-10

→ Sewer are pipes or conduits required to carry the sewage from one point to another in sewerage system.

→ Sewers differ from water pipes in respect to following:-

(i) flow through water pipes is under pressure hence these pipes can be laid @ any gradient (upward or downward) but flow in sewer is under gravity (open channel flow) hence they are always laid at downward gradient.

(ii) In water pipes amount of solid flowing are comparatively less then the amount of solid flowing in sewers hence more wear and tear (scouring) of sewer material takes place and has higher tendency of the solids to get deposited & lead to the chocking of sewer.

→ About 80% of water being supplied into community flows into the sewer.

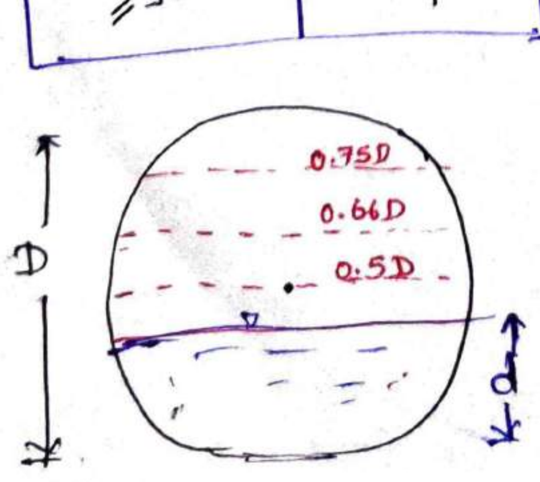
Assumption: Avg discharge = 0.8 avg. water demand.

→ Sewers are never designed to run at full depth.

If

D(mm)	$\frac{d}{D}$	FOS
< 400	$\frac{1}{2}$	2
400-900	$\frac{2}{3}$	1.5
≥900	$\frac{3}{4}$	1.33

F.O.S. = $\frac{\text{Max}^m \text{ depth at which sewer can run without overflow (D)}}{\text{Actual flow depth (d)}}$



(i) Additional space provided above the depth of flow helps to accomodate the additional sewage being produced over the assumed design flow of sewage.

(ii) This additional space also helps in accumulating methane produced during anerobic decomposition in sewer. There by helps in reducing the chances of explotion in the sewer.

→ Unless given fluctuation in the rate of flow of sewage in branch sewer is taken as follow:-

$$\text{Max}^m \text{ daily flow} = 2 \times \text{Avg daily flow.}$$

$$\text{Max}^M \text{ hourly flow} = 1.5 \text{ Max daily flow}$$

$$= 1.5 \times 2 \times \text{Avg daily flow}$$

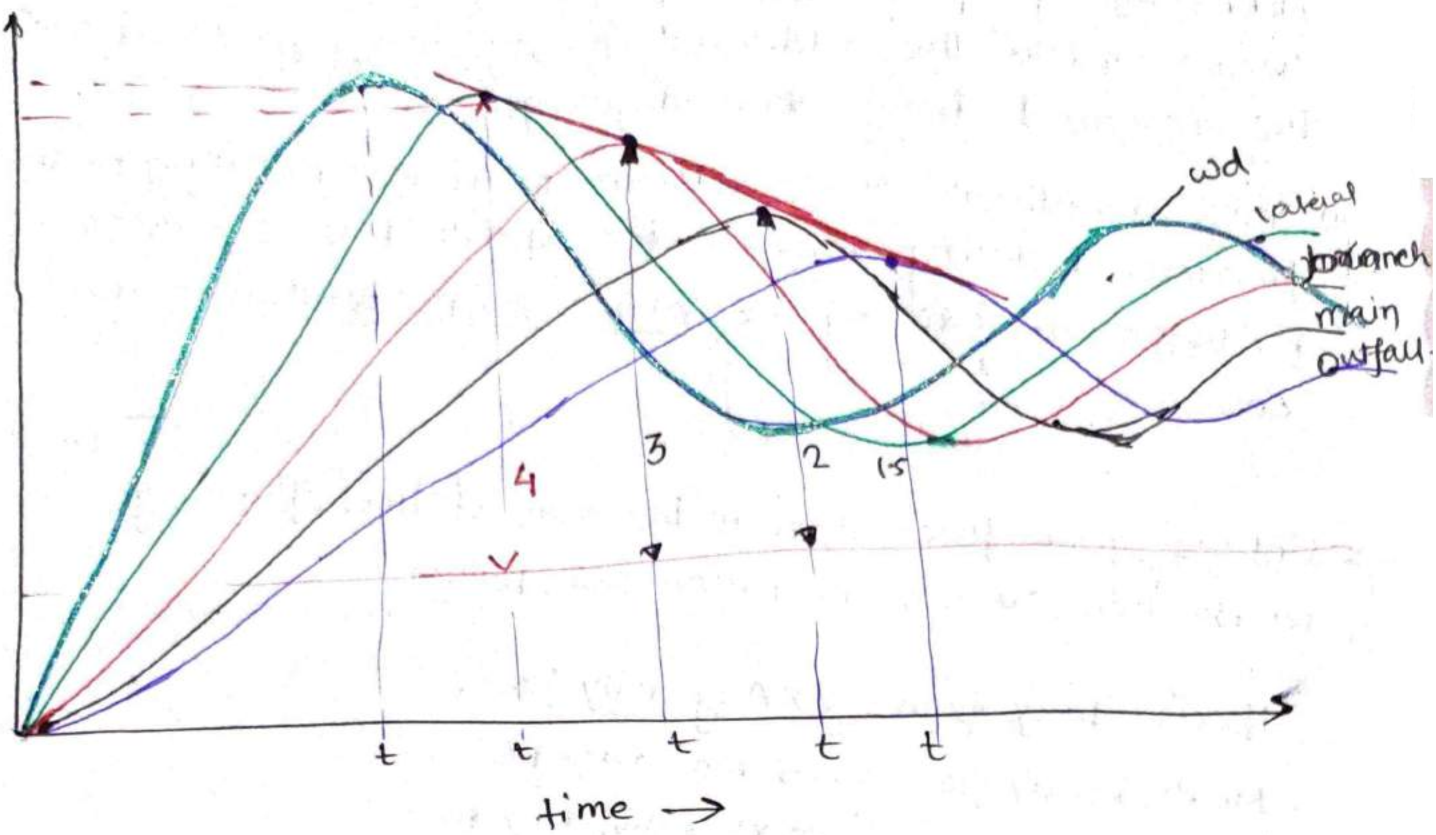
$$\boxed{\text{Max}^M \text{ hourly flow} = 3 \text{ Avg daily flow.}}$$

$$\text{Minimum daily flow} = \frac{2}{3} \text{ avg. daily flow.}$$

$$\text{Minimum hourly flow} = \frac{1}{2} \times \text{minimum daily flow.}$$

$$= \frac{1}{2} \times \left(\frac{2}{3} \times \text{Avg daily flow}\right)$$

$$\boxed{\text{Min}^M \text{ hourly flow} = \frac{1}{3} \text{ avg daily flow.}}$$



→ Fluctuation in lateral sewer is observed to be maximum & it tapper off from lateral to branch, branch to main, main to outfall sewer due to increase in sample size.

Type of Sewer	(m) diameter	fluctuation
Lateral	0.25	4
Branch	0.50	3
Main	1	2
Outfall	1.25	1.5

Note Fluctuation ie, $\frac{Q_{max}}{Q_{avg}} = \frac{18+\sqrt{P}}{4+\sqrt{P}}$

P = population of community in thousand.

Design:

→ Sewers are design to carry max^m hourly discharge for development and are checked at minimum discharge of self cleansing velocity.

→ Self cleansing velocity is that which do not permit the silting of solid in sewer moreover also carry out removal of solid which have already settled in it.

→ Self cleansing velocity for 1mm in organic particle and 5mm organic particles is 0.45 m/s

→ These are the size of particles which are generally present in sewage

→ Self cleansing velocity in sewer is given by

$$V_{se} = \sqrt{\frac{8K}{f}(G-1)gd} \quad \text{or} \quad V_s = \frac{1}{n} r^{1/6} \cdot \sqrt{K(G-1)d}$$

Chezy's equation — maning equation

K = constant which depend on the type of solid in sewage.

f = friction factor.

n = manning's constant

r = hydraulic mean depth.

→ This velocity must technically develop once in a day to avoid silting of solid in sewer and removal of those solid which have already settled., But for designing purpose it is considered at minimum discharge

→ The self cleansing velocity of 0.45 m/sec will be attained at minimum discharge if sewer are designed for design flow conditions and velocity at design discharge is in range of 0.8-0.9 m/s.

→ Max^m velocity of flow in sewer is also constrained as higher velocity leads to wear and tear (scouring) of sewer material thereby reduces their life span and discharge carrying capacity.

→ This limiting or non-scouring velocity mainly depends upon the material of the sewer. as

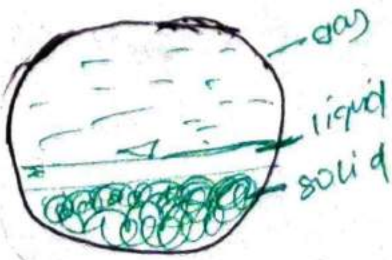
→ The problem of controling high velocity in sewer mainly rises in hilly areas where available ground slope may be very large or steep.

→ Non-scouring velocity in sewer are as follow:-

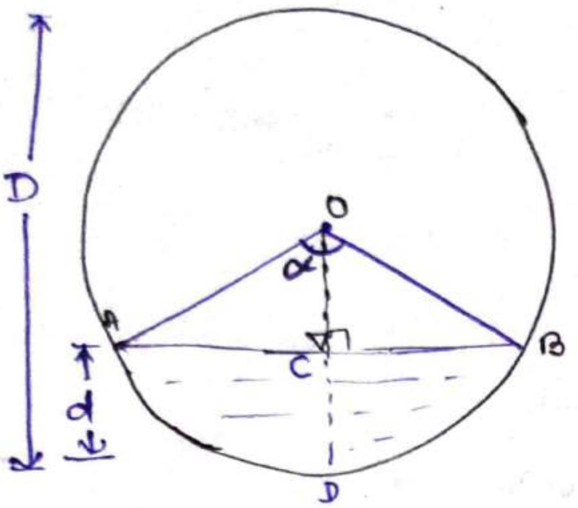
Sewer material	Limiting velocity (m/s)
→ Vitrified tile & glazed brick	4.5-5.5
→ cast Iron	3.5-4.5
→ Stone ware.	3-4
→ cement concrete	2.5-3
→ Ordinary brick-lined	1.5-2.5
→ Earthen channel	0.6-1.2

Note:- Vitrified tiles & glazed bricks are much more resistant to wear and tear compared to ordinary brick or concrete.

Hence the ordinary brick or concrete sewer are sometime coated with vitrified clay or glazed brick lining at their bottom (where abrasion is max^m due to solid).



* Hydraulic Properties of flow in sewers running partially full and completely full.



(i) Depth of flow

$= d = CD = OD - OC$

$= \frac{D}{2} - OC$

$= \frac{D}{2} - \frac{D}{2} \cos\frac{\alpha}{2}$

$\cos\frac{\alpha}{2} = \frac{OC}{D/2}$

~~$\sin\frac{\alpha}{2} = \frac{OC}{D/2}$~~

~~$OC = \frac{D}{2}\sin\alpha/2$~~

~~$\cos\frac{\alpha}{2} = AC$~~

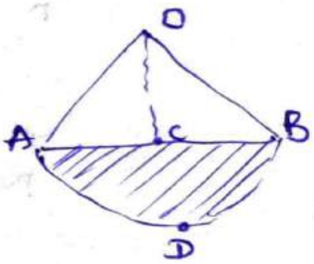
$\sin\frac{\alpha}{2} = \frac{AC}{D/2}$

$d = \frac{D}{2}\left(1 - \cos\frac{\alpha}{2}\right)$

$$\boxed{\frac{d}{D} = \frac{1 - \cos\alpha/2}{2}}$$

(ii) Area of flow

$a = \text{area } ADBCA = \text{area } ADBO - \text{Area } OAB$



If $\alpha = 360°$, area $OADB$, $A = \frac{\pi D^2}{4}$

$\alpha = \alpha°$, area $OADB$, $a = \frac{\pi D^2}{4} \times \frac{\alpha}{360°}$

$= \frac{A\alpha}{360°}$

(AB = 2AC)

$\text{Area } OAB = \frac{1}{2} \times AB \times OC$

$= \frac{1}{2} \times 2\frac{D}{2}\cos\frac{\alpha}{2} \times \frac{D}{2}\sin\frac{\alpha}{2}$

$= \frac{D^2}{4}\cos\frac{\alpha}{2}\sin\frac{\alpha}{2}$

$= \frac{D^2}{8}\sin\alpha$

$= \frac{A\sin\alpha}{2\pi}$

area of flow under partial flow condition, $a = \frac{A\alpha}{360} - \frac{A\sin\alpha}{2\pi}$

$$\boxed{\frac{a}{A} = \frac{\alpha}{360} - \frac{\sin\alpha}{2\pi}}$$

(6)

(iii) Perimeter of flow

p = length ADB.

if $\alpha = 360^\circ$, $P = 2\pi r = \pi D$

$\alpha = \alpha$ $\quad p = \frac{\alpha}{360^\circ} \times \pi D$

$p = P\frac{\alpha}{360^\circ}$

Proportionate perimeter $\boxed{\frac{p}{P} = \frac{\alpha}{360^\circ}}$

(iv) Hydraulic Mean Depth of flow., r

$r = \frac{\text{wetted area}}{\text{wetted perimeter}} = \frac{a}{p}$, $\quad R = \frac{A}{P}$

$\frac{r}{R} = \frac{\frac{a}{p}}{A/P} = \left(\frac{a}{A}\right)\left(\frac{P}{p}\right)$

$$\boxed{\frac{r}{R} = \frac{\frac{\alpha}{360} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}}$$

(v) Velocity of Flow.

$V = f(f, r, i)$ [f = friction, i = slope]

$i = \frac{h_L}{L} = \sin\theta$, $\quad S = \frac{h_L}{L'} = \tan\theta$

when θ is small

$\theta = \sin\theta = \tan\theta$.

$$\boxed{i = S}$$

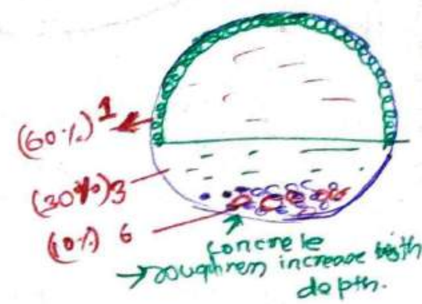
Manning's flow, $v = \frac{1}{n} r^{2/3} . s^{1/2}$ or $V = \frac{1}{N} R^{2/3} . S^{1/2}$

$$\frac{v}{V} = \frac{n}{N}\left(\frac{r}{R}\right)^{2/3} . \left(\frac{s}{S}\right)^{1/2}$$

[$s = S$, $N \neq n$, $N < n$]

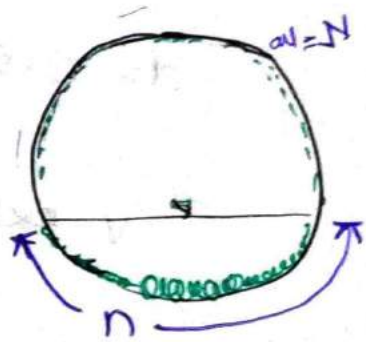
(N: Overall roughness of sewer; n: roughness in lower part)

we assume, $n = N$



$$\frac{v}{V} = \left(\frac{r}{R}\right)^{2/3}$$

$$\boxed{\frac{v}{V} = \frac{\left(\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}\right)^{2/3}}{\alpha/360^\circ}}$$



(vi) Rate of flow,

$q = a v$, $Q = A \times V$

$$\frac{q}{Q} = \left(\frac{a}{A}\right)\left(\frac{v}{V}\right)$$

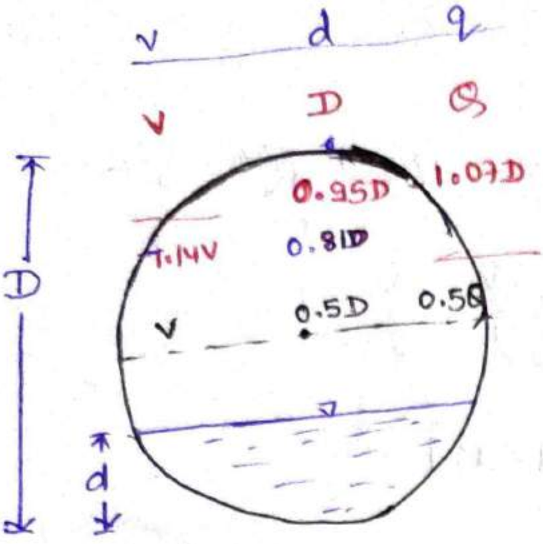
$$\boxed{\frac{q}{Q} = \left(\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}\right)\left(\frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}\right)^{2/3}}$$

Assuming $n =$ constant.

Assume n = constant

if sewer is running half full,

$$\frac{d}{D} = \frac{1}{2}$$



$$\frac{d}{2} = \frac{1-\cos\alpha/2}{2} = \frac{1}{2} \Rightarrow \alpha = 180^\circ$$

$$\frac{a}{A} = \frac{1}{2}, \quad \frac{p}{P} = \frac{1}{2}, \quad \frac{r}{R} = 1$$

$$\frac{v}{V} = 1, \quad \frac{q}{Q} = \frac{1}{2}$$

$$V = f(f, r, s)$$

$d = 0.5d \uparrow$ → S = constant
→ $f \downarrow$ (Assume f = constant)

$v \propto r = \dfrac{\text{wetted area} \uparrow\uparrow}{\text{wetted perimeter} \uparrow}$

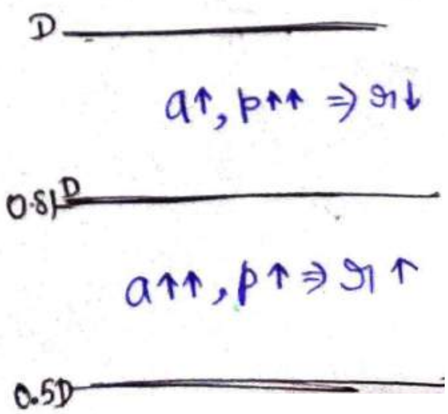
For v_{max} = $\dfrac{d(v/V)}{d\alpha} = 0$

$$\Rightarrow \frac{d}{dx}\left[\left(\frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}\right)^{2/3}\right] = 0$$

$$\tan\alpha = \alpha$$

$$\alpha = 256^\circ$$

$$\left.\frac{d}{D}\right|_{\alpha = 256^\circ} = 0.81$$



$$\frac{V_{max}}{V}\Big|_{\alpha=256^\circ} = 1.14$$

$V_{max} = 1.14V \Rightarrow$ V_{max} velocity is only 14% more than velocity at full depth of flow.

$$q = av$$

$$q = f[f, r, s, a]$$

$$q \propto r.a = \frac{a}{p}.a = \frac{a^2}{p}$$

For $q_{max} = \dfrac{d(q/Q)}{d\alpha} = 0$

$$\frac{d}{dx}\left[\left(\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}\right)\left(\frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}\right)^{2/3}\right] = 0$$

$$\alpha \approx 308^\circ$$

$$\frac{d}{D}\Big|_{\alpha=308^\circ} = 0.95$$

$$\frac{q_{max}}{Q}\Big|_{\alpha=308^\circ} = 1.07$$

$$q_{max} = 1.07Q.$$

It means maximum discharge is only 7% more than full discharge.

D

$a^2\uparrow,\ p\uparrow\uparrow,\ \Rightarrow \frac{a^2}{p}\downarrow$

0.95D

$a^2\uparrow\uparrow,\ p\uparrow\ \Rightarrow \frac{a^2}{p}\uparrow$

0.5D

If $\Delta d = 100\%$ $(0.5D - D)$

$V_{max} = 1.08 \, V_{avg}$. $q_{max} = 1.25 q_{avg}$.

→ This is the greatest advantage of circular section that fluctuation in velocity & discharge (8% , 25% , respectively) are least amongst other geometry of section available. Hence sewer are designed to be circular to avoid shock loading (sudden change in flow properties (v, q). shock loading in sewage treatment plant To avoid shock loading in sewage treatment plant which is disaster for micro-organisms carrying out treatment in the plant.

→ This advantage of circular section is available only if depth of flow is greater than half full, hence minimum depth of flow for which circular section design is 0.5 D.

→ The above statement are ~~co~~ precisely correct only as long as roughness (n) is supposed to be independent of depth.

→ However roughness varies with depth. as much as by 20% ~~or~~ more

→ The effect of variation of n is to reduce the proportionate velocity and discharge at lower depth of flow because roughness increases with lower depth.

→ If these variation of "n" are also considered more precise values of proportionate velocity & discharge are computed.

→ If roughness is also considered, velocity equal to ~~moor~~ or more than these produced in section flowing full, will be produced so long as the circular section flow 80% of depth as against half the depth when roughness is not considered.

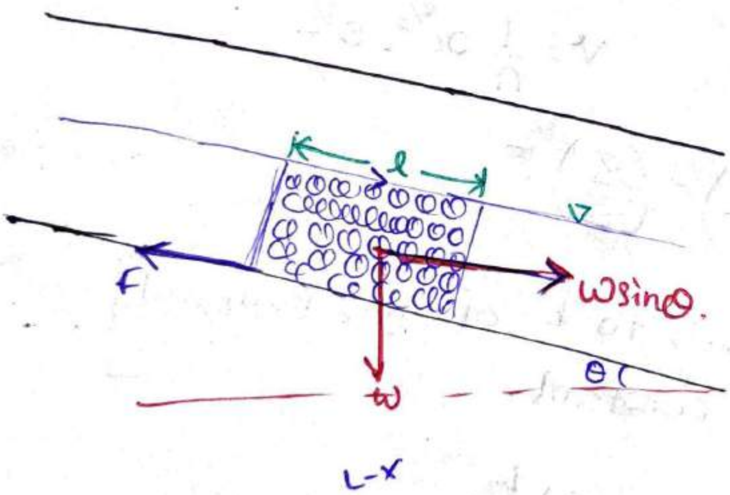
→ However if depth of flow is in between 50% to 80% full, sewer need not be placed on steeper gradient

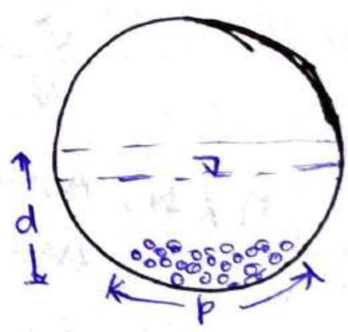
→ If two sewer have degree of self cleansing then shear stress or tractive stress acting on the sewage flowing in these sewers is also same.

Note:- Shear stress or tractive stress acting on the fluid flowing in open channel is given by

$$\boxed{\tau = \gamma . R S}$$

γ = unit weight of fluid
R = Hydraulic mean depth of flow.
S = slope of channel.

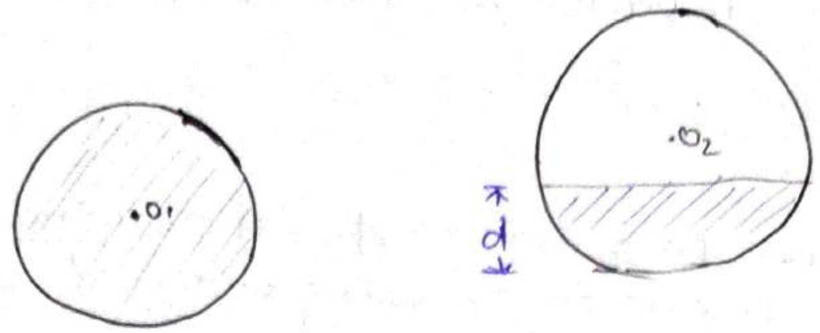




$$\tau = \frac{f}{a} = \frac{W \sin\theta}{a} \simeq \frac{W \tan\theta}{a}$$

$$\tau = \frac{\gamma . V \tan\theta}{a} = \frac{\gamma . a . l\, S}{P\, l} = \gamma . R S$$

$\tan\theta = S$
$R = \frac{a}{P}$



* For same degree of self cleansing

$$\boxed{\tau = \tau}$$

$$\gamma . RS = \gamma . r . s$$

($\gamma \neq \gamma$, Assume $\gamma \cong \gamma \cong \gamma_w$)

$$\boxed{\frac{S}{s} = \frac{r}{R}}$$

$$V = \frac{1}{N} R^{2/3} \cdot S^{1/2} \qquad v = \frac{1}{n} r^{2/3} \cdot s^{1/2}$$

$$\frac{v}{V} = \frac{N}{n}\left(\frac{r}{R}\right)^{2/3}\left(\frac{s}{S}\right)^{1/2}$$

[$n \neq N$, Assume sewer to be of same material.
Assume n = constant.]

$$\frac{v}{V} = \left(\frac{r}{R}\right)^{2/3}\left(\frac{R}{r}\right)^{1/2}$$

$$\boxed{\frac{v}{V} = \left(\frac{r}{R}\right)^{1/6}}$$

r = hydraulic mean depth of bigger sewer with partial flow.

R = hydraulic mean depth of smaller sewer with full flow.

~~$\frac{r}{R} = \frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}$~~ ~~$\alpha/360^\circ$~~

Note:- All the relation between hydraulic properties of flow at particles & full depth are valid for same sewer.

→ But can also be applied to two different sewer in one condition:-

(i) Sewage in both sewer is same.

(ii) Material of both sewer is same.

(iii) n is constant.

(iv) Sewer are of same size.

Q A 350mm dia sewer is to flow at 0.35m depth on a grade ensuring a degree of self cleansing equivalent to that obtained at full depth at a velocity of 0.8 m/sec.

compute

(a) Required grade (slope) ✓

(b) associated velocity.

Assume N = 0.014

$\frac{a}{A} = 0.315$ $\frac{r}{R} = 0.7705$.

$\frac{p}{P} = 0.472$

Soln

$V = 0.8 \, m/s$

$V = \frac{1}{N} R^{2/3} . S^{1/2}$

$0.8 = \frac{1}{0.014} . \left(\frac{\frac{\pi D^2}{4}}{\pi D}\right)^{2/3} . S^{1/2}$

$0.8 = \frac{1}{0.014} \times \left(\frac{0.35}{4}\right)^{2/3} . S^{1/2}$

$S = 3.29 \times 10^{-3}$

If two sewer have same degree of self cleansing

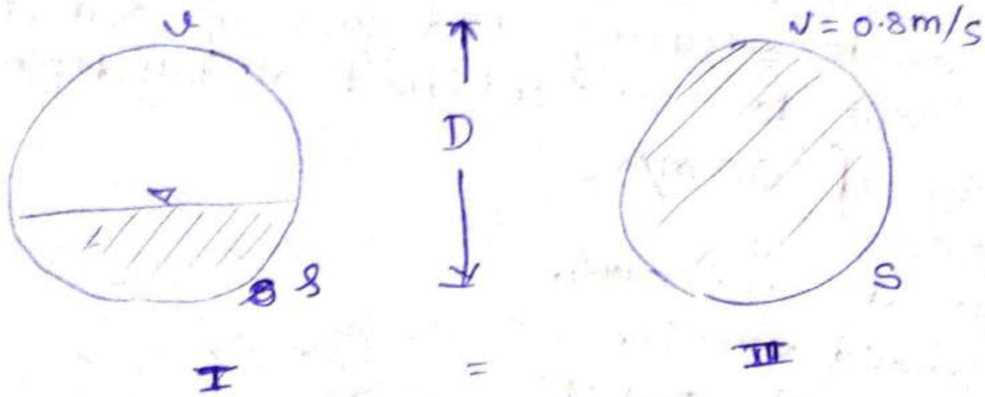
$\frac{s}{S} = \frac{R}{r} \Rightarrow s = \left(\frac{R}{r}\right) \times S$

$= 3.29 \times 10^{-3} \times \frac{1}{0.7705}$

$= 4.19 \times 10^{-3}$

$$\frac{v}{V} = \left(\frac{r}{R}\right)^{1/6}$$

$$v = (0.7705)^{1/6} \times 0.8$$
$$= 0.765 \text{ m/s}$$

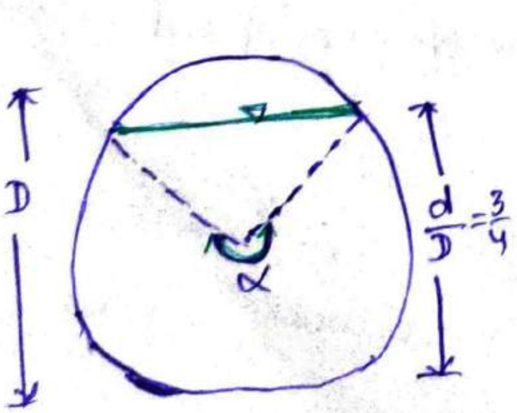


Q Design a sewer running at depth of $\frac{3}{4}$th full to serve the population of 36000 having water demand of 150 l/c/d at slope of $\frac{1}{600}$ assume $N = 0.012$

Design discharge through sewer = q_{max} = fluctuation of avg disch

Assuming sewer to be branch sewer, F = 3

$$q_{max} = 3\left[0.8 \times \frac{36000 \times 150 \times 10^{-3}}{86400}\right]$$
$$= 0.15 \text{ m}^3/\text{s}$$



$$\frac{d}{D} = \frac{1 - \cos \alpha/2}{2}$$

$$\frac{3}{4} \times 2 = 1 - \cos \alpha/2$$
$$\frac{\alpha}{2} = 120^\circ$$
$$\alpha = 240^\circ$$

$$\frac{q_{max}}{Q} = \left(\frac{a}{A}\right)\left(\frac{v}{V}\right)$$

$$= \left(\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}\right)\left(\frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}\right)^{2/3}$$

Put $\alpha = 240^\circ$

$$\frac{q_{max}}{Q} = (0.80)(1.13) = 0.911$$

$$Q = \frac{q_{max}}{0.911} = \frac{0.15}{0.91} = 0.164\, m^3/s$$

$$Q = A \times V$$

$$0.164 = \frac{\pi \times D^2}{4} \times \frac{1}{N} \cdot R^{2/3} \cdot S^{1/2}$$

$$= \frac{\pi D^2}{4} \times \cdot \left(\frac{\frac{\pi D^2}{4}}{\pi D}\right)^{2/3} \cdot S^{1/2} \cdot \frac{1}{N}$$

$$= \frac{\pi D^2}{4} \times \left(\frac{D}{4}\right)^{2/3} \cdot \left(\frac{1}{600}\right)^{1/2} \cdot \frac{1}{0.012}$$

$$0.164 = \frac{\pi}{4} \times \frac{D^{8/3}}{4^{2/3}} \cdot \left(\frac{1}{600}\right)^{1/2} \cdot \frac{1}{0.012}$$

$$D = 0.495$$
$$\simeq 0.5\, m$$

Check:- $q_{min} = \frac{1}{F} q_{avg}$

$$= \frac{1}{3} \times 0.05 = 0.0167\, m^3/s.$$

$$\frac{q_{min}}{Q} = \frac{0.0167}{0.164} = 0.1016$$

$$\frac{q_{min}}{Q} = \left(\frac{a}{A}\right)\left(\frac{v}{V}\right)$$

$$0.1016 = \left(\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}\right)\left(\frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\alpha/360^\circ}\right)^{2/3}$$

$$\alpha = 110.5^\circ$$

$$\frac{v}{V} = \left(\frac{\frac{\alpha}{360} - \frac{\sin\alpha}{2\pi}}{\alpha/360} \right)^{2/3} = 0.64 \quad \alpha = 110.5^\circ$$

$$\boxed{v = 0.64 \times V}$$

$$V = \frac{1}{N} R^{2/3} \cdot S^{1/2} = \frac{1}{N} \times \left(\frac{D}{4}\right)^{2/3} \cdot S^{1/2} = 0.85\,m/s$$

$$= \frac{1}{0.012} \times \left(\frac{0.5}{4}\right)^{2/3} \times \left(\frac{1}{600}\right)^{1/2}$$

$$v = 0.64 \times 0.85$$

$$= 0.64\ m/s < 0.45\ m/s$$

$$= 0.54 > 0.45\ m/s.$$

self cleansing velocity for 1mm or 5mm particle.

Redesign

Q Calculate the ratio of head loss per unit length in sewer running half full and completely full and having same mean velocity.

(a) 0.5 (b) 2 (c) 1 (d) $2^{2/3}$

$$i = \frac{\text{head loss}}{\text{per unit length}}$$

$$\frac{d}{D} = \frac{1}{2} \ ; \ \frac{v}{V} = 1 \ ; \ \frac{r}{R} = 1$$

$$v = V$$

$$\frac{1}{n} \cdot r^{2/3} \cdot i^{1/2} = \frac{1}{N} R^{2/3} \cdot I^{1/2}$$

$$\frac{i}{I} = \left(\frac{n}{N}\right)^2$$

so, if n is constant

$$\frac{i}{I} = 1$$

Egg Shaped Sewer

The circular sections are generally prefered to all other shape. of sewer because of following properties.

(i) They can be manfactured most easily and conveniently.

(ii) A circular sewer offers maximum area for a given parometer. thus provides the maximum hydraulic mean depth when running full or half full. Hence is the most hydraulically efficient section.

(iii) Circular section utilises minimum quantity of material and is therefore most economical.

(iv) It being uniform in curvature all around offers less opportunity of deposits.

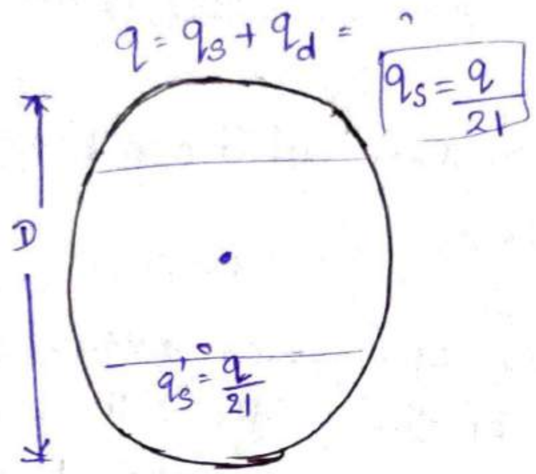
But all these advantages of circular section are available when its depth of flow is more than 0.5D Hence. these circular sections are suitable to be provided in seperate sewerage system where depth of flow remains above 0.5 D for most part of operation.

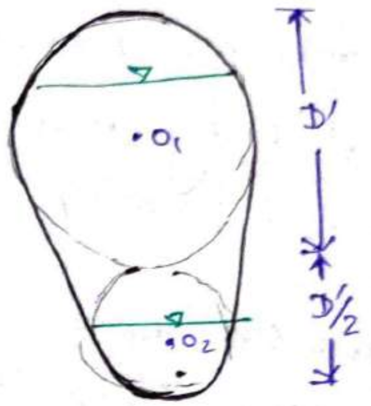
→ But in combined sewerage system, where both drainage and sanitary sewage is collected by single sewer, advantage of circular section would be available only during rainy season as for most part of year the sewer would run less than half full.

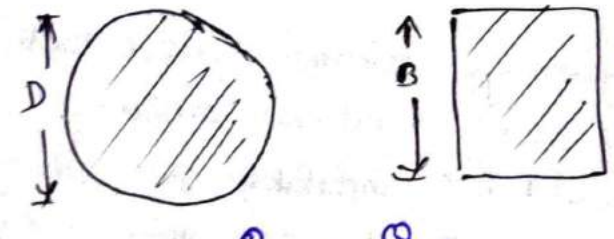
→ Hence in combined sewerage system, in order to take the advantage of circular section through out the year two such circular section are placed one over eachother such that upper bigger circular section is effective during rainy season and lower smaller section is effective during dry wheather flow, since the section appears like egg in shape it is termed as "egg shaped Sewer".

Note: If two sections are hydraulically equivalent then they carry same discharge while running full on the same grade & are of same material.

→ If a circular section of diameter "D" is hydraulically equivalent to Egg shaped section of total height "$\frac{3}{2}D'$" then $D' = 0.84D$







$$Q_o = Q_\square$$

$$A_o V_o = A_\square V_\square$$

$$\frac{\pi D^2}{4} \times \frac{1}{N} \times \left(\frac{D}{4}\right)^{2/3} S^{1/2} = B^2 \cdot \frac{1}{N}\left(\frac{B}{4}\right)^{2/3} \cdot S^{1/2}$$

$$D = 1.1B$$

Q Design the sewer for following data

$P = 70000$

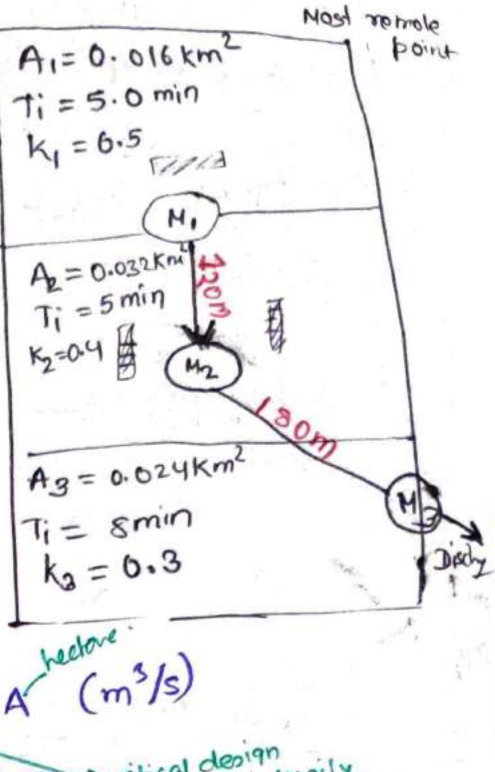
$APWP = 150\,l/c/d$

$N = 0.012$

$S = \frac{1}{500}$

Assume any data not given.

M = manhole



Diegn sanitory sewage dischage:-

$$q_{ss} = F\, q_{avg}$$

$$q_{ss} = 3 \times \left[\frac{0.8 \times 150 \times 70000 \times 10^{-3}}{86400}\right]$$

$$= 0.29\, m^3/sec.$$

Design drainage discharge, $q_D = \frac{1}{36} K\, p_c\, A$ (hectare) (m^3/s)

- K → Coefficient of runoff = $\frac{\text{runoff}}{\text{rainfall}} < 1$
- p_c → critical design rainfall intensity = cm/hr

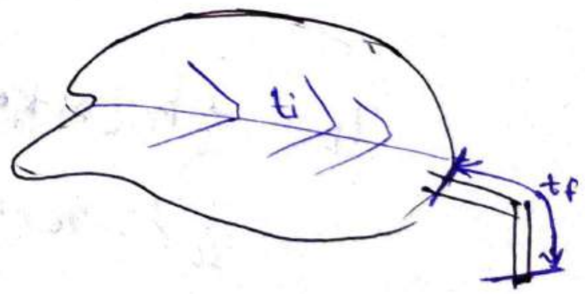
$p_c = f(t_c)$

t_c = time of concentration = time taken by water from remotest point to reach upto concered section.

$$\boxed{t_c = t_i + t_f}$$

t_i = Inlet time;

t_f = flow time.



If $t_c = (5\text{-}20)$ min

$$p_c = \frac{75}{10 + t_{c,\,min}} \quad (cm/hr)$$

if $t_c = (20\text{-}100)$ min

$$p_c = \frac{100}{20 + t_c} \quad (cm/hr)$$

For area 1

$t_1 = 5 min$, $t_f = \frac{L_1 + L_2}{V_f} = \frac{120+180}{V_f}$

Assume $V_f = 0.75 m/sec$, $t_f = \frac{300}{0.75 \times 60} = 6.67 min$

$t_c = t_i + t_f = 5 + 6.67 = 11.67 min$

For Area-2

$t_i = 5 min$, $t_f = \frac{L_2}{V_f} = \frac{180}{0.75 \times 60} = 4 min$

$t_c = 5 + 4 = 9 min$

For Area-3

$t_i = 8 min$, $t_f = 0$

$t_c = 8 + 0 = 8 min.$

tc for peak discharge, $t_c = 11.67 min. < 20 min$,

$P_c = \frac{75}{10 + 11.67} = 3.46 cm/hr.$

$$q_D = \frac{1}{36} P_c [A_1 K_1 + A_2 K_2 + A_3 K_3]$$

$$= \frac{1}{36} \times 3.46 \times [0.5 \times 0.016 + 0.4 \times 0.032 + 0.3 \times 0.024] \times 10^6 \times 10^{-4}$$

$= 0.268 m^3/s$

Total discharge $= 0.29 + 0.268$

$= 0.558 m^3/sec.$

$R = \frac{\pi/4 D^2}{\pi D} = \frac{D}{4}$

Assuming sewer to be running full,

$Q = 0.5587 \ m^3/$

$Q = A \times V$

$0.5587 = \frac{\pi D^2}{4} \times \frac{1}{N} (D/4)^{2/3} \cdot S^{1/2}$

$0.5587 = \frac{\pi D^2}{4} \times \frac{1}{0.012} \times \left(\frac{D}{4}\right)^{2/3} \cdot \frac{1}{500}$

$D = 76 cm.$

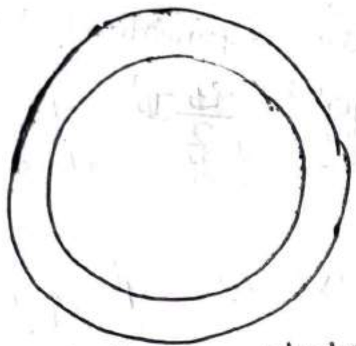
This circular section is hydraulically equivalent to an egg shaped section. of total height $\frac{3}{2} D'$

where, $D' = 0.84 \times D$
$= 0.84 \times 76$
$= 64 \ cm.$

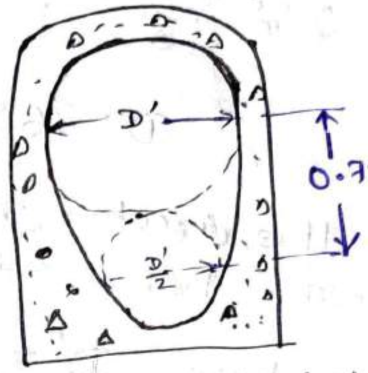
Sewer, its construction, Maintenance and its appurtenance

(i) Shape of Sewer.

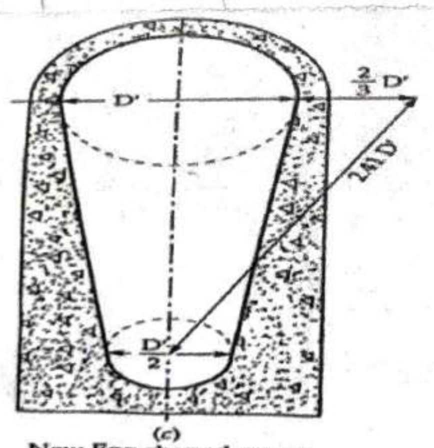
→ The sewer pipes are normally designed as circular in section. in some cases section provided is egg shaped also, however other geometry of section is also available to be used in special cases.



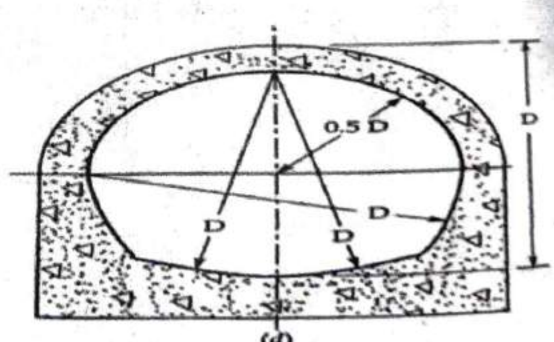
Circular shaped sewer
(Mostly used for all type of sewer)



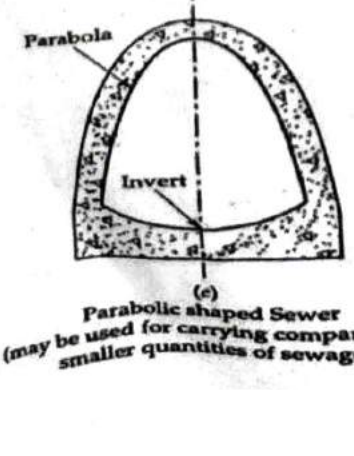
Standard egg shaped
(mostly used for combined sewer).



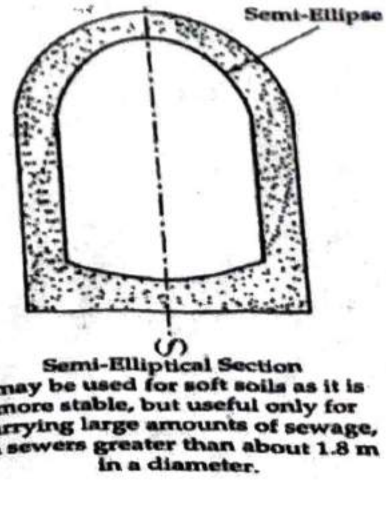
(c)
New Egg-shaped sewer
(may be preferred for combined sewers)



(d)
Horse shoe shaped sewer
(may be used for large sewers with heavy discharges, such as for Trunk and Outfall sewers)

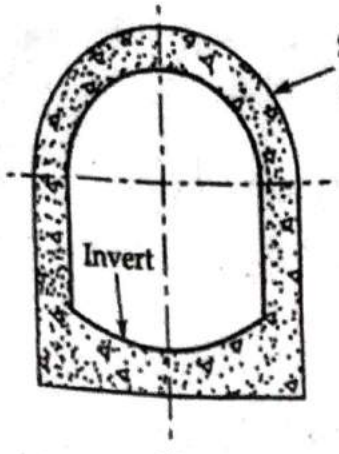


(e)
Parabolic shaped Sewer
(may be used for carrying comparatively smaller quantities of sewage.

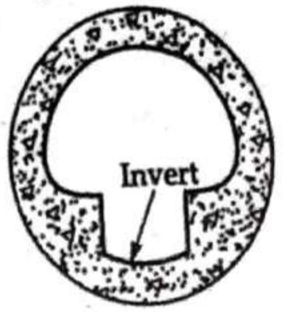


(f)
Semi-Elliptical Section
(may be used for soft soils as it is more stable, but useful only for carrying large amounts of sewage, in sewers greater than about 1.8 m in a diameter.

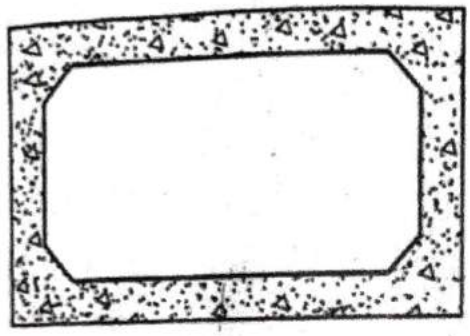
(..)
U-shaped section
(may be used for larger sewers
and especially in open cuts)



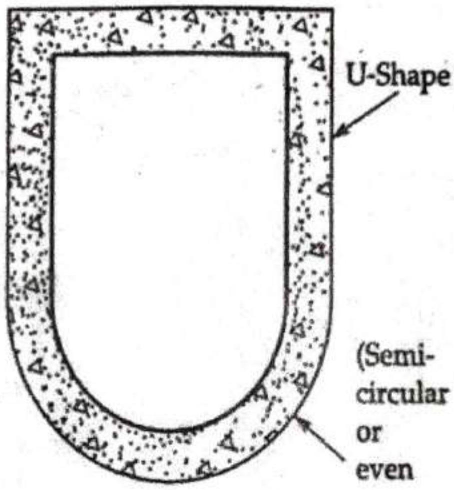
(i)
Semi-circular shaped sewer
(out-dated)

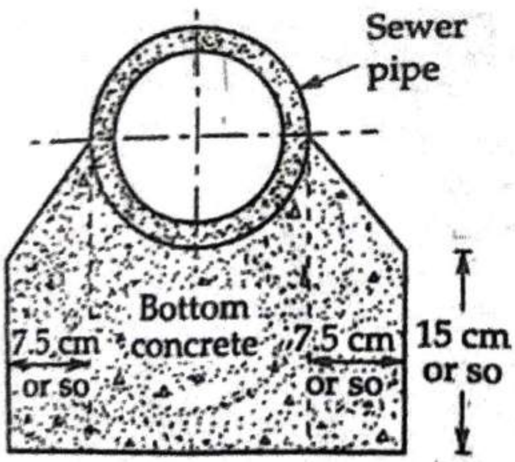


(j)
Basket handle shaped sewer
(out-dated)

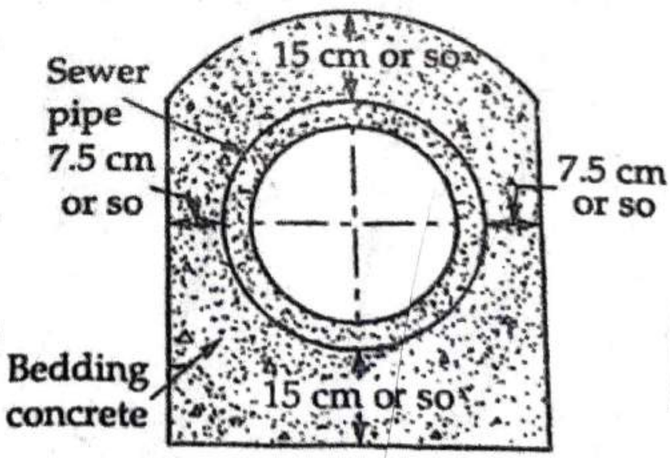


(g)
Rectangular shaped section
(generally used for covered
storm water drains)





(a) Bedding of sewers
in ordinary soils



(b) Bedding of sewers
in softer soils

Forces Acting on Sewer.

(i) Internal Pressure.

- The pressure exerted by the sewage from inside the pipe when running full is called internal pressure.
- Such a pressure may be exerted due to some faulty surcharge or due to overflow of the sewer flowing under gravity. or it may be exerted in outfall sewer which are designed to run at full depth.
- In most of the cases since flowing sewer is under gravity the internal pressure is ~~negli~~ not acting.

(ii) Pressure due to External load.

- Sewer bipes are mostly laid below the ground and placed in trenches and are backfilled. The weight of the pipe, wt of backfill & superimposed load due to traffic if any will be transfered over the pipe. which would produce compressive stressess

(iii) Flexural Stress

Sometimes the sewer pipes have to be carried and supported between the trestles, piers like beams or in some case rain water may wash off the ground from below the pipe resulting in the pipe being exposed like beams.

- In such cases flexural stresses are also developed in the pipes.

(iv) Temperature Stress.

When bipes are laid above the ground they are exposed to atmosphere and are therefore subjected to temperature changes.

→ They expand during day time and contract during night time.

→ If expansion and contraction is prevented due to fixation or friction over the support it results in development of temperature stresses.

Sewer Material

To decide the sewer material following factors must be considerd :-

(i) Resistance to Corrosion.
(ii) Resistance to abrassion/wear & tear.
(iii) should be strong & durable.
(iv) should be light weight (so easy to transport).
(v) should be impervious.
vi) should be cheap.
(vii) should be hydraulically efficient.

Different types of sewer Material Used are as follows: -

I) ASBESTOS CEMENT SEWER

→ Asbestos Cement pipes are manufactured from asbestos ~~sheet~~ fibre, silica & cement, mixed & converted under pressure to a dense homogenious material, possesing sufficient strength.

→ These sewers are (i) light in weight and easy to transport

(ii) Can be easily cut and assembled without skilled labour

(iii) Are hydraulically efficient.

(iv) Are not strong enough to bear heavy compressive load.

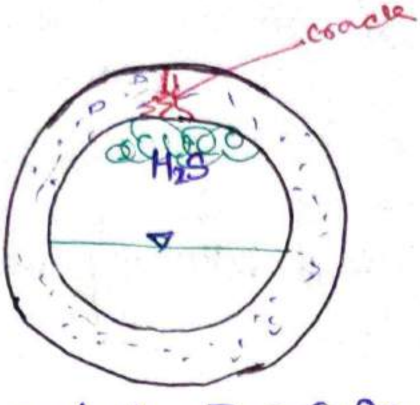
(v) Are susceptible to hydrogen sulphide (H_2S) corrosion at crown.

Due to these draw back of AC sewer they are used as verticals or to carry less foul seewage from kitchen and bathroom.

$C_1A + \bar{S} = CSA$

$C_3A + \bar{S} = C_3SA$

$C_4AF + \bar{S} = C_4SAF$.



$Ca(OH)_2 + \bar{S} \rightarrow CaSO_4$.

(ii) Plain cement Concrete or Reinforced Cement Concrete Sewer.

→ PCC pipes are manufactured for small size upto 0.45 m diameter while they are reinforced with steel for larger diameter sewers.

→ These sewers are strong in tension as well as in compression hence it take both high internal pressure and overburden pressure.

→ These pipes are resistant to erosion and abrasion.

→ They can be easily moulded and manufactured either at site or in casting yard.

→ They can be made up of any desired strength by proper designing.

→ They prove economical ~~and~~ in medium and large size hence are widely used for branch and main sewer

→ weight

→ These pipes are susptible to H_2S corrosion at crown.

→ In order to avoid hydrogen sulphide corrosion following major can be adopted:—

(i) Lining the enterior surface with vitrified clay.
(ii) Prohibiting the entry of waste containing sulphide.
(iii) Reducing sulphate content by pre-treatment.
(iv) Aerating and chloroniating the sewage.
(v) By adequately ventilating the sewer.
(vi) By making sewer to run full.
(vii) By adding such chemical to sewage which nuteralises already present sulphur compound.

Note:- If a thin steel shell pipe is applied with concrete to increase its resistance against corrosion is termed as "HUME STEEL PIPE".

(iii) Vitrified Clay Pipe or/Stoneware/Salt Glazed ~~Pipe~~ Sewer
→ These pipes are widely used for carrying the sewage and drainage as house connections as well as lateral ~~pipes~~ sewer.
→ These pipes are manufactured from clay and shales of special qualities which are first pulverised and mixed throughly with water.
→ This mixture is then used for casting standard pipe by heating it at high temperature. ($T \simeq 1200^\circ C$) where vitrification of clay takes place.
→ These pipe offers maximum advantage of being highly resistant to sulphide corrosion.
→ Their interior are very smooth, therefore ~~big~~ offer very high discharge carrying capacity.
→ They are highly impervious.
→ They are though weak in tension but are strong in compression.

→ Hence can be used to carry sewage under gravity but not under pressure.
→ These are economical, durable and easily available.
→ They are made of non-absorbant material hence is resistant against action of chemicals and salt.
→ They are heavy, bulky and brittle, difficult to transport, hence are casted smaller in size. therefore can't be used for branch and main sewer.

(iv) Brick Sewer

→ Brick sewer were used in the earlier days which is now being replaced by cement concrete sewers.
→ They are still used at the places where the raw ingredient required for manufacturing of concreting is not available.
→ They are preferred for constructing the combined sewers.
→ These sewers are generally plastered on their outer surface & coated with vitrified clay / ceramic block from inside to increase the resistance against sulphide attack.

(v) Cast-Iron Sewer

→ These pipes are structurally strong & stable and capable of withstanding both tensile and compressive stresses upto reasonable extent.
→ These are ~~cost~~ comparatively costly than concrete or stone ware pipes.
→ They are used for manufacturing of outfall sewers or sewers to be laid below heavy over burden pressure.

→ They are also used for sewer to be carried over trestles.

→ They are 100% leak proof hence they are used were contamination of nearby water pipe is to be avoided.

(vi) LEAD SEWER

→ These pipes are smooth and can be bent to take odd shape.

→ They are not effected by acid or alkaline sewage & can resist H_2S Corossion.

→ They are very costly. hence are manufactured in small sizes.

→ They are used as downtake pipe of flushing cisterns or waste pipe from wash basin or gysers connections.

(vii) Plastic Sewer

→ The use of plastic sewers can be done upto dia of 1.5m for carrying sewage.

Laying & testing of Sewer

→ All sewer pipes are generally laid starting from their outfall end (tail end) towards their starting end (Head End) as starting from tail end gives the advantage of utilisation of tail length even during the initial period of its construction. thus, insuring the functioning of sewerage system without waiting for its completion.

→ Laying of the sewer is carried out in flowing sequence of operation:→

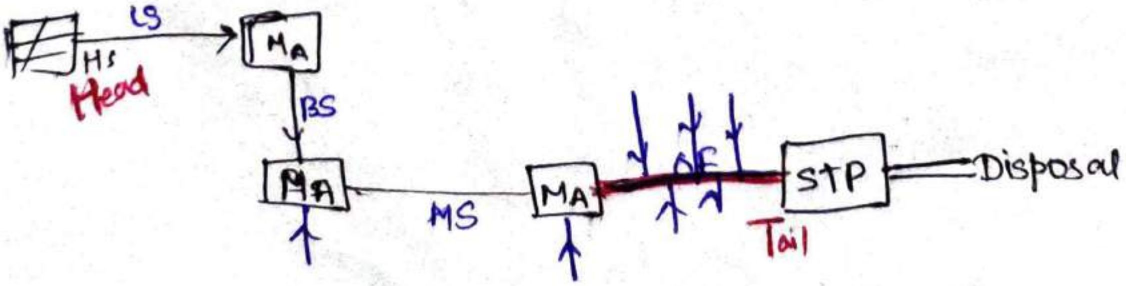
(i) Marking the center-line.

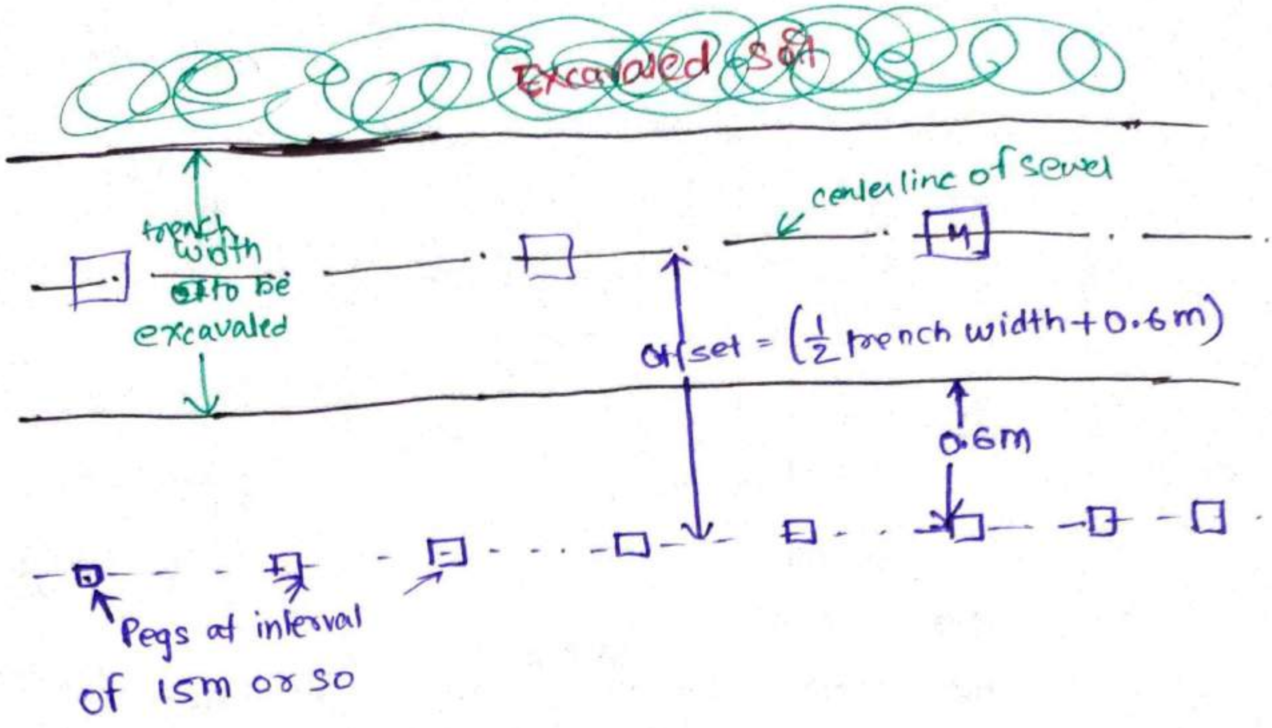
Marking the center line of sewer is done by locating the points where manholes are required to be constructed and then laying of pipes between the two manholes is done.

→ It is done by offset line method in which offset line on the ground is drawn parallel to the center line of sewer.

→ This offset line, usually is offseted from the center line of sewer by a distance of (half of trench width + 0.6m) and pegs are marked on the ground at a interval of 15m on this line.

→ This offset line is marked on that side of center line where excavated soil is not to be disposed off.



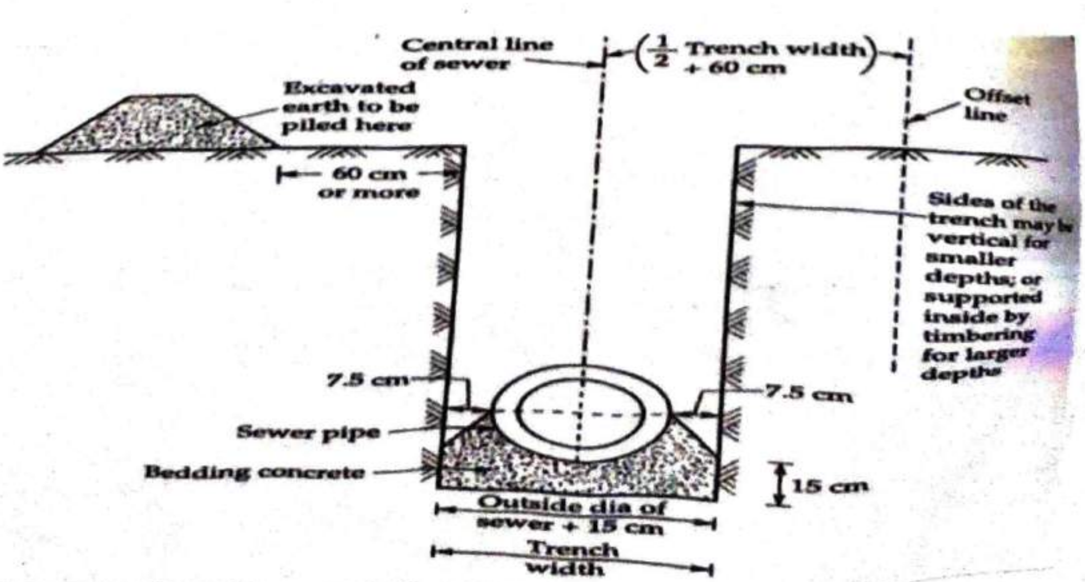


(iii) Excavation of Trench.

→ Once center line is marked excavation work is carried out either manually or mechanically for laying the sewer.

→ Width of the trench is kept 15cm more at the bottom than the diameter of sewer. so as to facilitate laying & joining of sewer

→ Depth of trench must be upto bottom of the embedded concrete.



(iii) Timbering or sheeting the trenches:

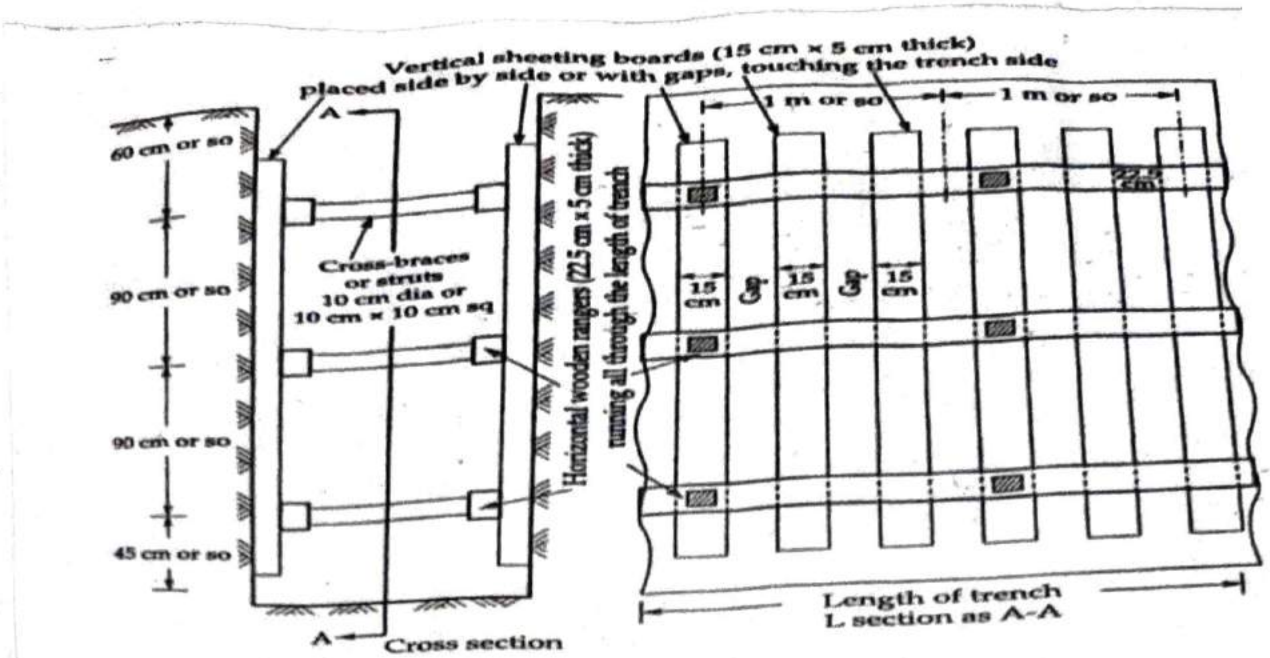
→ The trenches are excavated with vertical or sloping sides keeping in view the fact that soil may collapse or cave in

→ Hence when trenches are excavated in depth more than 2m or in ordinary soil it is necessary to support the soil. by sheeting and timbering (bracing) the trenches.

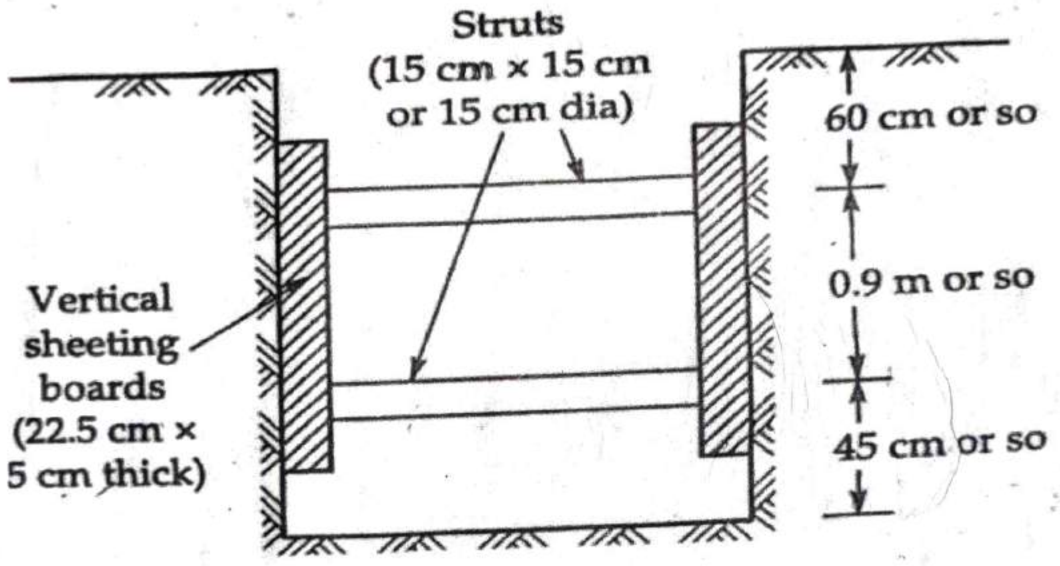
→ The sheeting boards are the wooden pieces of plank which are placed in actual contact with the trench side, either horizontally or vertically.

→ Braces are the cross-wooden pieces extending from one side of trench to the other side and may also be called as struts.

→ The ranger are the timber planks which transfer the load from the sheeting board to the struts.



Vertical sheeting boards (15 cm × 5 cm thick)
placed side by side or with gaps, touching the trench side
A
1 m or so
1 m or so
60 cm or so
90 cm or so
90 cm or so
45 cm or so
Cross-braces or struts 10 cm dia or 10 cm × 10 cm sq
Horizontal wooden rangers (22.5 cm × 5 cm thick) running all through the length of trench
15 cm
15 cm
15 cm
Length of trench
L section as A-A
A
Cross section



Struts
(15 cm × 15 cm
or 15 cm dia)
60 cm or so
0.9 m or so
45 cm or so
Vertical sheeting boards (22.5 cm × 5 cm thick)

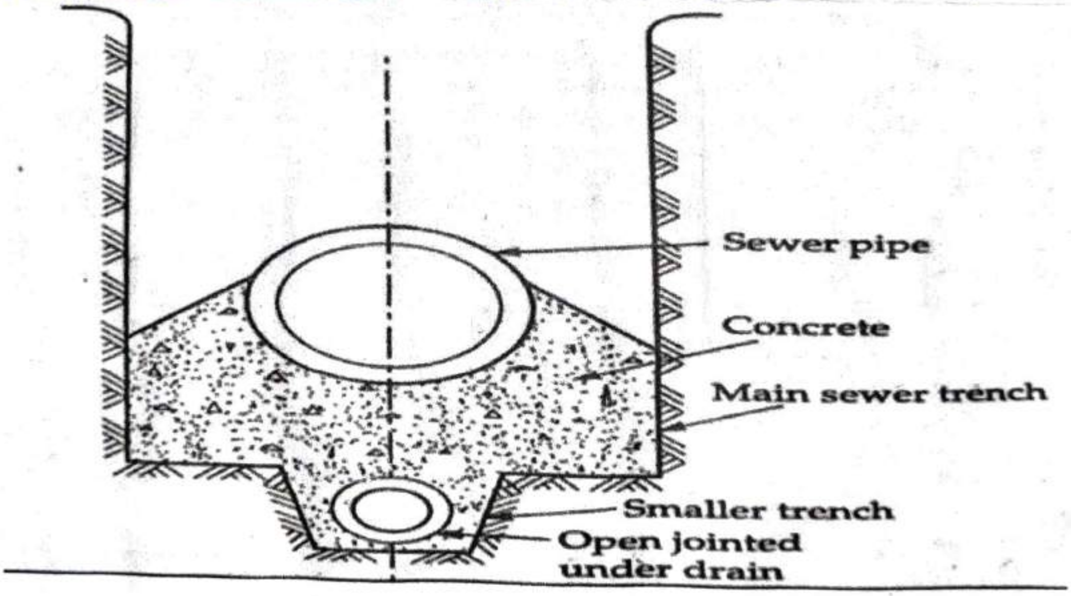
(iv) Dewatering of trench.

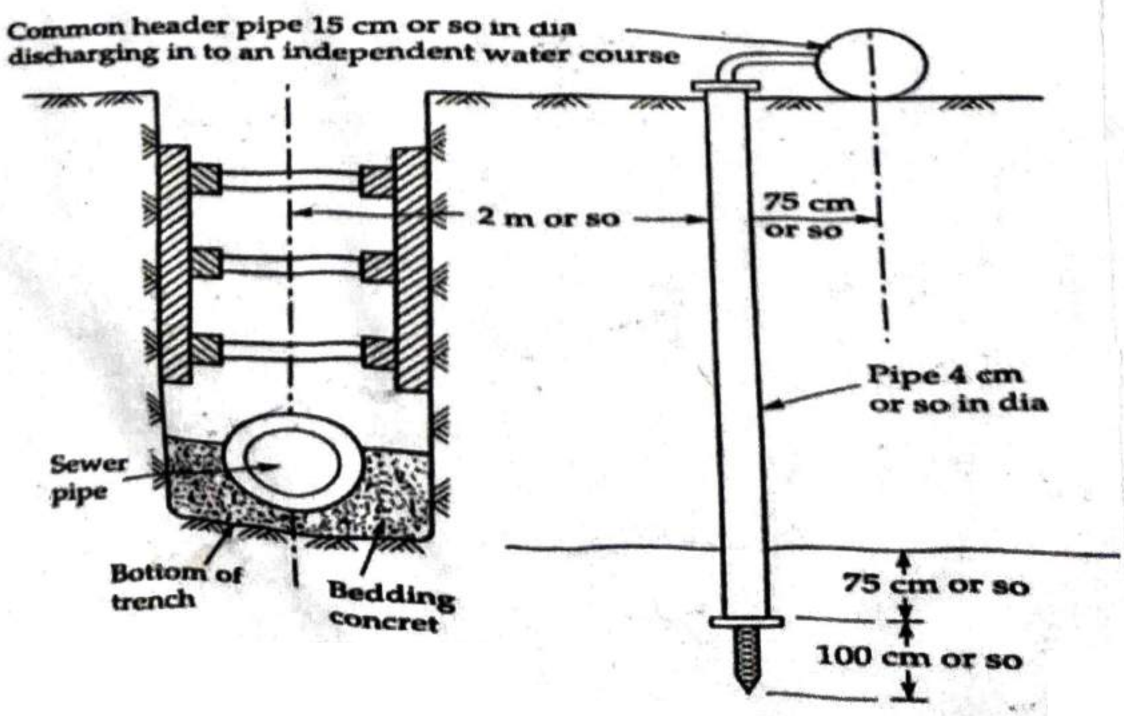
→ While excavating the trench water may enter into it, either when excavation is too deep or ground water table level is high.

→ This water creates the problem in further ~~excation~~ excavation and laying of sewer.

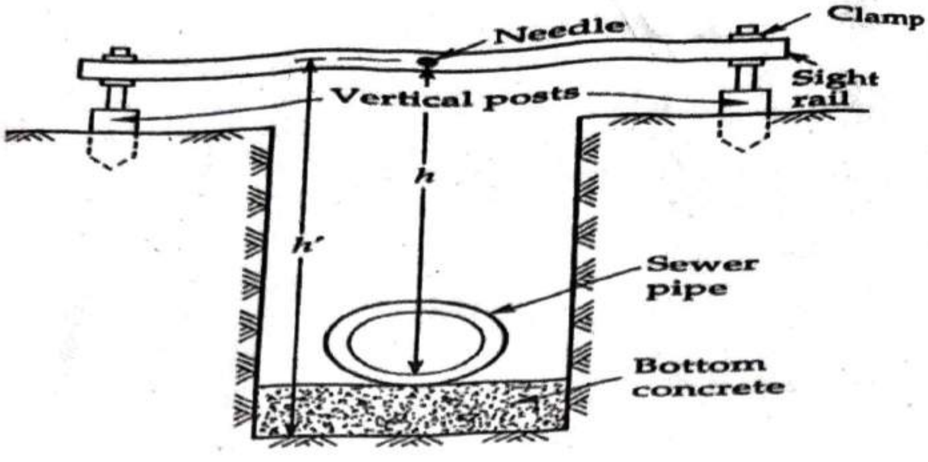
→ This water may also seep into the sewer there by increases the load over it.

→ Hence, to avoid this, water must be removed from the trench. either by open jointed underdrain which meet some surface source of water, or pumping the water by excavating ~~some~~ ~~in~~ sump in trench or with the help of well point discharge in case of sandy soil.

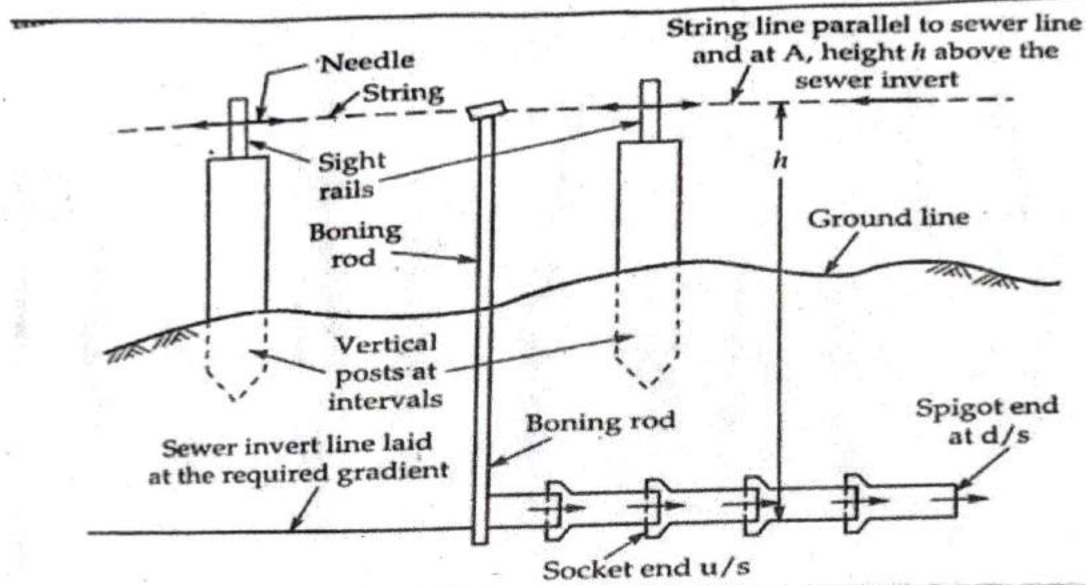




SHAPING THE TRENCH BOTTOM



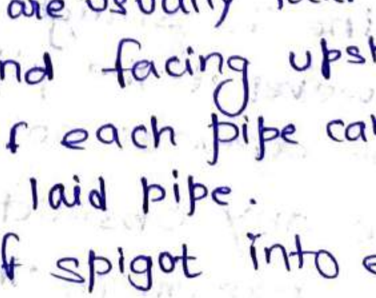
LAYING OF SEWER PIPES



(v) laying of sewer:-
After the bedding concrete has laid ints position, the sewers are lowered in trench either manually (for small sewers) or mechanically (for large sewer)

→ The sewer pipe length are usually laid from the lowest point. with the socket end facing upstream as in this way the spigot end of each pipe can be easily inserted in the socket of alread laid pipe.

→ After fiting the socket of spigot into each other the proper jointing is carried out.



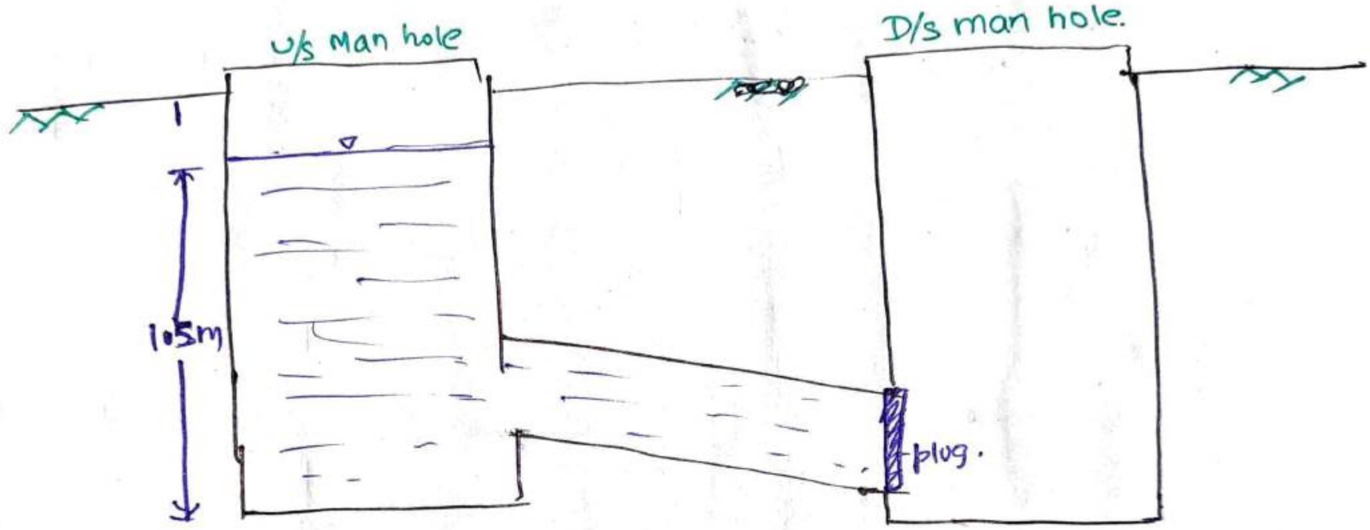
Testing of Sewer

(i) Test for leackage (water test)

→ The sewers are tested so as to ensure no leackage through their Joints after giving sufficient time to these joint to set in.

→ for this purpose the sewer pipe section are tested between manhole to manhole under a test pressure of 1.5m of water head.

→

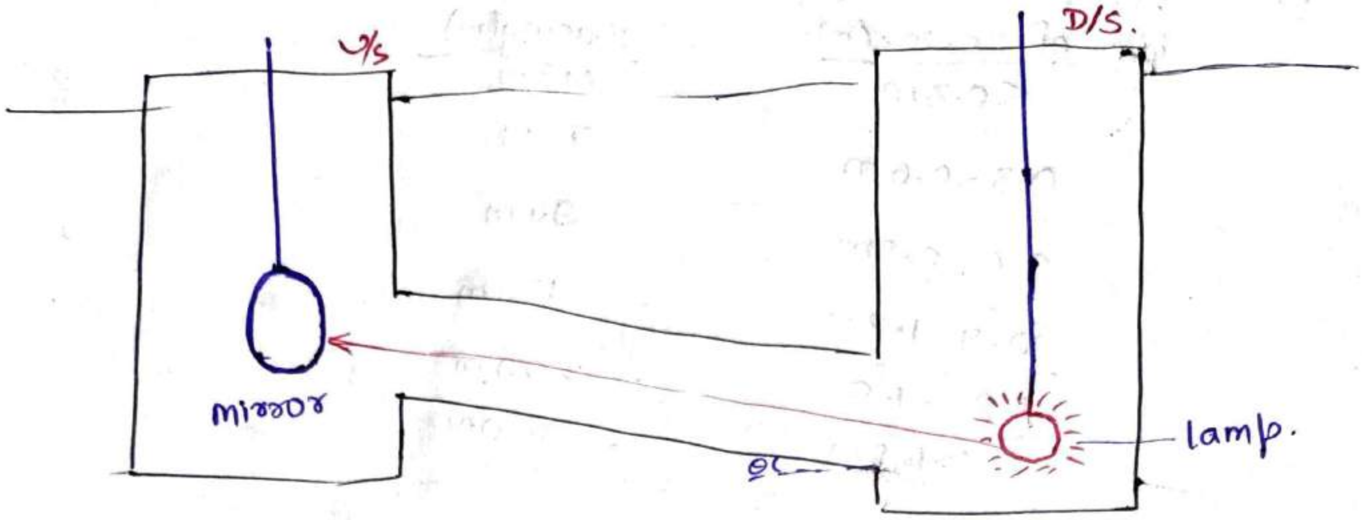


(ii) Test for straightness of alignment and obstruction.

→ The straightness of the sewer pipe can be tested by placing a mirror at one end of the sewer line and a lamp on the other end.

→ If the pipeline is straight the full circle light will be observed. however if the pipe line is not straight this would be aparent not full circle and mirror will also indicate any obstruction in the pipe.

→ Any obstruction present in the pipe can also be tested by inserting a ball/yarn of diameter 13mm smaller than the diameter of the sewer. at upper end, if this ball rolls down to the other end their is no obstruction in pipe.



Sewer Appurtenances.

→ Sewer Appurtenances are those structure which are constructed at suitable interval along a sewerage system which helps in efficient operation and maintenance

→ Sewer Appurtenances includes :-

(i) Manhole.

→ These are masonry or RCC chamber constructed at suitable interval along the sewer line for providing access into them.

→ These manholes are provided at the junction of two sewers and helps in their inspection, cleaning and maintenance → They are also provided in situations where :-

(i) Size of sewer changes.
(ii) Slope of sewer changes.
(iii) alignment of sewer changes
(iv) for Joining two different type of sewer.

→ As per IS 1742, Manholes spacing generally adopted on straight sewer reaches are:-

Size of sewer(m)	Spacing(m)
≤0.3m	45m
0.3 - 0.6 m	75m
0.6 - 0.9m	90 m
0.9 - 1.2 m	120m
1.2 - 1.5	250m
>1.5m	300m

→ As per IS - 4111 (Part-1), spacing is recomended are as follows.

Size of sewer (mm)	Spacing(m)
900 - 1500	90-150
1500 - 2000	150-200
> 2000	300

→ Allowance of 100m for every 1m dia of sewer is general rule in case of very large sewer.

→ Manholes can be clanified as follow :-

(i) Shallow : depth - 0.7 - 0.9m

(ii) Normal : ~~normal~~ depth upto 1.5m

(iii) Deep : depth more than > 1.5m

→ Covers of manholes are generally designed to be circular because of following reasons:-

(i) Round shape are easier to manufacture

(ii) Round shape manholes are easy to roll in order to carry them from one point to another.

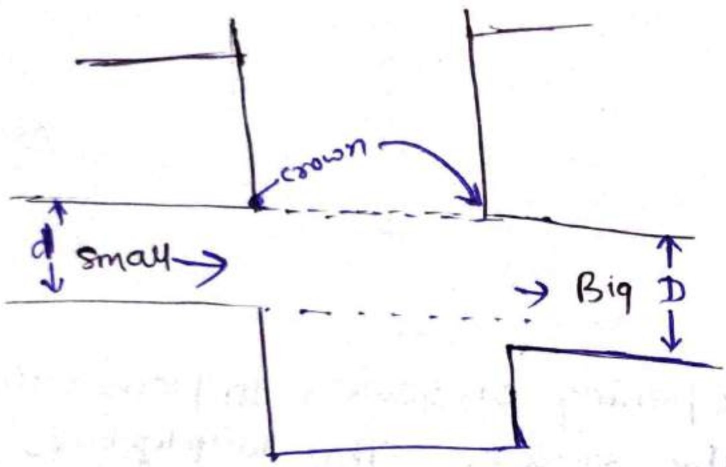
(iii) Round covers can easily slip into place and need not be lined up with the opening of manhole

(iv) Round cover manhole can't fall through the circular opening.

(v) Circular shape can resist compressive pressure from the surrounding uniformly.

(vi) It can't be unlocked easily.

→ In manholes crown of smaller incoming sewer is always matched with bigger outgoing sewer in order to avoid chocking of smaller incoming sewer in case of backing up of bigger outgoing sewer.



(ii) Drop-Manhole

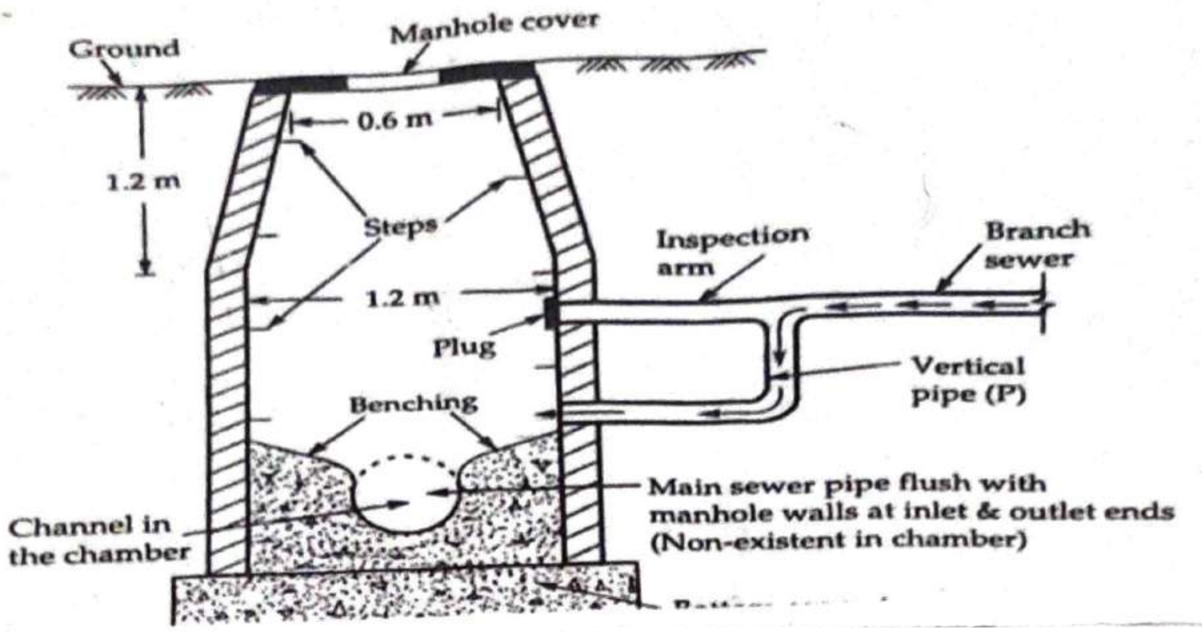
→ If sewer enters a manhole by more than 0.5 to 0.6m above the other ~~sewer~~ outgoing sewer the sewage is generally not allowed to fall directly into the manhole but is brought into it through a down pipe taken from incoming sewer, to the bottom of manhole.

→ If the drop is only of few meters, the down pipe can be kept sloping at an angle of 45°. (ramp) & if the drop is more vertical pipe is found economical. (drop manual)

→ The height of fall of sewage is reduced in order to avoid separation of solids

~~(iii) Lamp holes~~

→ ~~Lamp holes are sma~~



(iii) Lamp holes

→ Lamp holes are small opening on sewers to permit the insertion of lamp into the sewer. The lamplight is then viewed from upstream and downstream manholes

→ The obstructed light confirms the obstruction in the sewer.

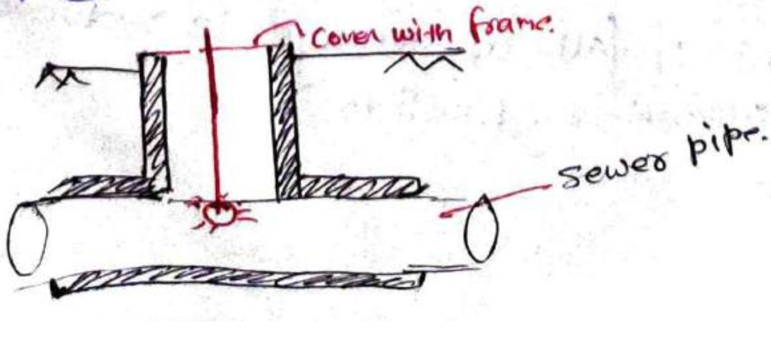
→ These lampholes are specially adopted:-

(i) when a bend in sewer is necessary.

(ii) Construction of manhole is difficult.

(iii) Spacing of manhole is more than usual.

(iv) They can also be used as flushing device & its cover is perforated it can be used for ventilation of sewer.

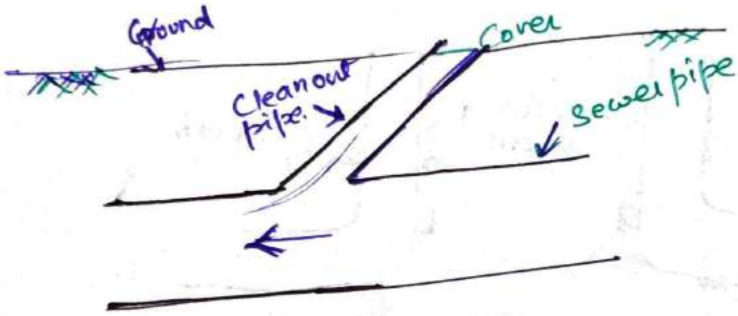


(iv) Clean Out

→ A clean out is inclined pipe extending from the ground surface and is connected to the underground sewer that is used for cleaning the sewer pipe.

→ It is generally provided at the upper end of lateral sewer in place of manholes.

→ Its functioning involves forcing water through the cleanout pipe to the lateral sewer. in order to remove the obstruction in it. If obstruction are large enough a flexible rod may be inserted through the clean out pipe. and forward and backward. action is imparted to it.



(v) Street Inlet / Gulies

→ Inlet are gullies or openings on the road surface at the lowest point for permiting rain water from roads and admiting it into underground strong water sewer. (drains.) or combined sewers.

→ These inlets are located along the road sides on straight road at spacing of 30 to 60m.

→ A street inlet is simple concrete box having opening either in horizontal and vertical direction. according to which these are classified as vertical/or horizontal inlet.

Note:- If street inlets are provided with additional small settling basin to settle grit, sand debris etc it is called catch basin. or catch pit.

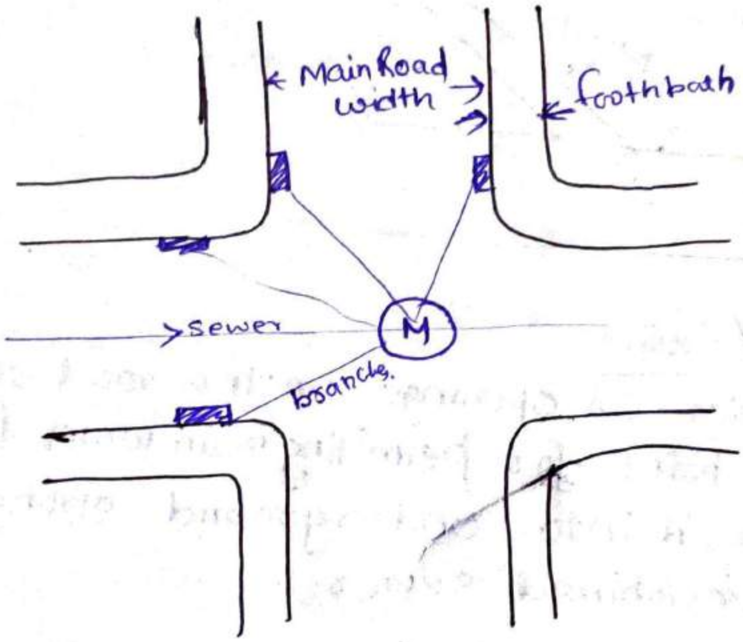
→ In addition to it a hood is also provided in this to prevent escape of gases from sewer into the catch basin.

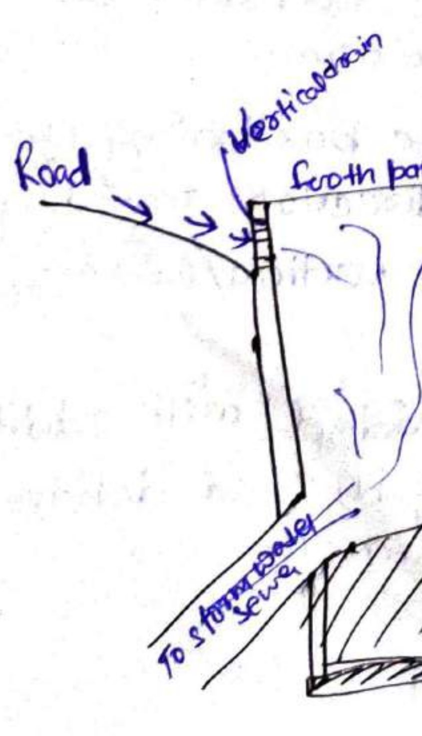
→ These are obsolete nowdays as:-

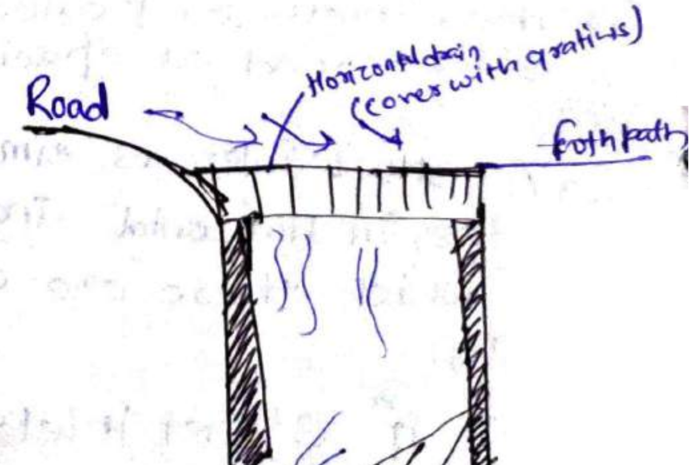
(i) Quality of road is improved over the period of time hence it is grit free.

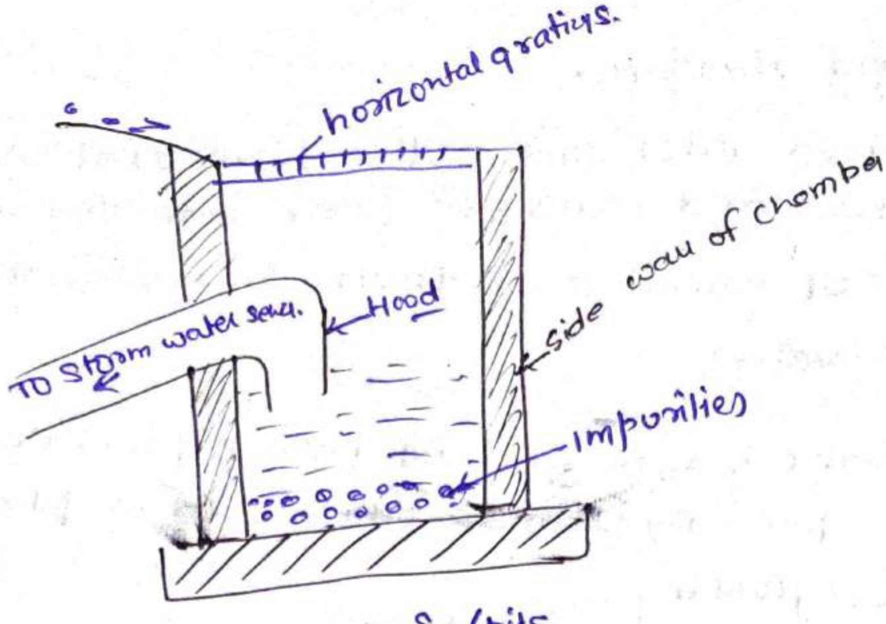
(ii) Sewers are designed at suitable gradient to ensure self cleaning velocity.

(iii) They lead to evolution of foul gases thereby develop unsanitary condition.









Catch basin/pits.

(vi) Flushing tank

→ Whenever there are any chances of blockage of sewer such in case of sewer laid on flat gradient not producing self cleansing velocity or near by to the dead end point of sewer flushing devices are installed.

→ These devices store water temporary. and throw it into the sewer for the purpose of flushing and cleaning the sewer.

→ These flushing devices are normally of two types

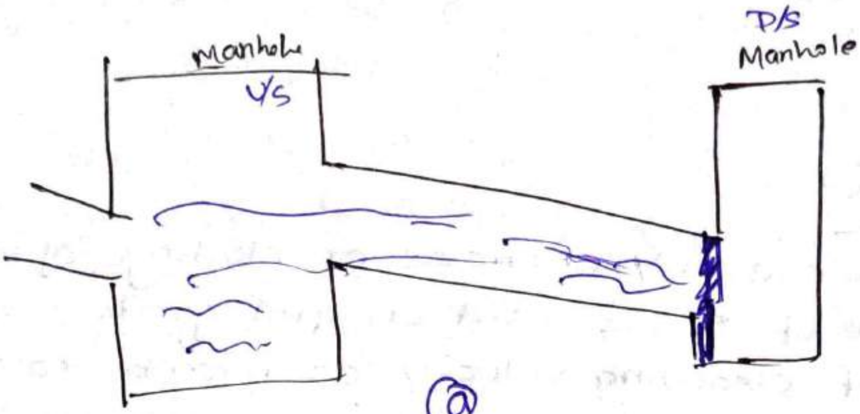
(i) Hand operated flushing operation.
(ii) flushing operation using automatic flushing tank.

Hand Operated Flushing Operation
→ It is carried out in flowing ways:-
• In this method one end of manhole is closed by sluice valve. The sewage entering into the manhole from inlet end will start collecting into it. When sufficient quantity of sewage gets accumulated

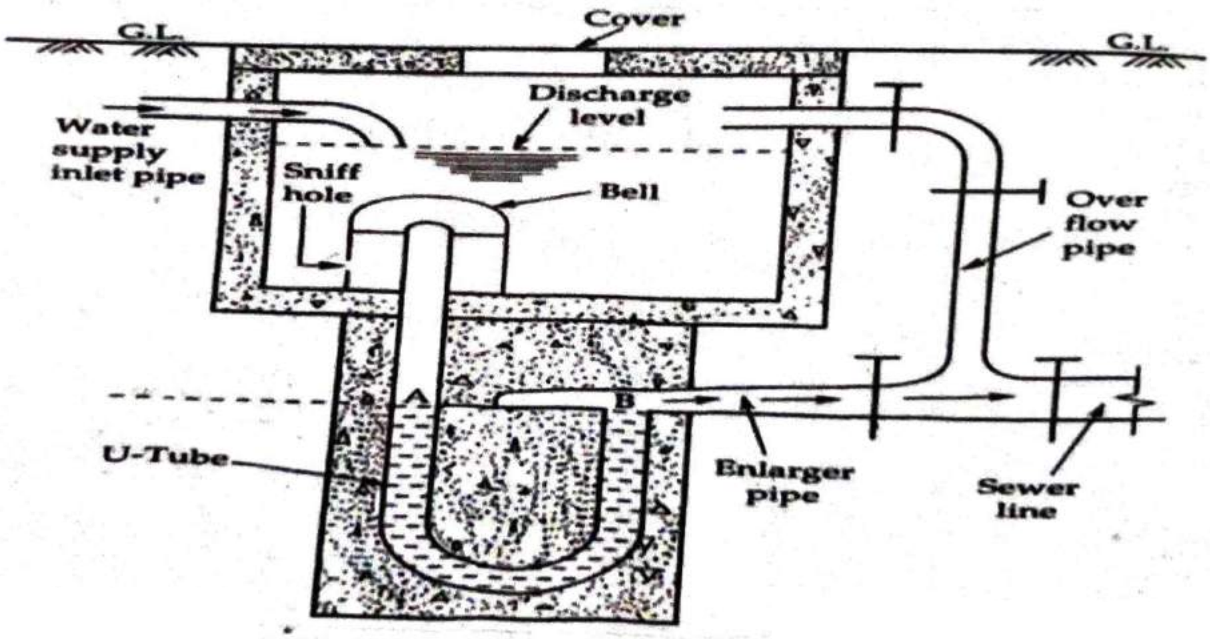
the outlet end is open.

(b) In this method inlet and outlet both end are closed by sluice valve and water is filled into the manhole. The flushing of sewer can then be carried out by opening the valves.

(c) In this method, one end of hose pipe is connected to a nearby fire hydrant & other end is place in manhole for flushing.



(a)



(vii) Oil & Grease trap.

→ Grease and oil traps are those traps which are constructed in a sewrage system to remove oil and grease from sewage before it enters into sewer line.

→ Such traps are located near to the source of oil & grease. such as automobile repair shop, workshop, garages, kitchen of hotels, oil and greece industries.

→ Oil & greece if not removed would lead to following:-

(i) It will enter the sewer and will stick to the sewer sides thus reduce the sewer capacity

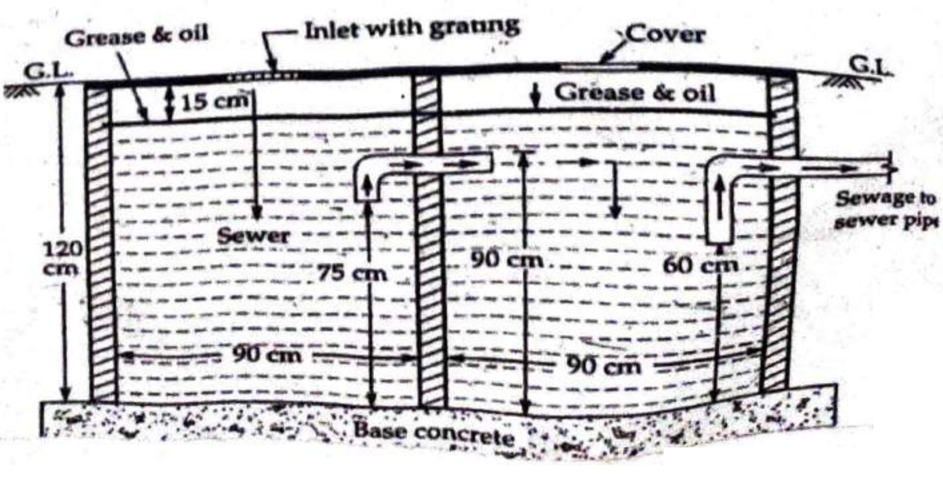
(ii) The suspended solid which would have, otherwise flow along with sewage would stick to the surface of sewer and reduce its discharge carrying capacity.

(iii) The presence of oil & grease leads to possibility of explosion in the sewer

(iv) It hampers the growth of micro-organism in treatment plant required for biological treatment.

→ The principle on which oil & grease trap work is that grease and oil are lighter than sewage hence float over the surface of sewage therby sewage is collected from bottom of these traps.

→ If sand is also desired to be removed from the sewage. dead space is provided at bottom of these traps.



(200)

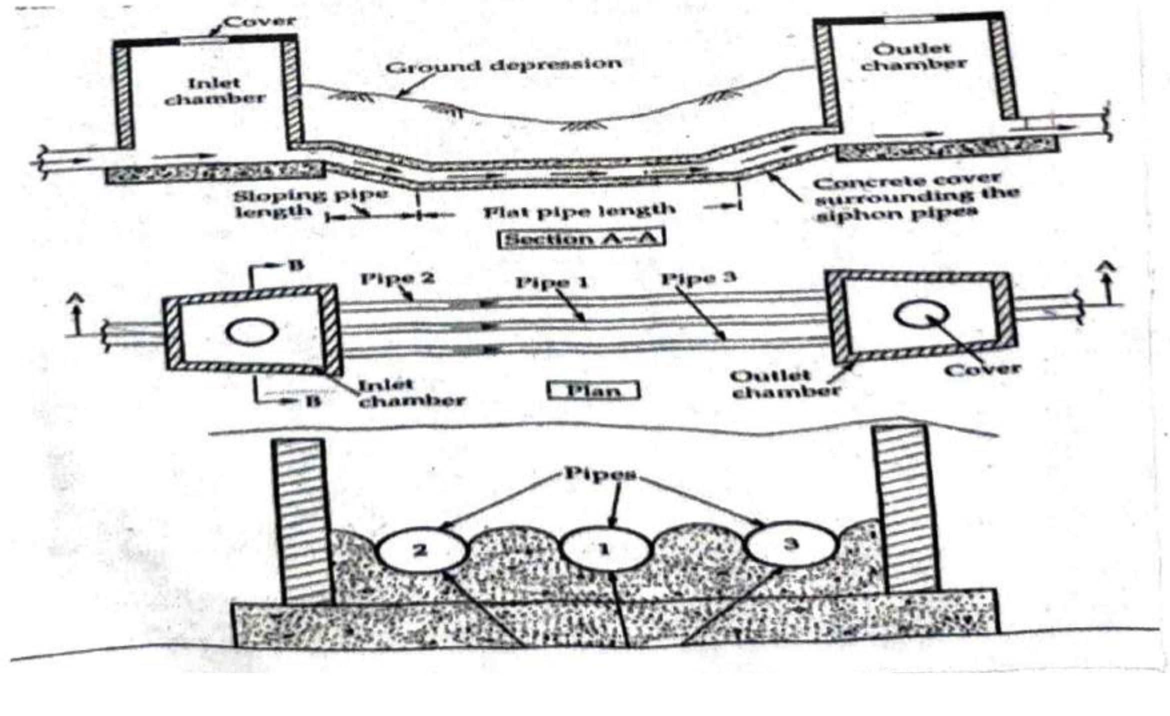
(viii) Inverted Siphon

→ Whenever a sewer pipe is to be dropped below the hydraulic gradient line for passing it beneath the valley road, railway track stream or canal or any other obstruction in the earth surface or where it passes beneath some other obstruction in its path It is termed as "inverted syphon."/Depression sewer or sag pipe.

→ The sewage through such a pipe line flows under pressure & not under gravity.

→ An inverted syphon is thus a sewer section constructed lower than adjacent sewer section & it runs full under gravity with pressure greater than Atmospheric pressure.

→ An inverted siphon is usually made up of siphon tubes made of cast iron or concrete



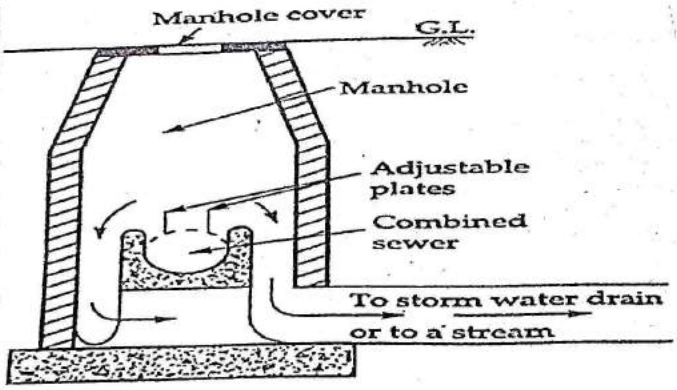
Storm Water Regulator / Storm Relief Work

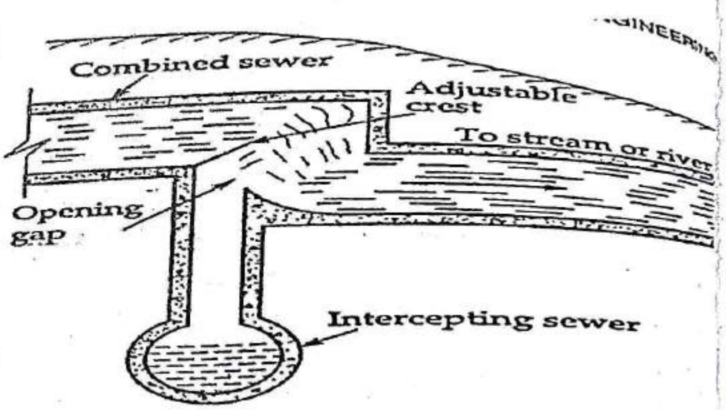
→ Storm Water Regulator are provided in combined sewerage system. and permits the diversion of excess storm water into the nearby stream.

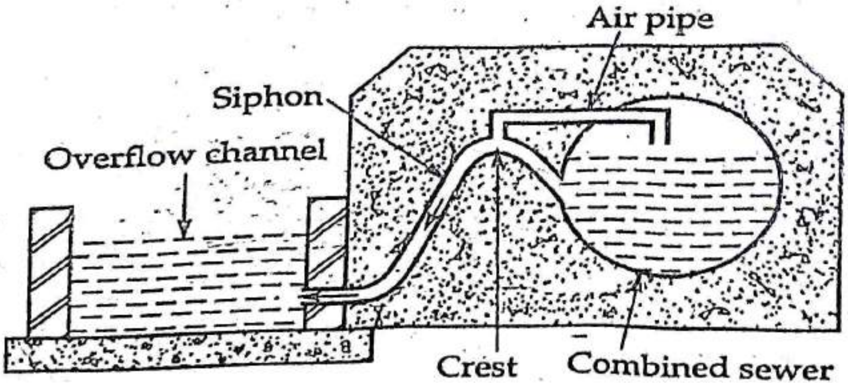
→ This excess sewage will mainly comprise of storm water and therefore it will not be effecting the quality of nearby stream.

→ storm regulators may be of following types:-

(i) Leaping weirs.
(ii) Overflow weir
(iii) Siphon spill way.







Maintenance, cleaning and ventilation of sewer.

clean → Sewers are maintained, generally in terms of their cleaning to keep them free from any clogging & to carry out the repairs to the damaged portion if any. so as to increase their life and ensure efficient functioning.

→ The sewer maintenance include, their frequent inspection & supervision measuring the rate of flow, cleaning & flushing and repairing the leakage joints. or any other damaged portion, protecting them against explosion.

→ Sewer should be practically clean so as to avoid their complete clogging.

→ Depending upon the type of sewer they can be cleaned manually or mechanically.

→ In order to clean the sewer comonly used device is steel cylinder of 20-25 cm diameter and 60-75cm length provided with sharp cutting edge. termed as cane rod.

→ Pills can also be used for cleaning of sewer. (These are light floating wooden or rubber hollow balls).

Ventilation
→ Various poisonous gases and explosive gases which are generally found in sewer are, H_2S, CO_2, CH_4, petrol vapours. hence proper precaution must be taken while entering the sewer as follows:-

(i) Before entering sewer through manhole its cover must be open about an hour before entering into it.

(ii) Test should be performed for the presence of different gases in the sewer.

→ H_2S gas may be deducted by exposing a sheet of paper moistened with lead acetate for five minutes near the sewer entry.

↳ If the paper turns black H_2S is present.

→ Presence of carbondioxide may be detected by lowering a minor safety lamp near the level of sewage in manhole. If the flame estinguishes within 5 minutes CO_2 is present.

→ The presence of methane may be deducted by lowering the minor's safety lamp in upper layer of sewer, methane being lighter than air is generally present in upper region, when gas is present it forms an explosive mixture with air. & gauge cylinder of the safety lamp gets filled with flame.

→ Hence ventilation of sewer must be carried out due to following reason:-

(i) To eliminate the gases accumulated in the sewer.

(ii) To ensure continuous flow of sewage into the sewer, by avoiding air blocks.

→ It can be achieved by use of ventilating columns,

(ii) use of ventilating manhole.

(iii) Proper design of sewer.

(iv) Use of mechanical devices.

(v) Unobstructed outflow.

(vi) House vents & soil pipes.

(vii) Artificial ventilation