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	Sewer Pipes
• It carries pure water.	• It carries contaminated water containing organic or inorganic solids which may settle in the pipe. It can cause corrosion of the pipe material.
• Velocity higher than self-cleansing is not essential, because of solids are not present in suspension.	• To avoid deposition of solids in the pipes self-cleansing velocity is necessary at all possible discharge.
• It carries water under pressure. Hence, the pipe can be laid up and down the hills and the valleys within certain limits.	• It carries sewage under gravity. Therefore it is required to be laid at a continuous falling gradient in the downward direction towards outfall point.
• These pipes are flowing full under pressure.	• 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:

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

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

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

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

3. Crimp and Burge's Formula

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

4. Hazen- Williams Formula

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

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-William's 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:

$$Vs = \sqrt{\frac{8K}{f'}(Ss - 1)g.d'} \qquad (5)$$

Where,

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

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

Ss = 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 ½ to ¾ full, the velocity at 'designed discharge' (i.e., ½ to ¾ 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 $(\text{H.M.D.})^{2/3}$. 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.V

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

R = A/P

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.