1.4. Design and Planning of a Sewerage System

The sewerage system must be properly and skilfully planned and designed, so as to remove the entire sewage effectively and efficiently from the houses, and up to the point of disposal. The sewers must be of adequate size, so as to avoid their overflow and subsequent damages to properties, and health hazards. In order to provide economically adequate sized sewers, it is necessary that the likely sewage discharge be estimated as correctly as possible. The sewer pipes should then be designed to be laid on a slope that will permit reasonable velocity of flow. The flow velocity should neither be so large, as to require heavy excavation and high lift pumping ; nor should it be so small, as to cause the deposition of solids in the sewer, bottoms.

The sewers are generally designed to carry the water from the basements, and should therefore, be atleast 2 to 3 m deep. As far as possible, they should be designed to flow under gravity with $\frac{1}{2}$ or $\frac{3}{4}$ th full. Owing to the requirements of seeking gravity flow, the sewage treatment plant should generally be located in a low lying area. The design of the treatment units also requires good engineering skill. In order to provide adequate and economical treatment, it is necessary to thoroughly study the constituents of the sewage

Since the treatment plant will have to be located at low level ; the flood protection devices both during construction and thereafter, should also have to be taken care of, by the design engineers.

where P = Population in thousands.

The **minimum flow** passing through a sewer is also an important factor in the design of the particular sewer ; because at low flow, the velocity will be reduced considerably, which may cause silting. *Hence, the slope at which the sewer is to be laid has to be decided in accordance with the requirement of minimum permissible velocity at the minimum flow.*

The minimum flows occurring through the sewers during night hours will affect the laterals to a maximum extent, and will affect the mains to a lesser extent. Thus, the minimum flows through laterals, may be even lesser than 25 per cent of the average ; while in the mains, they can be 50 to 70 per cent of the average. For moderate areas, such as involved for branch sewers, the following minimum flows may be assumed :

Minimum daily flow $= \frac{2}{3} \times$ Average daily ...(2.4)

Minimum hourly flow $= \frac{1}{2}$ Minimum daily flow

$= \frac{1}{3}$ *Average daily* ...(2.5)

The sewers must, therefore, be checked for minimum velocities at their minimum hourly flows (i.e. $\frac{1}{3}$ Average daily).

For areas of moderate sizes, such as involved for branch sewers, the maximum daily or hourly sewage flows, can be expressed as :

Maximum daily flow	= 2 times the average daily flow	...(2.1)
Maximum hourly flow	= 1.5 times the maximum daily	...(2.2)
	= *3 times the average daily.*	

4.2. Difference in the Design of Water Supply Pipes and Sewer Pipes

The hydraulic design of sewers and drains, which means finding out their sections and gradients, is generally carried out on the same lines as that of the water supply pipes. However, there are two major differences between the characteristics of flows in sewers and water supply pipes. These differences are :

(*i*) The water supply pipes carry pure water without containing any kind of solid particles, either organic or inorganic in nature. The sewage, on the other hand, does contain such particles in suspension ; and the heavier of these particles may settle down at the bottom of the sewers, as and when the flow velocity reduces, thus ultimately resulting in the clogging of the sewers. *In order to avoid such clogging or silting of sewers, it is necessary that the sewer pipes be of such a size and laid at such a gradient, as to generate self-cleansing velocities at different possible discharges.* The sewer materials must also be capable of resisting the wear and tear caused due to abrasion of the solid particles present in the sewage, with the interior of the pipe.

(*ii*) The water supply pipes carry water under pressure, and hence, within certain limits, they may be carried up and down the hills and the valleys ; whereas, the sewer pipes carry sewage as gravity conduits (or open channels)*, and they must, therefore, be laid at a continuous gradient in the downward direction up to the outfall point, from where the sewage will be lifted up, treated and disposed of.

4.3. Provision of Freeboard in Sewers and S.W. Drains

The *sanitary sewers*, as pointed out earlier, are designed large enough to carry the maximum sewage discharge while flowing half or three-fourth or two-third full. *Generally, the sewer pipes of sizes less than 0.4 m dia are designed as running half full at maximum discharge, and the sewer pipes greater than 0.4 m in dia are designed as running $\frac{2}{3}$rd or $\frac{3}{4}$th full at maximum discharge.*

The extra space, thus left, above the designed full supply line, will leave an ample margin, as to act as a factor of safety to counter-act against the factors, such as :

(*i*) low estimates of the average and maximum flows, made due to some wrong data obtained regarding the private water consumption by industries, or public, or about the quantity to be supplied from the water-works at the end of the design period.

(*ii*) large scale infiltration of storm water due to wrong or illegal connections, and that of underground water through cracks or open joints in the sewers.

(*iii*) unforeseen increase in population or water consumption and the consequent increase in sewage production.

The *storm water drains*, on the other hand, are generally not provided with so much margins above their FSLs, because the over-flowing of drains is not so much harmful, as is the overflowing of sewers, mainly because sewage is highly polluted as compared to the storm water. The storm water drains are, therefore, provided with nominal provisions of freeboard* above their designed full supply lines, as given in Table 4.1.

Table 4.1. Values of Freeboard to be adopted for the design of S.W. Drains

Peak discharge in the drain for which designed, in cumecs	*Freeboard to be left in metres*
Below 0.3	0.3
0.3—1.0	0.4
1—5	0.5
5—10	0.6
10—30	0.75
30—150	0.90
more than 150	1.0

→ Velocity in open channel flow

1. Manning's formula

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

n = constant

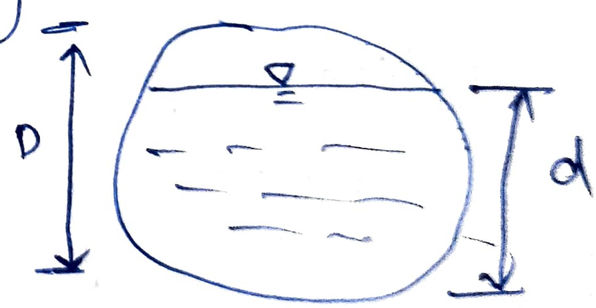
② Chezy's formula, $V = C\sqrt{RS}$

R → hydraulic mean depth

$R = \frac{A}{P}$; A → area of flow
P → wetted perimeter

→ Hydraulic characteristics of Circular sewer :-

* Sewers are designed as partially full channels. (d < D)
* Full flow (d = D)



Recommendation –

Dia	d/D
< 400 mm	$\frac{1}{2}$
400 – 900 mm	$\frac{2}{3}$
> 900 mm	$\frac{3}{4}$

Partial flow is preferred because —

① Fluctuated high discharge can be accomodated.

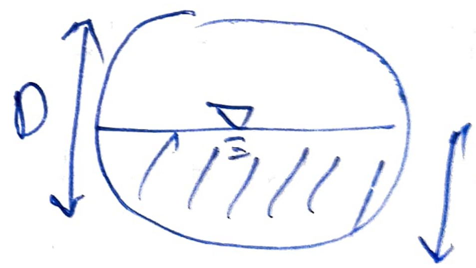
② To accomodated evolved gases.

(a) For full flow

$$R = \frac{A}{P} = \quad A = \frac{\pi D^2}{4}, \quad P = \pi D$$

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

(b) For half flow —

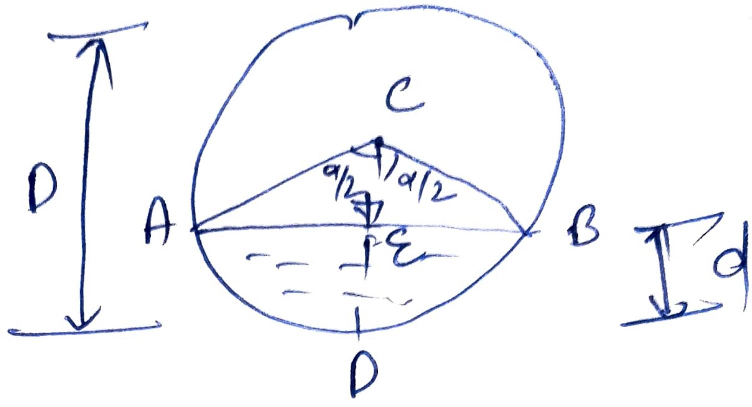


$$A = \frac{\pi D^2}{8}, \quad P = \frac{\pi D}{2}$$

$$R = \frac{\frac{\pi D^2}{8}}{\frac{\pi D}{2}} = \frac{D}{4}$$

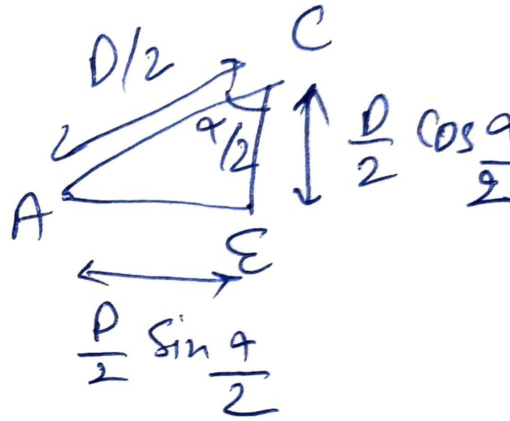
Partially full :-

Central angle = α



① $d = DE = CD - CE$

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



$$\boxed{\frac{d}{D} = \frac{1}{2}\left[1 - \cos\frac{\alpha}{2}\right]}$$

② Proportionate perimeter –

p = length of arc ADB

$p = \alpha . R \Rightarrow \alpha . \frac{D}{2}$

P = full flow wetted perimeter $= \pi D$

$$\boxed{\frac{p}{P} = \frac{\alpha . \frac{D}{2}}{\pi D} = \frac{\alpha}{2\pi}}$$

③ Proportionate area :-

a = Area of sector CADB – Area of Δ ABC

= area of sector CADB – 2 × area of Δ AEC

$= \frac{\alpha}{2\pi} \times \frac{\pi D^2}{4} - 2 \times \left[\frac{1}{2}\left(\frac{D}{2}\cos\frac{\alpha}{2}\right) \times \frac{D}{2}\sin\frac{\alpha}{2}\right.$

$$a = \frac{\pi D^2}{4}\left\{\frac{\alpha}{2\pi} - \frac{\sin\alpha}{2\pi}\right\}$$

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

(4) Proportionate H.M.D

$$\frac{r}{R} = \frac{a/p}{A/P} = \frac{a/A}{p/P}$$

$$\boxed{= \frac{\frac{\alpha}{2\pi} - \frac{\sin\alpha}{2\pi}}{\alpha/2\pi}}$$

(5) Proportionate Velocity –

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