Sanitary Engineering.

After the water that has been made available from well laid and properly executed water supply project has been consumed, it has to be suitably disposed off. The other wastes from the society are also to be carried and disposed off at suitable places so as to protect the public health. Thus the end of water supply scheme in a sense is the starting point of sanitary project.

Sanitary Engg. is the branch of public health Engg. which deals with the preservation & maintenance of health of the individual and the community by preventing communicable diseases. It consists of scientific and methodological collection, conveyance, treatment & disposal of waste matter so that public health can be protected from the offensive and injurious substances. Sanitation is the prevention of sporadic outbreak of diseases & can be achieved by either controlling or eliminating such environmental factors that contribute in some form or other to the transmission of diseases.

Sewage

Sewage indicates the liquid waste from the community. It includes waste water from bathrooms, kitchen, discharge from latrines, urinals, stables, industrial waste and also the ground surface and storm water that may be admitted into the sewer.

Refuse

Refuse is a general term used to indicate what is rejected or leftout as workless. It may be in liquid, semisolid or solid form and may be divided into 6 catergories.

1) Garbage
2) Rubbish
3) Sullage
4) Sewage
5) Subsoil water
6) Storm water

- Garbage

Garbage indicate dry refuse. It includes waste papers, decayed fruits & vegetables, grass and leaves and sweepings from streets, markets and other public places. Garbage contains large amount of organic matter.

- Rubbish

Rubbish indicates solid wastes from offices, residences & other bldgs. It also includes waste bldg materials, broken furnitures, papers, rags etc. Generally rubbish is dry and is of combustible nature.

- Sullage

Sullage is a term used to indicate the waste water from bathrooms, kitchens, washing places and wash basins etc. It doesn't create bad smells since organic matter in it is either absent or it is of negligible amount.

- Subsoil water

It is the groundwater that finds its entering into sewer through leaks.

- Storm water

It indicates the rainwater of the locality.

• Domestic Sewage

It is the sewage obtained from the laboratory basins, urinals and water closets of residential, commercial, office bldgs & cinema theatres. Since it contains human excreta & urine it is extremely foul in nature.

• Industrial Sewage

It is waste water obtained from the industrial and commercial establishments. It may contain objectionable organic compounds that may not be amenable to conventional treatment process.

Sewer

Its an underground conduit or drain through which sewage is carried to a point of discharge or disposal. Separate sewers are those which carry the household and industrial waste. Combined sewers are those which carry sewage and storm water.

Sewerage : The entire science of collecting & carrying sewage by water carriage s/m through sewers.

It means, the structures, devices, equipment & appurtenances intended for the collection, transportation & pumping of sewage & liquid waste excluding the works for treatment of sewage.

Methods of carrying refuse

Following are the two methods which are employed for the collection and disposal of refuse of a locality.

1. Conservancy system.
2. Water carriage system.

Conservancy system

In this system, the diff. types of refuse are collected separately and then each type is carried and suitably disposed off.

The garbage or dry refuse is collected from roads and streets in pans or baskets and then conveyed by cars, trucks etc. The storm water and sullage are collected and conveyed separately by closed or open channels. They are discharged in natural rivers or streams.

Water carriage system

In this system water is used as medium to carry the sewage to the point of its treatment or final disposal.

In this system, the garbage is collected and conveyed as in case of conservancy system. The storm water may be carried separately.

The quantity of water to be mixed with solid matter is quite sufficient and the dilution ratio of solid matter with water is so great that the mixture behaves more or less like water.

Sewerage system (Water carriage s/m)

Following are the three systems of sewerage

1. Separate system.
2. Combined system.
3. Partially separate system.

* Separate system

In this system, two sets of sewers are laid; one for carrying sewage and the other for carrying storm water. The sewage is carried to treatment plant and storm water is directly discharged into natural river or stream.

Advantages

1. The load on treatment unit become less.
2. The natural water is not unnecessarily polluted.
3. The sewers are small in size.
4. Economical when pumping is needed.

Disadvantages

1. Cleaning of sewer is difficult.
2. Maintenance cost are high.
3. The self cleansing velocity is not easily achieved.
4. The system requires two sets of sewers.

* Combined system

In this system, only one set of sewer is laid and it carries both namely sewage and storm water. The sewage and storm water are carried to the sewage treatment plant.

Advantages

1. Its easy to clean a combined sewer.
2. Maintenance cost are reasonable.
3. Storm water reduces the strength of the sewage by dilution.
4. System requires only one set of sewers.

Disadvantages

1. During heavy rain the combined sewer may overflow and it may thus put public health in danger.
2. Combined sewer will get easily silted and it may become foul in dry weather.

3. The load on treatment plant increases.

4. The sewers are large in diameter.

5. The storm water is unnecessarily polluted.

6. It is uneconomical when pumping is required.

* Partially supplied system

In this system, arrangement is made to permit early washings by rain into the sewers carrying sewage. But when the quantity of storm water exceeds a particular limit it is collected and conveyed in open drains to the natural river or stream.

Advantages

1. It combines the advantages of both the above system.
2. The entry of storm water avoids silting in sewers.
3. The problem of disposing storm water from houses is simplified.
4. The sewers are of reasonable size.

Disadvantages

1. The quantity of storm water admitted to sewer may increase the load on pumping & treatment units.
2. The velocity of flow is small in dry weather. Thus self cleansing velocity may not be achieved.

Waste water treatment systems

The waste water treatment / sewage treatment is a broad term that applies to many process, operations or combination of process & operation that can reduce the objectionable properties of water carried waste and render it less dangerous and repulsive to men. Thus the waste water should be treated before its ultimate disposal inorder to

- Reduce the spread of communicable diseases caused by the pathogenic organisms in the sewage.
- To prevent the pollution of surface and groundwater.

Waste water treatment is a combination of physical, chemical and biological process.

Unit operations

Methods of treatment in which the application of physical forces predominate are known as unit operations.

Unit processes

The method of treatment in which chemical or biological activity are involved are known as unit process.

There are 3 types of unit operations & processes.

1. Physical unit operations
2. Chemical unit processes.
3. Biological unit processes.

Physical unit ~~processes~~ operations

Physical unit processes are those in which appln. of physical forces predominate. They consists of screening, mixing, flocculation, sedimentation, floatation etc.

Chemical unit processes

Chemical unit processes are those in which removal of contaminants are brought about by chemical activity. They consists of chemical precipitation, gas transfer, adsorption, ion exchange, electrodialysis etc.

Biological unit processes

Biological unit processes are those in which removal of contaminents are brought about by biological activity. Common examples are activated sludge process, trickling filtration, sludge digestion etc.

In addition to the various stages of treatment of waste water mentioned above the processing and disposal of sludge obtained from the above treatment methods is of equal importance.

* Quantity of sewage

Inorder to determine the section of the sewer it is essential to know the total quantity of waste water or sewage that would flow through the sewer. The total waste water flow can be divided into two components:

→ ~~Dry~~ DWF   Dry Weather Flow
→ SWF   Storm Weather Flow

DWF

This is sometimes written as DWF and consists of two types of sewage

1) Domestic / sanitary sewage.
2) Industrial waste.

Domestic wastewater

A certain quantity of water is being supplied daily by the water works dept. for domestic uses. This water gets consumed in various ways and therefore all of it doesn't reach sewers. The waste water reaching the sewers will be that part of water which is used for flushing w/c, urinals, washing cloths, bathing, washing utensils etc.

Industrial wastewater

This is the wastewater generated by the Industry after consuming water for its manufacturing processes.

Factors affecting dry weather flow

The sanitary sewage depends on the dry weather flow or quantity of sanitary sewage depends on following factors.

1. Rate of water supply.
2. Population growth.
3. Design period
4. Type of area served.
5. Infiltration of groundwater

Rate of water supply

The qnty. of waste water produced from a community would naturally depends upon the rate of water supply per capita per day. The qnty. of wastewater entering the sewer would be less than the total quantity of of water supplied. This is because of the fact that water is lost in domestic consumption, evaporation, lawn sprinkling, fire fighting, industrial consumption etc. However private source of water supply & infiltration of the subsoil water in the sewers increases the waste water flow rate. This extra water that enters the sewer can be assumed to approximately equal to the water lost in consumption etc. However one is sure that no extra water enters the sewers the wastewater quantity may be assumed to be 80% of the total quantity of water supplied.

Population growth

Just as in the case of water supply project, the future popln. after 2 or 3 decades is determined by applying any suitable method of popln. forecast.

Design period.

The branches and main sewers are designed for the popln. which may occur at the end of one generation of 30 yrs. This period of 30 yrs is calle design period. However the pumping plants etc are designed for a design period of 5 - 10 yrs only. The treatment units are designed for 10 - 30 yrs period.

Type of area served.

The quantity of waste water produced depends upon whether the area served is residential, commercial or industrial. The waste water from the residential area directly depends upon the rate of water supply. If there is no infiltration of water in the sewers & if there are no private source of supply the waste water produced from the residential area may be assumed to be equal to 70 - 80 % of the water supplied through the public supply system.

Infiltration of subsoil water

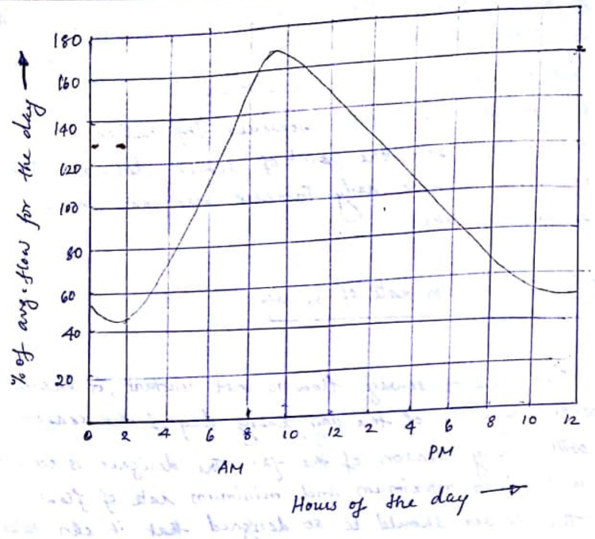
Ground water / subsoil water may infiltrate into the sewers through the leaky joints. Exfiltration is the reverse process which indicates the flow of waste water from the sewer into the ground. While due to the infiltration the quantity of flow through sewer increases, exfiltration results in decrease in the flow and consequent increase in the pollution of ground water. Both infiltration as well as exfiltration are undesirable and take place due to imperfect joints. However infiltration is much more imp. from the point of sewer design. Also infiltration unnecessarily increase the load on the treatment works.

★ Variations in rate of sewage.

The rate of sewage flow is not constant, it varies with every hr. of the day, every day of the season & with every season of the yr. The designer is concerned with both maximum and minimum rate of flow. The sewer should be so designed that it can take the max. load.

At the same time they should be laid at such longitudinal gradient that there are no deposits in the sewers at the min. flow. Both the max. & min. flows are expressed as % of the avg. rate of flow.

In the residential area the sewage flow raises by about 6 AM & reaches the max. b/w 8 AM & 10 AM. Then it falls gradually till min. flow is reached b/w 1 - 4 PM. The rate of flow then raises again.



The hrly, daily & seasonal variations of sewage flow (DWF) of a town affects the working of not only sewers but also the pumping stations and treatment plant. The hrly rate of waste water flow is affected by the hrly variations in water consumption. In general the waste water discharge curve closely ∥ʟ the water consumption curve but with a time lag of few hrs.

Temp. & climate conditions are the principle factors affecting the seasonal rate of sewage flow. For Indian condns, the avg. rate of sewage flow may be assumed to occur in Oct/Nov. & March/April. Min. rate of flow may be obtained during the Dec/Jan while max. rate may be obtained during June/July. If the annual avg. rate of flow is taken as 100, then the max. seasonal flow may be about 120, The max. monthly flow may be 140, The max. day flow may be about 150 – 180 & Max. hrly flow may be 200 – 300.

Peaking Factors → Depends on: Sewer type, Population

The effect of daily variation in sewage flow is max. on domestic & lateral sewers; Because they receive the flow directly from the source. This effect diminishes gradually as the flow reaches the branches & mains. Various sewers in sewer networks are designed not for the avg. annual flow rate, but for a flow rate which is higher than avg. flow rate by a peaking factor.

Peaking factor is the ratio of peak flow to avg. flow.

Domestic sewer	6
Lateral	4–6
Branch	3
Main	2.5
Trunk / outfall	2

* Wet Weather Flow (WWF)

When rainfall takes place a part of it infiltrates or percolates into the ground surface while the remaining flows over the land depending upon permeability of ground, its surface slope and many other factors. The amount of water flowing over the ground surface, pavements, house, roofs etc. is commonly known as runoff or storm water. This storm water is ultimately drained through the sewers otherwise the streets, roads etc would be flooded.

The amount of peak storm water flow may be several times more than DWF. In the case of combined system the sewers are normally not designed for the peak storm water flow, otherwise the size of the sewers would be alarmingly large. The storm water flow is also known as wet weather flow & is abbreviated as WWF.

Factors affecting storm water flow

1. Catchment area
2. Ground slope.
3. Permeability of ground.
4. Extent of impervious areas such as buildings, paved yards, non absorbent road surfaces etc.
5. Extent of vegetation growth.
6. Rainfall intensity.
7. Rainfall duration
8. Condition of ground prior to rainfall.
9. Concentration or compactness of catchment area.
10. Climatic conditions such as wind, humidity, temp. etc

For the purpose of estimating storm water flow for sewer design the following two methods are commonly followed.

1. Rational method
2. Empirical method.

Rational method

Rational formula is commonly used for design of storm drains in takes into account of the following factors:

$t = 20-100$ min, $a = 40$, $b = 20$

t = storm duration 5-20 min, $a = 30$, $b = 10$

i) Catchment area (A).

ii) Impermeability factor (I)

iii) Intensity of rainfall (R) $\Rightarrow$

$$R_i = \frac{25.4a}{t+b} \text{ mm/h}$$

The rational formula can be expressed as follows in its generalized form.

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$$Q = KAIR_i \quad \text{---} (1)$$

Q = Runoff in m^3/s

k = constant.

Let A = Catchment area in hectares.

A_i = Impervious area = AI

R_i = Intensity of rainfall in mm/hr.

Inorder to find corresponding value of factor k we have

$$Q = (10^4 A) \, I \, \frac{R_i}{1000 \times 3600}$$

$$Q = \frac{AIR_i}{360} = \frac{A_i R_i}{360} \quad \text{---} (2)$$

$$Q = k A_i R_i$$

$$\therefore k = \frac{1}{360}$$

The eqn (2) is sometimes expressed in the following form.

$$Q = \frac{1}{360} C R_i A$$

where C is called coefficient of runoff.

<u>Catchment area</u>

Catchment area served by given storm water sewer can be found directly from the map of the town showing the positions of the streets, houses, playgrounds, sewers etc.

<u>Impermeability factor</u>

The storm water flow depends upon the imperviousness of surface over which rainfall takes place. If the ground is relatively impervious more runoff takesplace. The % of rainwater that is available in the form of runoff is known as Impermeability factor or runoff coefficient.

<u>Intensity of rainfall</u>

The value of factor R_i can be workedout from the rainfall records of the area. However R is also depends upon

* frequency
* duration of storm

<u>Time of concentration</u>

The time of concentration is defined as the largest time without unreasonable delay, that will be req. for a drop of water to flow from the farthest point of drainage area to the point of concentration.

When rainfall just starts all over the catchment area simultaneously the raindrop falling just near the sewer inlet will enter the sewer first. The rate of flow at this state will be very small. But it will gradually increases as more and more area contribute to the flow. Finally, when the whole area is contributing max. rate of runoff will be obtained, which will be equal to rate of precipitation over the whole of the impervious area. The time req. from the beginning of rainfall to the one corresponding to the achievement of max. rate of runoff is called the time of concentration. This max. rate of runoff will continue till the rainfall stops. After that the runoff will gradually decrease.

Empirical Formula -

Rational formula is used only when the area draining water into the sewer is smaller than 400 ha. The empirical formula given below are applicable under certain specific conditions. The various empirical formula use the following variable.

i) Catchment area.
ii) Rate of intensity of rainfall in mm/hr.
iii) Relative imperviousness.
iv) Slope of ground 'S' in m/1000 m length.

Burkli Zeigler formula

$$Q = 296\, C R_i A \left(S/A \right)^{1/4}$$

Q = Runoff in lit/sec.
R_i = Max. rate of rainfall in mm/hr.
A = Catchment area in ha.
S = Slope of ground surface in m/1000 m.
C = Constant, 0.5 – 0.9, (0.7 avg).

Mc Math's formula

$$Q = 292\, C R_i A \left(S/A \right)^{1/5}$$

Metcalf and Eddy's formula

$$Q = 28.32 \left[\frac{25000}{247A + 125} + 15 \right]$$

Talboots' formula

$$Q = 87000 A_k^{1/4}$$

Dicken's formula

$$Q = 14 C A_k^{3/4}$$

A_k = area in km².

Ryve's formula

$$Q = 15 C A_k^{2/3}$$

Inglis's formula.

$$Q = \frac{123100 A_k}{\sqrt{A_k + 10.4}}$$

Tanning's formula

$$Q = 3125 A_k^{5/8}$$

Problems

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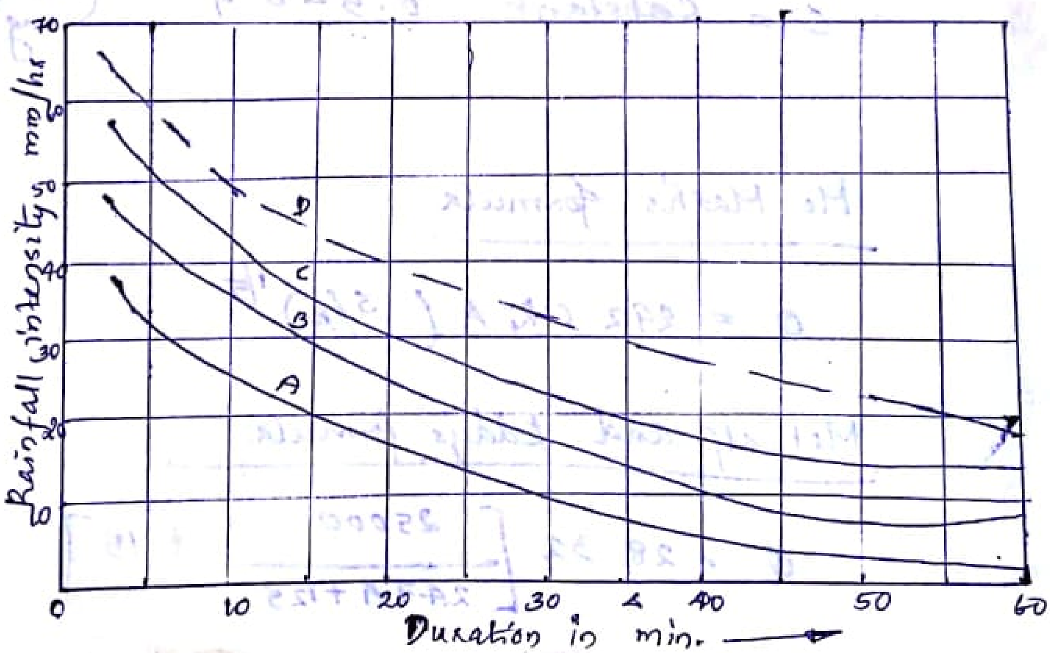
Rainfall intensity curve.



A = 5 yr curve
B = 10 yr curve
C = 15 yr curve
D = Max. curve

Fig. shows typical rainfall intensity curves for various frequencies or slopes. The value of rainfall intensity Ri can be determined for any given ~~type~~ time of concentration tc using this curve.

Hydraulic design of sewers

After the determination of the qnty of sewage the next step is to design the sewer system. The sewers and drains are generally designed as open channels except when it is essentially required to design when flowing under pressure as is the case of inverted syphons and discharge lines from sewage pumping stations which always flow under pressure. Various empirical formula which have been suggested for determining the gradients necessary to obtain design velocity of flow are given below :

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Chezy's formula

$$V = C\sqrt{RS}$$

where V = velocity of flow in channel in m/s.

R = Hydraulic mean depth of channel.

$\frac{A}{P}$ $R = \frac{D}{4}$ for circular c/s

S = Hydraulic gradient.

C = Chezy's constant.

The chezy's constant C depends upon various factors such as size, shape, roughness etc. of channel. The value of C can be obtained by using either by Kutter's formula or Bazin's formula.

By knowing the velocity of flow V, the channel section is designed by $Q = AV$.

Q = Discharge in m^3/sec

Kutter's formula

$$C = \frac{\left(23 + \frac{0.00155}{S}\right) + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{S}\right) \times \frac{N}{\sqrt{R}}}$$

where R = Hydraulic mean depth

N = Rugosity coefficient → value depend upon the nature of inside surface of sewer

S = slope.

Rugosity Coefficient , N

Sl. No.	Pipe material	Value of N for full depth for Good interior surface condn.	Fair interior surface condition.
1.	Salt glazed stoneware pipe	0.012	0.014
2.	C.C pipe	0.013	0.015
3.	Cast iron pipe	0.012	0.013
4.	Brick unglazed sewer / drain	0.013	0.015
5.	Asbestos cement	0.011	0.011
6.	Plastic (smooth) pipe	0.011	0.011

Bazin's formula.

$$C = \frac{157.6}{1.81 + \frac{k}{\sqrt{R}}}$$

where k = Bazin's constant as given below.

Bazin's constant k,

Sl. No.	Pipe material	Value of k.
1.	Very smooth pipe	0.11.
2.	Smooth brick & concrete pipe	0.29.
3.	Rough brick & concrete surface.	0.50
4.	Smooth rubble & masonry surfaces.	0.83
5.	Good earthen channels	1.54
6.	Rough earthen channels.	3.17

Manning's formula.

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

where N = Rugosity coeff. as it is same as where given by Kutter's.

Hazen William's formula.

$$V = 0.85 \, C R^{0.63} S^{0.54}$$

The value of C is given below.

C.

Sl. No	Type of pipe material.	Value of C for New pipes	Design purpose.
1.	Concrete RCC pipes	140	110
2.	Cast iron pipes	130	100
3.	Galvanized iron pipes	120	100
4.	Steel pipes with welded joints	140	100
5.	Steel pipes with rivetted joints	110	95
6.	Welded steel pipes with cement lining	140	110
7.	Asbestos cement pipes	150	120
8.	Plastic pipes	150	120

Min. & Max. velocity generated in sewers.

Flow velocities in the sewers should be such that neither the suspended material in sewage get silted up, nor the sewage pipe material get scoured out.

Min. velocities

The silting of sewers can be avoided by generating such velocity that won't permit the solids to settle down. i.e. The velocity should be such as to cause automatic self cleansing effect. The generation of such a min. self cleansing velocity in the sewers atleast once a day is important.

Self cleansing vel. for various types of suspended solids present in the sewage.

Sl. No.	Nature of sewage Particle present in the sewage	Self cleansing velocity (m/s)
1.	Angular stones	1.0
2.	Round pebbles	0.5 to 0.6
3.	Fine gravel	0.3
4.	Coarse sand	0.2
5.	Fine sand & clay	0.15
6.	Fine clay & silt	0.075

Self cleansing vel. for various dia. of pipe.

Sl. No.	Dia. of pipe	Self cleansing vel. (m/s)
1.	15 – 25 cm	1

Effects of flow variation on velocity in sewer.

The sewage discharge flowing through a sewer doesn't remain constant all the time but varies considerably from time to time. Due to this variation in discharge the depth of flow varies and hence the hydraulic mean depth (HMD) varies. Due to this change in the HMD, the flow velocity affected from time to time.

Since the velocity developed in a sewer of a given section and grade will be less as when the flow reduces it is necessary to check the sewer for maintaining a min. velocity of about 0.45 m/sec at the time of min. flow. The designer should also ensure that a velocity of about 0.9 m/sec is developed atleast at the time of max. flow and preferably during the avg. flow periods also.

On the other hand, if the available ground slopes are ~~are~~ neither too steep nor too flat, the condition of developing velocities about 0.9 m/sec at avg. flow may be practically possible and hence may be insisted.

Design of circular sewers

The sewers of circular section are more commonly used. However, sometimes egg shaped or horse shoe shape or rectangular shape are also be used.

The circular sewers may sometimes run full or partially full. When they run

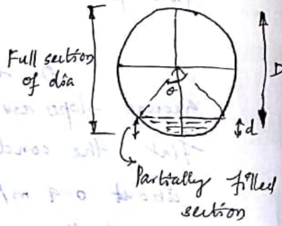
* full their hydraulic properties will be as given below:-

$A = \frac{\pi}{4} D^2$ $\quad D$ = Dia of pipe.

$P = \pi D$

$\therefore$ HMD $= \frac{A}{P} = \frac{D}{4}$.

* When the sewers is running partially full



The depth at partial flow $d = \frac{D}{2} - \frac{D}{2}\cos\frac{\theta}{2}$.

$= \frac{D}{2}\left[1 - \cos\theta/2\right]$

where θ is the central angle in degree

$\therefore$ Proportionate depth $\frac{d}{D} = \frac{\frac{D}{2}\left[1 - \cos\theta/2\right]}{D}$

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

Area of c/s while running partially full

$$a = \frac{\pi D^2}{4}\frac{\theta}{360} - \frac{D}{2}\cos\theta/2 \times \frac{D}{2}\sin\theta/2.$$

$$= \frac{\pi D^2}{4}\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right].$$

$2\sin\theta/2\cos\theta/2 = \sin\theta$

$\therefore$ Proportionate area $\frac{a}{A} = \frac{\frac{\pi D^2}{4}\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]}{\frac{\pi D^2}{4}}$

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

Wetted perimeter $p = \pi D\frac{\theta}{360}$

$\therefore$ Proportionate perimeter $= \frac{p}{P} = \frac{\pi D\,\theta/360}{\pi D}$

$$\boxed{\frac{p}{P} = \frac{\theta}{360}}$$

Hydraulic Mean depth $r = \frac{a}{p} = \frac{D}{4}\left[1 - \frac{360 \sin\theta}{2\pi\theta}\right]$

Proportionate HMD $= \frac{r}{R} = \frac{\frac{D}{4}\left[1 - \frac{360 \sin\theta}{2\pi\theta}\right]}{D/4}$

$$\boxed{\frac{r}{R} = 1 - \frac{360 \sin\theta}{2\pi\theta}}$$

Velocity of flow

+ When sewer is running full

$$V = \frac{1}{N} R^{2/3} \sqrt{S_0}$$

+ Velocity of flow when running partially full

$$v = \frac{1}{n} r^{2/3} \sqrt{S_0}.$$

Bed slope $S_0 = S$ remains same whether the pipe run full or partially full.

∴ Proportionate velocity $\frac{v}{V} = \frac{\frac{1}{n} r^{2/3}\sqrt{S_0}}{\frac{1}{N} R^{2/3}\sqrt{S_0}}$

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

Assuming that the roughness coeff. N doesn't vary with depth we have $n = N$:

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

$$\boxed{\frac{v}{V} = \left[1 - \frac{360 \sin\theta}{2\pi\theta}\right]^{2/3}}$$

∴ Discharge when pipe is running partially full $= q = av$

Discharge when pipe running full $Q = AV$.

∴ Proportionate discharge $\frac{q}{Q} = \frac{av}{AV}$

$$= \left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]\left[1 - \frac{360 \sin\theta}{2\pi\theta}\right]^{2/3}$$

In all the above derived eqns. except θ everything is constant and hence by giving values of θ all the 6 proportionate elements can be easily calculated.

But taking proportionate depth $\frac{d}{D}$ as reference values of other elements can be foundout. for the readymade computed values shown in Tables.

From the table it can be seen that velocity in partially filled circular section equal or exceed those in full sections.

Max. velocity is obtained not when the sewer is running full, but when depth of flow is 0·81 times the full depth and is about 12·5% greater than when running full.

Similarly the max discharge is obtained not when the sewer is running full but when depth is about 0·95 times the full depth and is about 7% greater than when running full.

The above statements are correct only the roughness is indpt of depth. The effect of variation of N reduces the proportionate velocities and discharges at lower depths of flow, because roughness increases with lower depth. If this variations of N are also considered, more precise values of proportionate velocities & discharges can be computed out as shown in Table 2.

These precise proportionate velocities & discharges can be plotted by firm lines in fig. given below to obtain std. chart which is very useful in obtaining diff. elements by knowing any one of them. Values of Table 1 are also plotted by dotted curves.

Sewers flowing with depth b/w 50% & 80% full need not be placed on steeper gradients to be as self cleansing as sewers flowing full. The reason is that velocity & discharge depends upon tractive force. The self cleansing velocity can be computed with the help of eqn.

$$V_s = \frac{N}{n} \times \left(\frac{r}{R}\right)^{1/6} V$$

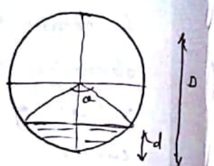
1. Design a sewer for a discharge of 800 l/sec running half full. Assume slope $S = 0.0001$

$q = 800$ l/sec

$= 0.8\ m^3/sec$

$\frac{d}{D} = 0.5 = \frac{1}{2}$

$S = 0.0001$



Since it is running half full

$\theta = 180°$

$\theta/2 = 90°$

$a = \frac{\pi D^2}{4}\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]$ $\sin 180 = 0$

$= \frac{\pi D^2}{4}\left[\frac{180}{360}\right]$

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

$p = \pi D \frac{\theta}{360} = \frac{\pi D}{2}$

$r = \frac{a}{p} = \frac{\pi D^2/8}{\pi D/2} = D/4$

$v = \frac{1}{n} r^{2/3} \sqrt{S}$

$= \frac{1}{n}\left(\frac{D}{4}\right)^{2/3} \sqrt{0.0001}$

$q = av$ Assume $n = 0.012$

$0.8 = \frac{\pi D^2}{8} \times \frac{1}{0.012} \times \left(\frac{D}{4}\right)^{2/3} \sqrt{0.0001}$

$0.8 = 0.1299\ D^{8/3}$

$D = 1.98$ m

2. Design a sewer for half flow condition.

Population = 50,000.

Water supply = 150 lpcd

Max. flow = 5 DWF (Dry weather Flow)

Slope = 1 in 625.

Manning's coeff. = $n = 0.013$.

Ans Total quantity of water supplied $= 50{,}000 \times 150$

$= 7.5 \times 10^6$ l/d

Assume avg. discharge of sewage = 80% of water supplied.

$\therefore$ Avg. discharge of sewage $= 0.80 \times 7.5 \times 10^6$ l/d

$= 6 \times 10^6$ l/d

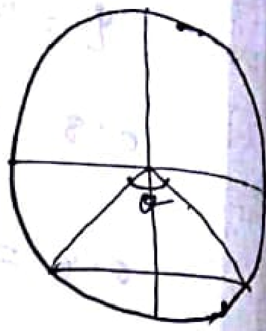
Max. discharge of sewage = 5 DWF

$= 5 \times 6 \times 10^6$

$= 30 \times 10^6$ l/d

$= 30 \times 10^3\ m^3/d$

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



$\therefore \theta = 180^\circ$.

$\cos \theta/2 = 0$

$\sin \theta = 0$

Area of c/s $a = \frac{\pi D^2}{4}\left[\frac{\theta}{360} - \frac{\sin\theta}{2\pi}\right]$

$= \frac{\pi \times D^2}{4}\left[\frac{1}{2}\right] = \frac{\pi D^2}{8}$

Wetted perimeter $p = \pi D \frac{\theta}{360}$

$= \frac{\pi D}{2}$

$r = \frac{a}{P} = \frac{\pi D^2/8}{\pi D/2} = \frac{D}{4}$.

$V = \frac{1}{n} r^{2/3} \sqrt{s}$

$= \frac{1}{0.013}\left(\frac{D}{4}\right)^{2/3} \sqrt{\frac{1}{625}}$

$q = av$

$\frac{30 \times 10^3}{24 \times 60 \times 60} = \frac{\pi D^2}{8} \times \frac{1}{0.013} \times \frac{D^{2/3}}{4^{2/3}} \cdot \sqrt{\frac{1}{625}}$

~~$D^{8/3}$ = 62563.1 ⟹ D =~~

$$D = 0.88 \text{ m}.$$

Check for self cleansing velocity at max discharge

$$r = \frac{D}{4} = \frac{0.88}{4} = 0.22 \text{ m}.$$

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

$$= \frac{1}{0.013} \times (0.22)^{2/3} \sqrt{\frac{1}{625}}$$

$$V = 1.12 \text{ m/s}.$$

This is much more than the self cleansing velocity of 0.9 m/sec.