Module 7:
Hydraulic Design of Sewers and Storm Water Drains

Lecture 9 :
Hydraulic Design of Sewers and Storm Water Drains (Contd.)

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 hr can be considered for design, all of which is contributing to surface runoff. What will be the discharge in the sewer in m^3/Sec? Find the diameter of the sewer if running full at maximum discharge.

Solution:

Total population of the area = population density x area

= 185 x 60 x 10^2

= 1110 x 10^3 persons

Average sewage flow = 350 x 11.1 x 10^5 Liters/day

= 388.5 x 10^6 L/day

= 4.5 m^3/sec

Storm water flow = 60 x 10^6 x (12/1000) x [1/(24 x 60 x 60)]

= 8.33 m^3/sec

Maximum sewage flow = 1.5 x average sewage flow

= 1.5 x 4.5 = 6.75 m^3/sec

Total flow of the combined sewer = sewage flow + storm flow

= 6.75 + 8.33 = 15.08 m^3/sec

Hence, the capacity of the sewer = 15.08 m^3/sec

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 and 0.06 for organic solids.

Solution

Minimum velocity i.e. self cleansing velocity

$$Vs = \sqrt{\frac{8k}{f'}(Ss-1)gd'}$$

$$Vs = \sqrt{\frac{8x0.04}{0.03}(2.65-1)x9.81x0.001}$$

= 0.4155 m/sec say 0.42 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 m

Hydraulic Mean Depth = D/4 = 0.4/4 = 0.1 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

Average water supplied = 80000 x 190 x (1/24 x 60 x 60 x 1000) = 0.176 m^3/sec

Sewage production per day, (considering 80% of water supply) = 0.176 x 0.8 = 0.14 m^3/sec

Maximum sewage discharge = 3 x 0.14 = 0.42 m^3/sec

Now for d/D = 0.7, q/Q = 0.838, v/V = 1.12

Therefore, Q = 0.42/0.838 = 0.5 m^3/sec

Now

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

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

Therefore, D = 0.78

V = Q/A = 1.04 m/sec

Now, v/V = 1.12

Therefore v = 1.12 x 1.04 = 1.17 m/sec

This velocity is less than limiting velocity hence, OK

Check for minimum velocity

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

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

For q/Q = 0.09, d/D = 0.23 and v/V = 0.65

Therefore, the velocity at minimum flow = 0.65 x 1.04 = 0.68 m/sec

This velocity is greater than self cleansing velocity, hence OK

d_{min} = 0.23 x 0.78 = 0.18 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 235 LPCD, n = 0.013, S = 1 in 600

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 that the full supply level (FSL) at no place 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 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 in to 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 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 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 in cm/h = 75/(t + 5).
2. Explain the importance of considering minimum and maximum velocity while designing the sewers.
3. Explain 'Selfcleansing 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.