

Module 7: Hydraulic Design of Sewers and Storm Water Drains

Lecture 7 : Hydraulic Design of Sewers and Storm Water Drains

7.1 General Consideration

Generally, sewers are laid at steeper gradients falling towards the outfall point with circular pipe cross section. Storm water drains are separately constructed as surface drains at suitable gradient, either rectangular or trapezoidal section. Sewers are designed to carry the maximum quantity of sanitary sewage likely to be produced from the area contributing to the particular sewer. Storm water drains are designed to carry the maximum storm runoff that is likely to be produced by the contributing catchment area from a rain of design frequency and of duration equal to the time of concentration.

7.2 Requirements of Design and Planning of Sewerage System

The sewerage scheme is designed to remove entire sewage effectively and efficiently from the houses to the point of treatment and disposal. Following aspects should be considered while designing the system.

- The sewers provided should be adequate in size to avoid overflow and possible health hazards.
- For evaluating proper diameter of the sewer, correct estimation of sewage discharge is necessary.
- The flow velocity inside the sewer should neither be so large as to require heavy excavation and high lift pumping, nor should be so small causing deposition of the solid in the sewers.
- The sewers should be laid at least 2 to 3 m deep to carry sewage from basement.
- The sewage in sewer should flow under gravity with 0.5 to 0.8 full at designed discharge, i.e. at the maximum estimated discharge.
- The sewage is conveyed to the point usually located in low-lying area, where the treatment plant is located.
- Treatment plant should be designed taking into consideration the quality of raw sewage expected and to meet the discharge standards.

7.3 Difference Between Water Supply Pipes and Sewer Pipes

The major difference between the water distribution network and sewerage system is presented in the Table 7.1.

Table 7.1: Comparison between the water distribution network and sewage collection system

Water Supply Pipes

- It carries pure water.
- Velocity higher than self-cleansing is not essential, because of solids are not present in suspension.
- It carries water under pressure. Hence, the pipe can be laid up and down the hills and the valleys within certain limits.
- These pipes are flowing full under pressure.

Sewer Pipes

- It carries contaminated water containing organic or inorganic solids which may settle in the pipe. It can cause corrosion of the pipe material.
- To avoid deposition of solids in the pipes self-cleansing velocity is necessary at all possible discharge.
- It carries sewage under gravity. Therefore it is required to be laid at a continuous falling gradient in the downward direction towards outfall point.
- Sewers are design to run partial full at maximum discharge. This extra space ensures non-pressure gravity flow. This will minimize the leakage from sewer, from the faulty joints or crack, if any.

7.4 Provision of Freeboard in Sewers

7.4.1 Sanitary Sewers

Sewers with diameter less than 0.4 m are designed to run half full at maximum discharge, and sewers with diameter greater than 0.4 m are designed to flow 2/3 to ¾ full at maximum discharge. The extra space provided in the sewers provides factor of safety to counteract against the following factors:

1. Safeguard against lower estimation of the quantity of wastewater to be collected at the end of design period due to private water supply by industries and public. Thus, to ensure that sewers will never flow full eliminating pressure flow inside the sewer.
2. Large scale infiltration of storm water through wrong or illegal connection, through underground cracks or open joints in the sewers.
3. Unforeseen increase in population or water consumption and the consequent increase in sewage production.

7.4.2 Storm Water Drains

Storm water drains are provided with nominal freeboard, above their designed full supply line because the overflow from storm water drains is not much harmful. Minimum of 0.3 m free board is generally provided in storm water drains.

7.5 Hydraulic Formulae for Determining Flow Velocities

Sewers of any shape are hydraulically designed as open channels, except in the case of inverted siphons and discharge lines of pumping stations. Following formulae can be used for design of sewers.

1. Manning's Formula

This is most commonly used for design of sewers. The velocity of flow through sewers can be determined using Manning's formula as below:

$$v = \frac{1}{n} r^{2/3} s^{1/2} \quad (1)$$

Where,

v = velocity of flow in the sewer, m/sec

r = Hydraulic mean depth of flow, m

= a/p

a = Cross section area of flow, m^2

p = Wetted perimeter, m

n = Rugosity coefficient, depends upon the type of the channel surface i.e., material and lies between 0.011 and 0.015. For brick sewer it could be 0.017 and 0.03 for stone facing sewers.

s = Hydraulic gradient, equal to invert slope for uniform flows.

2. Chezy's Formula

$$v = C r^{1/2} s^{1/2} \quad (2)$$

Where, C is Chezy's constant and remaining variables are same as above equation.

3. Crimp and Burge's Formula

$$v = 83.5 r^{2/3} s^{1/2} \quad (3)$$

4. Hazen- Williams Formula

$$V = 0.849 C R^{0.63} S^{0.54} \quad (4)$$

The Hazen-Williams coefficient 'C' varies with life of the pipe and it has high value when the pipe is new and lower value for older pipes. For example for RCC new pipe it is 150 and the value recommended for design is 120, as the pipe interior may become rough with time. The design values of 'C' for AC pipes, Plastic pipes, CI pipes, and steel lined with cement are 120, 120, 100, and 120, respectively. Modified Hazen-Williams equation is also used in practice.

7.6 Minimum Velocity: Self Cleansing Velocity

The velocity that would not permit the solids to settle down and even scour the deposited particles of a given size is called as self-cleansing velocity. This minimum velocity should at least develop once in a day so as not to allow any deposition in the sewers. Otherwise, if such deposition takes place, it will obstruct free flow causing further deposition and finally leading to the complete blocking of the sewers. This minimum velocity or self-cleansing velocity can be worked out as below:

$$V_s = \sqrt{\frac{8K}{f'} (S_s - 1) g d'}$$

Where,

(5)

K = constant, for clean inorganic solids = 0.04 and for organic solids = 0.06

f' = Darcy Weisbach friction factor (for sewers = 0.03)

S_s = Specific gravity of sediments

g = gravity acceleration

d' = diameter of grain, m

- Hence, for removing the impurities present in sewage i.e., sand up to 1 mm diameter with specific gravity 2.65 and organic particles up to 5 mm diameter with specific gravity of 1.2, it is necessary that a minimum velocity of about 0.45 m/sec and an average velocity of about 0.9 m/sec should be developed in sewers.
- Hence, while finalizing the sizes and gradients of the sewers, they must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average discharge.
- While designing the sewers the flow velocity at full depth is generally kept at about 0.8 m/sec or so. Since, sewers are generally designed for 1/2 to 3/4 full, the velocity at 'designed discharge' (i.e., 1/2 to 3/4 full) will even be more than 0.8 m/sec. Thus, the minimum velocity generated in sewers will help in the following ways:

- Adequate transportation of suspended solids,
- Keeping the sewer size under control; and
- Preventing the sewage from decomposition by moving it faster, thereby preventing evolution of foul gases.

7.7 Maximum Velocity or Non-scouring Velocity

The interior surface of the sewer pipe gets scored due to the continuous abrasion caused by suspended solids present in sewage. The scoring is pronounced at higher velocity than what can be tolerated by the pipe materials. This wear and tear of the sewer pipes will reduce the life span of the pipe and their carrying capacity. In order to avoid this, it is necessary to limit the maximum velocity that will be produced in sewer pipe at any time. This limiting or non-scouring velocity mainly depends upon the material of sewer. The limiting velocity for different sewer material is provided in Table 7.2.

Table 7.2 Limiting or non-scouring velocity for different sewer material

Sewer Material	Limiting velocity, m/sec
Vitrified tiles	4.5 – 5.5
Cast iron sewer	3.5 – 4.5
Cement concrete	2.5 – 3.0
Stone ware sewer	3.0 – 4.5
Brick lined sewer	1.5 – 2.5

The problem of maximum or non-scouring velocity is severe in hilly areas where ground slope is very steep and this is overcome by constructing drop manholes at suitable places along the length of the sewer.

7.8 Effect of Flow Variations on Velocities in a Sewer

The discharge flowing through sewers varies considerably from time to time. Hence, there occur variation in depth of flow and thus, variation in Hydraulic Mean Depth (H.M.D.). Due to change in H.M.D. there occur changes in flow velocity, because it is proportional to $(H.M.D.)^{2/3}$. Therefore, it is necessary to check the sewer for minimum velocity of about 0.45 m/sec at the time of minimum flow (1/3 of average flow) and the velocity of about 0.9 to 1.2 m/sec should be developed at a time of average flow. The velocity should also be checked for limiting velocity i.e. non-scouring velocity at the maximum discharge.

For flat ground sewers are designed for self-cleansing velocity at maximum discharge. This will permit flatter gradient for sewers. For mild slopping ground, the condition of developing self-cleansing velocity at average flow may be economical. Whereas, in hilly areas, sewers can be designed for self-cleansing velocity at minimum discharge, but the design must be checked for non-scouring velocity at maximum discharge.

Example: 1

Design a sewer for a maximum discharge of 650 L/s running half full. Consider Manning's rugosity coefficient $n = 0.012$, and gradient of sewer $S = 0.0001$.

Solution

$$Q = A \cdot V$$

$$0.65 = (\pi D^2/8) (1/n) R^{2/3} S^{1/2}$$

$$R = A/P$$

$$\text{Solving for half full sewer, } R = D/4$$

Substituting in above equation and solving we get $D = 1.82$ m.

Comments: If the pipe is partially full it is not easy to solve this equation and it is time consuming.

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7.9 Hydraulic Characteristics of Circular Sewer Running Full or Partially Full

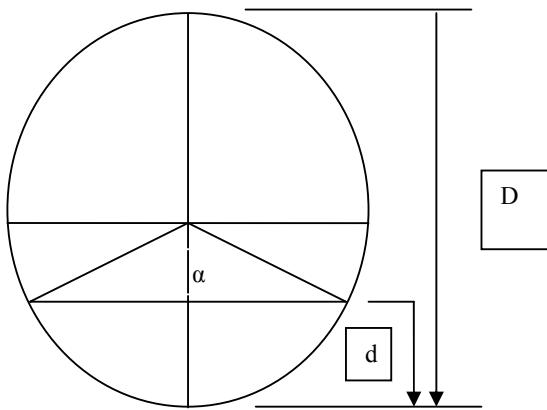


Figure 7.1 Section of a circular sewer running partially full

a) Depth at Partial flow

$$d = \left[\frac{D}{2} - \frac{D}{2} \cos\left(\frac{\alpha}{2}\right) \right] \quad (6)$$

b) Therefore proportionate depth

$$\frac{d}{D} = \frac{1}{2} \left[1 - \cos\left(\frac{\alpha}{2}\right) \right] \quad (7)$$

c) Proportionate area

$$\frac{a}{A} = \left[\frac{\alpha}{360} - \frac{\sin \alpha}{2\pi} \right] \quad (8)$$

d) Proportionate perimeter: $\frac{p}{P} = \frac{\alpha}{360}$ (9)

e) Proportionate Hydraulic Mean Depth

$$\frac{r}{R} = \left[1 - \frac{360 \sin \alpha}{2\pi \alpha} \right] \quad (10)$$

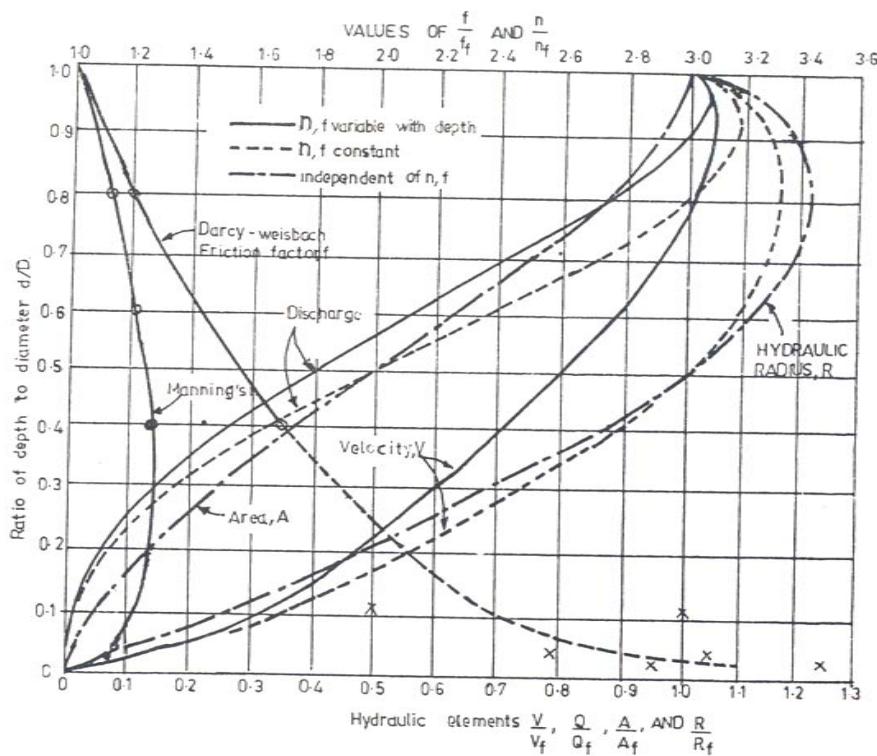
f) Proportionate velocity $\frac{v}{V} = \frac{N}{n} \frac{r^{2/3}}{R^{2/3}}$ (11)

In all above equations except 'α' everything is constant (Figure 7.1). Hence, for different values of 'α', all the proportionate elements can be easily calculated. These values of the hydraulic elements can be obtained from the proportionate graph prepared for different values

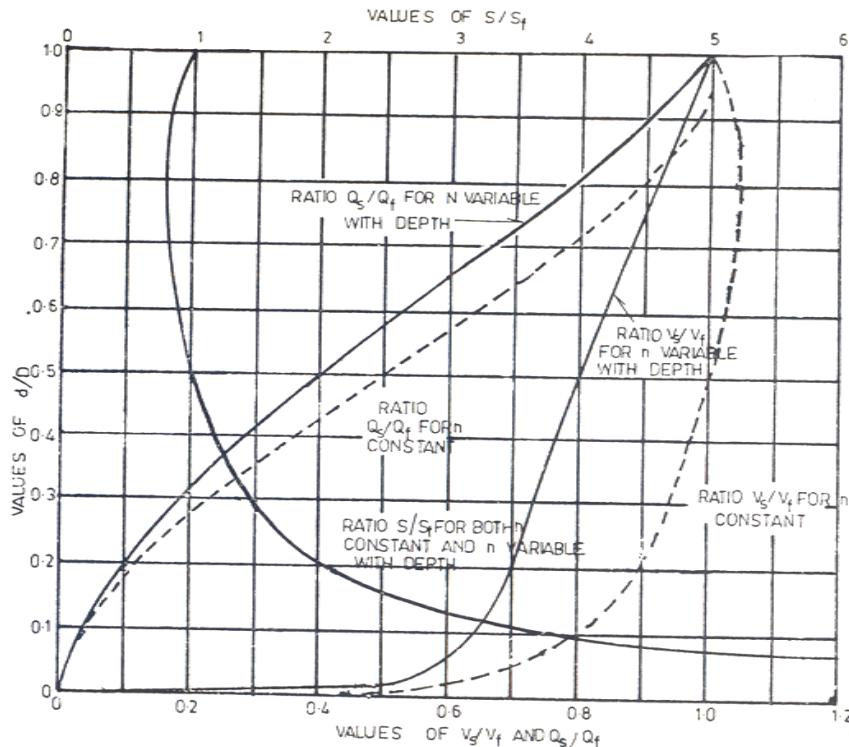
of d/D (Figure 7.2). The value of Manning's n can be considered constant for all depths. In reality, it varies with the depth of flow and it may be considered variable with depth and accordingly the hydraulic elements values can be read from the graph for different depth ratio of flow.

From the plot it is evident that the velocities in partially filled circular sewer sections can exceed those in full section and it is maximum at d/D of 0.8. Similarly, the discharge obtained is not maximum at flow full condition, but it is maximum when the depth is about 0.95 times the full depth.

The sewers flowing with depths between 50% and 80% full need not to be placed on steeper gradients to be as self cleansing as sewers flowing full. The reason is that velocity and discharge are function of tractive force intensity which depends upon friction coefficient as well as flow velocity generated by gradient of the sewer. Using subscript 's' denoting self cleansing equivalent to that obtained in full section, the required ratios v_s/V , q_s/Q and s_s/S can be computed as stated below:



(a) Hydraulic elements for circular sewer



(b) Hydraulic elements of circular sewer possessing equal selfcleaning properties at all depths

Figure 7.2 Proportionate graph for circular sewer section (CPHEEO Manual, 1993)

Consider a layer of sediment of unit length, unit width and thickness 't', is deposited at the invert of the sewer (Figure 7.3). Let the slope of the sewer is θ degree with horizontal. The drag force or the intensity of tractive force (τ) exerted by the flowing water on a channel is given by:

$$\tau = \gamma_w \cdot R \cdot S \quad (12)$$

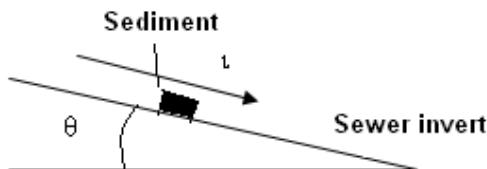


Figure 7.3 A sediment particle moving on the sewer invert

Where,

γ_w = unit weight of water

R = Hydraulic mean depth

S = slope of the invert of the sewer per unit length

With the assumption that the quantity of tractive force intensity at full flow and partial flow implies equality of cleansing, i.e., for sewers to be same self-cleansing at partial depth as full depth:

$$t = T$$

$$\text{Therefore, } \gamma_w \cdot r \cdot s_s = \gamma_w \cdot R \cdot S \quad (13)$$

$$\text{Hence, } s_s = (R/r) S$$

$$\text{Or } \frac{s_s}{S} = \frac{R}{r} \quad (14)$$

Therefore,

$$\frac{v_s}{V} = \frac{N}{n} \left(\frac{r}{R} \right)^{2/3} \left(\frac{s_s}{S} \right)^{1/2} \quad (15)$$

OR, by substituting $r/R = S/s_s$

$$\frac{v_s}{V} = \frac{N}{n} \left(\frac{r}{R} \right)^{1/6} \quad (16)$$

And

$$\frac{q_s}{Q} = \frac{N}{n} \frac{a}{A} \left(\frac{r}{R} \right)^{1/6} \quad (17)$$

Example: 2

A 300 mm diameter sewer is to flow at 0.3 depth on a grade ensuring a degree of self cleansing equivalent to that obtained at full depth at a velocity of 0.9 m/sec. Find the required grade and associated velocity and rate of discharge at this depth. Assume Manning's rugosity coefficient $n = 0.013$. The variation of n with depth may be neglected.

Solution:

Manning's formula for partial depth

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

For full depth

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

Using $V = 0.90$ m/sec, $N = n = 0.013$ and $R = D/4 = 75$ mm = 0.075 m

$$0.90 = \frac{1}{0.013} 0.075^{2/3} S^{1/2}$$

$$S = 0.0043$$

This is the gradient required for full depth.

$$\text{and, } Q = A \cdot V = \pi/4 (0.3)^2 \times 0.90 = 0.064 \text{ m}^3/\text{s}$$

At depth $d = 0.3D$, (i.e., for $d/D = 0.3$) we have $a/A = 0.252$ and $r/R = 0.684$ (neglecting variation of n)

Now for the sewer to be same self cleansing at 0.3 m depth as it will be at full depth, we have the gradient (s_s) required as $s_s = (R/r)S$

$$\text{Therefore, } s_s = S / 0.684$$

$$= 0.0043 / 0.684 = 0.0063$$

Now, the velocity v_s generated at this gradient is given by

$$\begin{aligned} v_s &= V \frac{N}{n} \left(\frac{r}{R} \right)^{1/6} \\ &= 1 \times (0.684)^{1/6} \times 0.9 \\ &= 0.846 \text{ m/s} \end{aligned}$$

The discharge q_s is given by

$$\begin{aligned} q_s &= Q \frac{N}{n} \frac{a}{A} \left(\frac{r}{R} \right)^{1/6} \\ q_s &= 1 \times (0.258) \times (0.939) \times (0.064) \\ &= 0.015 \text{ m}^3/\text{s} \end{aligned}$$

Example: 3

A combined sewer was designed to serve an area of 60 sq. km with an average population density of 185 persons/hectare. The average rate of sewage flow is 350 L/Capita/day. The maximum flow is 50% in excess of the average sewage flow. The rainfall equivalent of 12 mm in 24 h can be considered for design, all of which is contributing to surface runoff. What will be the discharge in the sewer? Find the diameter of the sewer if running full at maximum discharge.

Solution:

$$\begin{aligned} \text{Total population of the area} &= \text{population density} \times \text{area} \\ &= 185 \times 60 \times 10^2 \\ &= 1110 \times 10^3 \text{ persons} \end{aligned}$$

$$\begin{aligned} \text{Average sewage flow} &= 350 \times 11.1 \times 10^5 \text{ Liters/day} \\ &= 388.5 \times 10^6 \text{ L/day} \end{aligned}$$

$$= 4.5 \text{ m}^3/\text{sec}$$

$$\begin{aligned}\text{Storm water flow} &= 60 \times 10^6 \times (12/1000) \times [1/(24 \times 60 \times 60)] \\ &= 8.33 \text{ m}^3/\text{sec}\end{aligned}$$

$$\begin{aligned}\text{Maximum sewage flow} &= 1.5 \times \text{average sewage flow} \\ &= 1.5 \times 4.5 = 6.75 \text{ m}^3/\text{sec}\end{aligned}$$

$$\begin{aligned}\text{Total flow of the combined sewer} &= \text{sewage flow} + \text{storm flow} \\ &= 6.75 + 8.33 = 15.08 \text{ m}^3/\text{sec}\end{aligned}$$

Hence, the capacity of the sewer = $15.08 \text{ m}^3/\text{sec}$

Hence, diameter of the sewer required at the velocity of 0.9 m/s can be calculated as

$$\pi/4 (D)^2 \times 0.90 = 15.08 \text{ m}^3/\text{s}$$

Hence, $D = 4.62 \text{ m}$

Example: 4

Find the minimum velocity and gradient required to transport coarse sand through a sewer of 40 cm diameter with sand particles of 1.0 mm diameter and specific gravity 2.65, and organic matter of 5 mm average size with specific gravity 1.2. The friction factor for the sewer material may be assumed 0.03 and roughness coefficient of 0.012. Consider $k = 0.04$ for inorganic solids and 0.06 for organic solids.

Solution

Minimum velocity i.e. self cleansing velocity

$$V_s = \sqrt{\frac{8k}{f'}} (S_s - 1) g d'$$

$$V_s = \sqrt{\frac{8 \times 0.04}{0.03}} (2.65 - 1) \times 9.81 \times 0.001$$

$$= 0.4155 \text{ m/sec say } 0.42 \text{ m/sec}$$

Similarly, for organic solids this velocity will be 0.396 m/sec

Therefore, the minimum velocity in sewer = 0.42 m/sec

Now, Diameter of the sewer $D = 0.4 \text{ m}$

Hydraulic Mean Depth = $D/4 = 0.4/4 = 0.1 \text{ m}$

Using Manning's formula:

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

$$0.42 = (1/0.012) \times (0.1)^{2/3} \times S^{1/2}$$

$$S = 1/1824.5$$

Therefore, gradient of the sewer required is 1 in 1824.5.

Example : 5

Design a sewer running 0.7 times full at maximum discharge for a town provided with the separate system, serving a population 80,000 persons. The water supplied from the water works to the town is at a rate of 190 LPCD. The manning's $n = 0.013$ for the pipe material and permissible slope is 1 in 600. Variation of n with depth may be neglected. Check for minimum and maximum velocity assuming minimum flow 1/3 of average flow and maximum flow as 3 times the average. (for $d/D = 0.7$, $q/Q = 0.838$, $v/V = 1.12$)

Solution

$$\text{Average water supplied} = 80000 \times 190 \times (1/24 \times 60 \times 60 \times 1000) = 0.176 \text{ m}^3/\text{sec}$$

$$\text{Sewage production per day, (considering 80% of water supply)} = 0.176 \times 0.8 = 0.14 \text{ m}^3/\text{sec}$$

$$\text{Maximum sewage discharge} = 3 \times 0.14 = 0.42 \text{ m}^3/\text{sec}$$

$$\text{Now for } d/D = 0.7, q/Q = 0.838, v/V = 1.12$$

$$\text{Therefore, } Q = 0.42/0.838 = 0.5 \text{ m}^3/\text{sec}$$

Now

$$Q = \frac{1}{n} \frac{\pi D^2}{4} \left(\frac{D}{4} \right)^{2/3} S^{1/2}$$

$$Q = \frac{1}{0.013} \frac{\pi D^2}{4} \left(\frac{D}{4} \right)^{2/3} \left(\frac{1}{600} \right)^{1/2}$$

$$\text{Therefore, } D = 0.78 \text{ m}$$

$$V = Q/A = 1.04 \text{ m/sec}$$

$$\text{Now, } v/V = 1.12$$

$$\text{Therefore } v = 1.12 \times 1.04 = 1.17 \text{ m/sec}$$

This velocity is less than limiting velocity hence, OK

Check for minimum velocity

$$\text{Now } q_{\min} = 0.14/3 = 0.047 \text{ m}^3/\text{sec}$$

$$q_{\min}/Q = 0.047/0.5 = 0.09$$

From proportional chart, for $q/Q = 0.09$, $d/D = 0.23$ and $v/V = 0.65$

Therefore, the velocity at minimum flow = $0.65 \times 1.04 = 0.68 \text{ m/sec}$

This velocity is greater than self cleansing velocity, hence OK

$$d_{\min} = 0.23 \times 0.78 = 0.18 \text{ m}$$

Comment: If the velocity at minimum flow is not satisfactory, increase the slope or try with reduction in depth of flow at maximum discharge or reduction in diameter of the sewer.

Assignment: Solve the above problem with population 100000 persons and pipe flowing 0.75 full at maximum discharge. The rate of water supply is 150 LPCD, $n = 0.013$, and permissible $S = 1$ in 600.

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Lecture 9 : Hydraulic Design Of Sewers And Storm Water Drains (Contd.)

7.10 Design of Storm Water Drains for Separate System

Important points for design

Storm water is collected from streets into the link drains, which in turn discharge into main drains of open type. The main drain finally discharges the water into open water body. As far as possible gravity discharge is preferred, but when it is not possible, pumping can be employed. While designing, the alignment of link drains, major drains and sources of disposal are properly planned on contour maps. The maximum discharge expected in the drains is worked out. The longitudinal sections of the drains are prepared keeping in view the full supply level (FSL) so that at no place it should go above the natural surface level along the length. After deciding the FSL line, the bed line is fixed (i.e. depth of drain) based on following consideration.

- a. The bed level should not go below the bed level of source into which storm water is discharged.
- b. The depth in open drain should preferably be kept less than man height.
- c. The depth is sometimes also decided based on available width.
- d. The drain section should be economical and velocities generated should be non-silting and non-scouring in nature.

The drain section is finally designed using Manning's formula. Adequate free board is provided over the design water depth at maximum discharge.

7.11 Laying of Sewer Pipes

- Sewers are generally laid starting from their outfall ends towards their starting points. With this advantage of utilization of the tail sewers even during the initial periods of its construction is possible.
- It is common practice, to first locate the points where manholes are required to be constructed as per drawing, i.e., L-section of sewer, and then laying the sewer pipe straight between the two manholes.
- The central line of the sewer is marked on the ground and an offset line is also marked parallel to the central line at suitable distance, about half the trench width plus 0.6 m. This line can be drawn by fixing the pegs at 15 m intervals and can be used for finding out center line of the sewer simply by offsetting.
- The trench of suitable width is excavated between the two manholes and the sewer is laid between them. Further excavation is then carried out for laying the pipes between

the next consecutive manholes. Thus, the process is continued till the entire sewers are laid out.

- The width of the trench at the bottom is generally kept 15 cm more than the diameter of the sewer pipe, with minimum 60 cm width to facilitate joining of pipes.
- If the sewer pipes are not to be embedded in concrete, such as for firm grounds, then the bottom half portion of the trench is excavated to confirm the shape of the pipe itself. In ordinary or softer grounds, sewers are laid embedded in concrete.
- The trench is excavated up to a level of the bottom embedding concrete or up to the invert level of the sewer pipe plus pipe thickness if no embedding concrete is provided. The designed invert levels and desired slope as per the longitudinal section of the sewer should be precisely transferred to the trench bottom.
- After bedding concrete is laid in required alignment and levels. The sewer pipes are then lowered down into the trench either manually or with the help of machines for bigger pipe diameters.
- The sewer pipe lengths are usually laid from the lowest point with their sockets facing up the gradient, on desired bedding. Thus, the spigot end of new pipe can be easily inserted on the socket end of the already laid pipe.

7.12 Hydraulic Testing of Sewers

7.12.1 Test for Leakage or Water Test

The sewers are tested after giving sufficient time for the joints to set for no leakage. For this sewer pipe sections are tested between the manholes to manhole under a test pressure of about 1.5 m water head. To carry this, the downstream end of the sewer is plugged and water is filled in the manhole at upper end. The depth of water in manhole is maintained at about 1.5 m. The sewer line is inspected and the joints which leak are repaired.

7.12.2 Test for Straightness of alignment

This can be tested by placing a mirror at one end of the sewer line and a lamp at the other end. If the pipe line is straight, full circle of light will be observed.

Backfilling the trench: After the sewer line has been laid and tested, the trenches are back filled. The earth should be laid equally on either side with layer of 15 cm thickness. Each layer should be properly watered and rammed.

Questions

1. A 900 m long storm sewer collects water from a catchment area of 40 hectares, where 35% area is covered by roof ($C=0.9$), 20% area by pavements ($C=0.8$) and 45% area is covered by open plots ($C=0.15$). Determine the average intensity of rainfall and diameter of storm water drain. Assume the time of entry = 3 min; velocity at full flow = 1.45 m/sec; gradient of sewer = 0.001, and roughness coefficient = 0.013. The intensity of rainfall, cm/h = $75/(t + 5)$.
2. Explain the importance of considering minimum and maximum velocity while designing the sewers.
3. Explain 'Self-cleansing velocity'.
4. Explain important consideration while finalizing alignment and bed line of storm water drain.
5. Find the gradient required in sewer of 0.5 m diameter to maintain self cleansing velocity at flow full condition.
6. Write short notes on laying of sewer pipes. What hydraulic tests are conducted on the sewers?
7. Prepare notes on sewer maintenance.

Answers

Q. 1: Overall runoff coefficient = 0.5425; Average intensity of rainfall = 4.09 cm/h; Storm water quantity = $2.465 \text{ m}^3/\text{sec}$; and diameter of storm water drain = 1.556 m