UNIT 6 COLLECTION AND CONVEYANCE OF SEWAGE

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6.1 INTRODUCTION

Collection of wastewater is done by a sewerage system. Sewerage systems can be classified into combined sewerage and separate sewerage. Combined sewerage carries both stormwater and wastewater, while separate sewerage carries stormwater or wastewater separately. Recent trends have been for the development of separate sewerage systems. The main reason for this is that stormwater is generally less polluted than wastewater, and that treatment of combined wastewater and stormwater is difficult during heavy rainfalls, resulting in untreated overflows. In practice, there is usually ingress of stormwater into wastewater sewerage pipes, because of unsealed pipe joints, and unintentional or illegal connections of rainwater runoff.

The objective of a public wastewater collection and conveyance system is to ensure that sewage (or excreta and sullage) discharged from the communities is properly collected and transported to the treatment plant and disposed off without causing any public health and environmental problems. Stormwater and surface runoff can cause significant public health and environmental problems. Flooding, soil erosion, and water pollutants like fertilizers, pesticides, oil, organics and other substances are some of the major problems associated with uncontrolled stormwater and surface runoff. Increasing urbanization has increased the frequency and severity of these problems. It is, therefore, necessary to provide storm drains for the removal of excess water from the streets, parking lots, parks and gardens.

Major role of the sewer system can be listed as

- improvement in the living environment by removing and treating wastewater discharges,
- prevention of inundation by removing rainwater,
- preservation of water quality in public water areas, and
- essential element of the urban infrastructure in supporting wholesome and cultural urban life and urban activities.

Providing an adequate sewer system for the area requires careful engineering. It should be properly and skillfully planned and designed so as to transport the entire sewage effectively and efficiently from the houses and up to the point of disposal. The sewer must be adequate in size or they will overflow and cause property damage, danger to health and nuisance. Adequacy in size of sewers calls for correct estimation of the amount of sewage and use of hydraulics to determine proper size and grades of sewers, which will permit reasonable velocity of flow. This flow should neither be too large as to require heavy excavations and high lift pumping nor should it be too small to cause deposition of solids in sewer bottom with accompanying odours and stoppages.

In this unit, we will learn the procedures that are followed in the design of sanitary and storm sewer system.

Sewer appurtenances are devices essential, in addition to pipes and conduits, for the proper functioning of any complete system of sanitary, storm or combined sewers. These appurtenances include manholes, lampholes, flushing tanks, ventilation shafts, inverted siphons, inlets, catch basins, junction chambers, diversion chambers, tide gates and other structures or devices of special design.

Objectives

After studying this unit, you should be able to

- understand the components of a sewer system including appurtenances and materials,
- explain the preliminary considerations related with design of a sewer system, and
- design sanitary sewer and storm drainage systems.

6.2 ESTIMATION OF SANITARY SEWAGE

The sewer capacity to be provided must be determined from analysis of the present and future quantities expected. The estimation is based upon the contributory population and the per capita flow of the sewage and both the factors depend on the design period. The design period is defined as the length of time upto which the capacity of a sewer will be adequate. While deciding on design period, consideration must be given to the useful life of structures and equipment employed. A design period of 30 years (excluding construction period) is recommended for all types of sewers. The design population will have to be estimated considering all the factors influencing the future growth and development of the area in the industrial, commercial, educational, social, and administrative spheres. Special factors causing sudden immigration should also be accounted to the extent possible. Population forecast is frequently done based on past demographic data and applying an appropriate population forecast method, e.g. Arithmetical Increase, Incremental Increase, Geometrical Increase, or Logistic Method.

A detailed discussion on the population forecast is, however, beyond the scope of this unit. For new settlements, design flows can be calculated based on the design population and projected water consumption for domestic use and commercial and industrial activity. In case a master plan containing land use pattern and zoning regulation is available, the anticipated population can be based on the ultimate densities (Table 6.1).

Table 6.1 : Suggested Densities Based on the Size of Town (CPHEEO, 1993)

Sl. No	Size of Town (Population)	Density of Population per Hectare
1.	Upto 5,000	75-150
2.	5,000 to 20,000	150-250
3.	20,000 to 50,000	250-300
4.	50,000 to 100,000	300-350
5.	Above 100,000	350-1000

Knowledge of rates of wastewater flow is required in the hydraulic and process design of a wastewater treatment plant. Hydraulic design seeks to minimize overload problems (backups; flooding), while process design seeks to avoid inefficient operation (e.g. insufficient substrate or insufficient retention). The design must accommodate the variation in domestic wastewater flow rates and the associated waste load (BOD, SS), which occurs over the day. Flow rates are low after midnight when little domestic wastewater is discharged. At that time, a substantial part of the dry weather flow is infiltration and sewage strength is weak. Flow rates increase in the morning as water demand rises and reaches its peak again in the evening at bedtime. There is also a dramatic difference in wastewater flows in dry versus wet periods.

Design flows are best determined from field measurements of wastewater flows. Sanitary sewage is mostly the spent water of the community draining into sewer system with infiltration of some ground water and a fraction of stormwater from the area. Where actual flow rates are not available, rates may be estimated from water use records. About 40-90% of the per capita consumption of water becomes wastewater, since some water is lost due to evaporation, seepage into ground, leakage etc. In arid regions, mean sewage flows may be as little as 40% of water consumption. In well-developed areas the flows may be as high as 90%. Generally, 80% of the water supply may be expected to reach the sewers. However, the sewers should be designed for a minimum wastewater flow of 100 litres per capita per day.

Estimate of flow in sanitary sewers may include certain flows due to infiltration of groundwater through joints. Since sewers are designed for peak discharges, allowances for groundwater infiltration for the worst condition in the area should be made (refer Table 6.2).

Table 6.2 : Ground Water Infiltration (CPHEEO, 1993)

Units	Minimum	Maximum
Liters/ha.d	5,000	50,000
Liters/km.d	500	5,000
Liters/d/manhole	250	500

With improved standards of workmanship and quality and availability of various construction aids, these values tend to minimum rather than the maximum.

The flow in sewers varies from hour to hour and also seasonally. But for the purpose of hydraulic design estimated peak flows are adopted. The peak factor or the ratio of maximum to average flows depends upon contributory population (Table 6.3).

Table 6.3 : Peak Factor for Contributory Population (CPHEEO, 1993)

Contributory Population	Peak Factor
up to 20,000	3.00
20,000 to 50,000	2.50
50,000 to 7,50,000	2.25
above 7,50,000	2.00

The peak factors also depend upon the density of population, topography of the site, hours of water supply and, therefore, individual cases may be further analysed if required. The minimum flow may vary from 1/3 to 1/2 of average flow.

6.3 ESTIMATION OF STORM RUNOFF

Storm runoff is that portion of the precipitation, which drains over the ground surface. The design of stormwater sewers begins with an estimate of the rate and volume of surface runoff. When rain falls on a given catchments, a part of the precipitation is intercepted by the vegetation cover which mostly evaporates, some part hits the soil and some of it percolates down below and the rest flows on ground surface. Estimation of such runoff reaching the storm sewers is dependent on intensity and duration of precipitation, characteristics of the tributary area and time required for such flow to reach the sewer. More the intensity of rain, the higher will be the peak runoff rate.

The characteristics of the drainage area such as imperviousness, topography including depressions and water pockets, shape of the drainage basin and duration of the precipitation determine the fraction of the total precipitation, which will reach the sewer. This fraction is known as the coefficient of runoff.

The time period after which the entire area begins contributing to the total runoff, at a given monitoring point, is known as the *time of concentration,* vis-a-vis, that point – it is also obviously defined as the time it takes a drop of water to flow from hydraulically most distant point of the basin to the outlet of the basin. The duration of rainfall that is equal to the time of concentration is known as the *critical rainfall duration.* The rational formula expresses the relationship between peak runoff, and rainfall, as follows :

$$Q = 10 . C . i . A$$

where Q = Runoff in m^3/hr,

C = A dimensionless runoff coefficient,

i = Intensity of rainfall in mm/hr, and

A = Area of drainage district in hectares.

It may be reiterated that Q represents only the maximum discharge caused by a particular storm.

The portion of rainfall, which finds its way to the sewer, is dependent on the imperviousness and the shape of the drainage area apart from the duration of storm. The percent imperviousness of the drainage area can be obtained from the records of a particular district. In the absence of such data, Table 6.4 below may serve as a guide.

Table 6.4 : Percentage of Imperviousness for Various Areas (CPHEEO, 1993)

Sl. No	Type of Area	Percentage of Imperviousness
1.	Commercial and Industrial Area	70-90
2.	Residential Area	
	High Density	60-75
	Low Density	35-60
3.	Parks and Undeveloped Areas	10-20

When several different surface types or land use which comprise the drainage area, a composite or weighted average value of the imperviousness runoff coefficient can be computed, such as :

$$I = \frac{1}{A} \times (A_1 \times I_1 + A_2 \times I_2 + A_3 \times I_3 + \ldots + A_n I_n)$$

where the subscripts refer to respective sub-drainage area types, and A obviously is the total drainage area.

The weighted average runoff coefficients for rectangular areas of length four times the width as well as for sector shaped areas with varying percentages of impervious surface for different time of concentration are given in Table 6.5. Although these are applicable to particular shape areas, they also apply in a general way to the areas, which are usually encountered in practice. Errors due to difference in shape of drainage are within the limits of accuracy of the rational method and of the assumptions on which it is based.

Table 6.5 : Runoff Coefficients (CPHEEO, 1993)

Duration, *t*, minutes →	10	20	30	45	60	75	90	100	120	135	150	180
Weighted Average Coefficient ↓												
1. **Sector Concentrating in Stated Time**												
(a) Impervious	0.525	0.588	0.642	0.700	0.740	0.771	0.795	0.813	0.828	0.840	0.850	0.865
(b) 60% Impervious	0.365	0.427	0.477	0.531	0.569	0.598	0.622	0.641	0.656	0.670	0.682	0.701
(c) 40% Impervious	0.285	0.346	0.395	0.446	0.482	0.512	0.535	0.554	0.571	0.585	0.597	0.618
(d) Pervious	0.125	0.185	0.230	0.277	0.312	0.330	0.362	0.382	0.399	0.414	0.429	0.454
2. **Rectangle (Length = 4 × Width) Concentrating in Stated Time**												
(a) Impervious	0.550	0.648	0.711	0.786	0.808	0.837	0.856	0.869	0.879	0.887	0.892	0.903
(b) 50% Impervious	0.350	0.442	0.499	0.551	0.590	0.618	0.639	0.657	0.671	0.683	0.694	0.713
(c) 30% Impervious	0.269	0.360	0.414	0.464	0.502	0.530	0.552	0.572	0.588	0.601	0.614	0.636
(d) Pervious	0.149	0.236	0.287	0.334	0.371	0.398	0.422	0.445	0.463	0.479	0.495	0.522

6.4 STORM SEWER SYSTEMS

Storm drainage system is put in place to convey surface runoff to the designated point of storage, or disposal. Storm drainage system is allowed to periodically surcharge and overflow causing local flooding, with a predictable recurrence interval. It is the result of having selected a storm return period for estimating the magnitude of corresponding peak flow, and then basing the size of the pipeline on this data. Sanitary sewers, on other hand, are designed to carry a peak flow for a given projected population; and, thus, without overflowing. However, it may be mentioned that a sanitary sewer may overflow sometimes due to excessive inflow of ground or surface water because of poor construction or maintenance. Storm sewers are usually having a much larger diameter than the separate sanitary sewers for the same area that they serve – it is so because storm sewers have to be sized to carry larger peak flows, though these carry no flow during dry weather season. Further, storm sewers are placed at shallow depths to minimize excavation: whereas, sanitary sewers are placed in relatively deeper trenches to accommodate service connection.

6.4.1 Layout and Design

A stormwater collection system (also referred to as storm sewage) is a network of inlets, and pipes that are laid along the street, etc. The usual location of the sewers is near the kerb/edge of the pavement – it allows connecting the inlet boxes with fewer manholes and using less pipe lengths. Drains carrying stormwater are laid to produce gravity flow to the designed water body, or a storage facility or as in some instances to a special treatment unit. Installation of a pumping facility is, in the first instance, avoided due to a very large peak flow capacity required to deal with maximum stormwater flow.

Storm sewers are generally made of circular reinforced concrete pipes. Sometimes elliptical sections are used when the depth of pipe (from the ground) is very shallow, in order to achieve ease for covering the pipe with soil over the minor axis of the pipe. Other material for storm pipes can also be used, such as, corrugated metal pipes.

6.4.2 Inlets

In a stormwater system, an inlet is a device (a structure) that intercepts the surface runoff, and directing it into the underground sewer system. Apart from their appropriate location and spacing, inlets should be provided with sufficient capacity to entrap and direct surface water as fast as possible with a view to avoid backups on the ground surface after taking into account factors like clogging, nuisance to traffic, hydraulic capacity, and desired safety. It is within this context that flooding across street intersections is avoided.

There are three basic types of inlets that are in use, such as, kerb inlets, gutter (or grate) inlets and combined inlets. A kerb inlet has a vertical opening along the kerb itself. It is through this opening that the runoff flow finds entry into the sewer system. With reference to child safety the kerb opening should be less than 150 mm high, which, however, limits the intake capacity of the inlet. A gutter inlet is a horizontal opening provided directly in the pavement itself; and, it is covered with cast iron grating to obstruct the entry of large-size debris. The gutter type inlet, however, obstructs the smooth flow of traffic (particularly bicycles, etc.), and the grating is subject to being plugged with debris.

A combination inlet incorporates both a kerb and a gutter opening in its design. The gutter grating can be depressed to gain additional hydraulic capacity. The combination inlet is, obviously, the least subject to the menace of clogging.

If the drain invert happens to be above the bottom of the inlet basin, then this inlet basin is termed *catch basin*. In fact, the catch basin is meant to trap the grit, sand and leaves etc. that may be washed into it. Sometimes catch basins are discouraged to be incorporated as a feature of stormwater collection design due to requirement for periodic cleaning, odour menace and mosquito problem, and, therefore, only inlet basins are adopted as the design feature of the collection system at the inlet point. Appropriate design, and adopting self-cleansing drain slopes would in that case maintain the collection system free from blockage problems.

6.4.3 Stormwater Detention

The modem stormwater strategy favours a temporary engineered storage of water in the basin in preference to immediate conveyance to the nearest designated water body or any other outfall point. It is obvious that this storage is over and above the natural detention that does take place in any given basin. It has been observed that ponding of rainwater by design on rooftops, or over parking lots, of course for a short duration, does amount to enough storage so that the peak runoff rates are reduced perceptibly. In this context, it may be pointed out that the physical features of roughness elements in a channel section, such as grass-line open drainage channels, are important to retard the flow of stormwater, thus contributing to the on-site stormwater detention in the form of valley storage.

The concept of constructing smaller reservoirs to detain, for sometime, water coming from streets, parking lots, etc., and then releasing under controlled conditions as required is gaining growing acceptance. These devices are best suited to manage the runoff from relatively short and intense local storms that would otherwise cause frequent flooding and severe erosion, with the consequent effects. Some particular benefits of stormwater storage through engineered detention can be listed as under :

(a) Peak runoff rates are reduced.

(b) Both the frequency and severity of flooding are attenuated.

(c) Surface water quality is maintained to a satisfactory standard.

(d) Sedimentation in streams gets reduced due to reduction of soil erosion.

(e) While water stands detained, the chances of recharge of acquifer increase; however, much depends on the permeability of the soil.

However, the on-site stormwater detention basins need to be looked after for appropriate maintenance. They are subject to sedimentation and deposition of debris being the first stop that is applied on the surface flow; and their outlet structures, therefore, generally get easily clogged. Another problem relates to weed control and breeding of mosquitoes in stagnant waters; moreover, the safety of children of the locality cannot be left unattended. The beneficiaries must be motivated to share the responsibility of maintenance; or any appropriate agency, like area municipality, can attend to this aspect. A storage basin may retain water for all the time (i.e. with no outlets provided) forming a permanent pond, and can also be harnessed to provide aesthetic and recreational advantages to the community. Such storage is known as *retention basin.* There is a third type of storage structure, namely, *recharge basin* that allows the stored stormwater to percolate into the underlying aquifer, and thus recharging and replenishing the ground water reserves in addition to the primary function of controlling the storm runoff. It is, however, understood that the underlying soil must be permeable to an appropriate degree for relatively rapid infiltration. It is helpful if the seasonal high water table is at least 0.5 m below the bottom of the tank.

SAQ 1

(a) What are the basic components of sanitary sewer system?

(b) Distinguish between sanitary sewer and storm drainage system.

6.5 DESIGN OF SEWER SYSTEM

We now know that sanitary sewers are designed to carry domestic wastes originating from the sanitary conveniences of dwellings, business buildings, factories or institutions including industrial wastes produced in the area that these serve. Whereas storm sewers carry surface runoff developed during or following the period of rainfall over concerned area including street wash. In sanitary sewer system, lateral sewer collects discharges from houses and carries them to another branch sewer, and has no tributary sewer lines. Branches or sub-main lines receive waste-water from laterals and convey it to large mains. A main sewer, also called trunk or outfall sewer, carries the discharge from large areas to the treatment plant. Manholes are provided at intersection of sewer lines and also at regular intervals to facilitate regular inspection and cleaning. Surface waters enter a storm drainage system through inlets located in street gutters or depressed areas that collect natural drainage. Catch basins under street inlets are connected to the main storm sewer located in the street right-of-way, often along the centre line, by short pipelines. Since no house connections are required, the storm sewers may not depend upon the individual lots, and this may permit them to be run by shorter routes than that of sanitary sewers. Pipelines gradients follow the general slope of the ground surface such that water entering can flow downhill to a convenient point for discharge. Storm sewer pipes are set shallower as compared to sanitary sewers as far as possible.

A major difference in design philosophy between sanitary and storm sewers are that the latter are assumed to surcharge and overflow periodically. For example, a storm drain sized on the basis of a ten-year rainfall frequency presumes that one storm every ten years will exceed the capacity of the sewer. However, sanitary sewers are designed and constructed to prevent surcharging. Where backup of sanitary sewers does occur, it is more frequently attributable to excess infiltration of ground water through open pipe joints and unauthorized drain connections. A second easily recognizable difference between sanitary and storm sewers is the pipe sizes that are needed to serve a given area. Storm drains are larger than the pipes collecting domestic wastewater. Consequently, only a small amount of infiltrating rain water results in overloading domestic sewers.

6.5.1 Flow in Sewers

The flow in sewers varies widely from hour to hour and also seasonally. The flow in sewer is said to be steady, if the rate of discharge at a point in a conduit remains constant with time, and if discharge varies with time, it is unsteady. If velocities and depth of flow are same from point to point along the conduit, the steady open channel is said to be uniform flow, and non-uniform if either the velocity, depth or both are changing.

For the purpose of hydraulic design of sewers following assumptions are made :

(a) The flow of wastewater in its sewers is steady and uniform. The unsteady and non-uniform waste water flow characteristics are accounted in the design by proper sizing of manholes.

(b) The available head in waste water lines is utilized in overcoming surface resistance and, in small part, in attaining kinetic energy for the flow.

(c) The designs of sewers are based on Peak Flow Discharge.

Flow Formulae

It is the design practice to use the Manning's formula for open channel flow and the Hazen-Williams formulae for closed conduit or pressure flow.

Manning's Formula

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

For circular conduits

$$V = \frac{1}{n} \times 3.968 \times 10^{-3} \times D^{2/3} \times S^{1/2}$$

$$Q = \frac{1}{n} \times 3.118 \times 10^{-6} \times D^{2/3} \times S^{1/2}$$

where, Q = Discharge in litres per seconds,

S = Slope of hydraulic gradient,

D = Internal diameter of pipe line in mm,

R = Hydraulic radius in metre,

V = Velocity in metre per seconds, and

n = Manning's coefficient of roughness.

Hazen-Williams Formula is expressed as follows :

$$V = 0.849 \times C \times R^{0.63} \times S^{0.54}$$

For circular conduits, the expression becomes

$$V = 4.567 \times 10^{-3} \times C \times D^{0.63} \times S^{0.54}$$

and $$Q = 3.1 \times 10^{-4} \times C \times D^{2.63} \times S^{0.54}$$

where, Q = Discharge in kilo litre per day,

D = Internal diameter of pipe in mm,

V = Velocity in metre per seconds,

R = Hydraulic radius in metre,

S = Slope of hydraulic gradient, and

C = Hazen-Williams coefficient.

The Charts based on Manning's and William Hazen formulae for circular pipe flowing full is mostly used in design work. Given any two values of four parameters (quantity of flow, diameter of pipe, slope of pipe or velocity) the remaining two can be determined. *Manual on Sewerage and Sewage Treatment* may be referred for design calculations.

6.5.2 Velocities

At the time of design it is to be ensured that a minimum velocity is maintained in the sewers during minimum flow conditions so that no solid gets deposited in the sewer and at the same time the velocity should not be excessive to cause erosion in sewer pipes.

Velocity at Minimum Flow

In order to prevent settlement of sewage solids, the sewers are designed for minimum flow velocity. The minimum velocity at which no solid gets deposited at the bottom of sewer is called *self cleansing velocity.* The self cleansing velocity in sewer is determined by Shields formula :

$$V = \frac{1}{n} \times R^{2/3} \times (K_S \times (S_S - 1)\ d_p)^{1/2}$$

In which

S_s = Specific gravity of particle,

d_p = Particle size,

K_s = A dimensionless constant with a value of about 0.04 to start motion of granular particles and about 0.8 for adequate self cleansing of sewers,

R = Hydraulic radius of the sewer, and

n = Manning's coefficient.

The Shields formula indicates that velocity required to transport material in sewers is only slightly dependent on conduit shape and depth of flow but mainly dependent on the particle size and specific weight. It is a practice to design sewer for self cleansing velocity at ultimate peak flow to be achieved at the end of design period. This is done on the assumption that although silting might occur at minimum flow, but the same would be flushed out during the peak flow.

Limiting Velocity

Excessive velocity of flow may cause erosion of sewer pipe. Therefore, it is usually limited to 3.0 metre per second.

Depth of Flow

From considerations of ventilation in wastewater flow, sewers are designed to flow 0.8 full at ultimate peak flow.

SAQ 2

(a) Write importance of following in the design of sewer :

  (i) Self cleansing velocity

  (ii) Limiting velocity

(b) A 600 mm sewer pipe, $n = 0.013$, is placed on a slope of 0.002. At what depth of flow does the velocity of flow equals to 0.60 m/second.

(c) If a 250 mm sewer pipe, $n = 0.013$, is placed on a slope of 1 in 150, what would be the velocity and discharge when sewer is flowing at 0.20 and 0.80 of its full depth respectively.

6.5.3 Design Procedure of a Sewer System

The design of sewer system entails preliminary investigations, detailed survey, the actual design, and preparation of final drawings and correction of plans to confirm changes made, during the construction. In the design of a sewer system, the decisions are location, size, its grade, depth of sewer, sewer material and other appurtenances to be added such as manhole, junctions and other structures to minimize turbulence and save-head losses and prevent deposits. The aim of design is not only to make the sewer system functional, but also build the system at lowest cost ensuring durability over the life of the system.

Preliminary Investigation Design of Sewer System

The anticipation of future growth in any community in terms of population or commercial and industrial expansion forms the basis for preparation of plan for providing the amenities including installation of sewers in the area to be served. The anticipated population, its density and its waste production is generally estimated for a specified planning period. The manual on sewerage and sewage treatment recommends this period as 30 years, however this may also vary depending upon the local conditions. The prospective disposal sites are selected and their suitability is evaluated with regard to physical practicability for collection of sewage, effects of its disposal on surrounding environment and cost involved.

Detailed Survey

The presence of rock or underground obstacles such as existing sewers, water lines, electrical or telephone wires, tunnels, foundations etc. have significant effect upon the cost of construction. Therefore, before selecting the final lines and grades for sewers necessary information regarding such constructions is collected from various central and state engineering departments.

Besides the location of underground structure, a detailed survey regarding paving characteristics of the streets, the location of all existing underground structures, the location and basement elevations of all buildings, profile of all streets through which the sewer will run, elevations of all streams, culverts, and ditches, and maximum water elevations therein are also made. The above details are noted on the map. The scale of the map may vary depending upon the details desired.

Manual on Sewerage and Sewage Treatment recommends the following scales for various plans and drawings depending upon the detailed information desired.

(a) Index Plan – 1 : 100,000 or 1 : 200,000

(b) Key Plan and general layout – 1 : 10,000 or 1 : 20,000

(c) Zonal Plans – 1 : 2,500 or 1 : 5,000

(d) Longitudinal sections of sewers – 1 : 500 or 1 : 2,250 or 1 : 2,500

(e) Structural drawings – 20 or 1 : 50 or 1 : 100 or 1 : 200

Layout of System

The sewer system layout involves the following steps :

(a) Selection of an outlet or disposal point.

(b) Prescribing limits to the drainage valley or zonal boundaries.

(c) Location of trunk and main sewers.

(d) Location of pumping stations if found necessary.

A tentative layout is prepared by drawing sewer lines along the streets or utilities easements. Arrows show the direction of flow, which is generally the direction in which ground slopes. The disposal point may be a treatment plant or a pumping station or a watercourse, a trunk or intercepting sewer. It is desirable to have discharge boundaries following the property limits. The boundaries of sub zones are selected on the basis of topography, economy or other practical consideration. Trunk and main sewers are located in the valleys.

The most common location of sanitary sewer is in the centre of the street. A single sewer serves both sides of the street with approximately same length for each house connection. In very wide streets, it may be economical to lay a sewer on each side of the street adjacent to curb or under the footpath. Manholes are provided at all sewer intersections, changes in horizontal direction, major change in slopes, change in size and at regular intervals. These manholes are numbered as per the method described in the nomenclature.

The vertical layout is dictated by the need to provide minimum cover and the desirability of minimum excavation depending upon the pipe size and expected loads. It is design practice to provide a minimum cover of 1 m at the starting point in the case of sanitary sewer network and 0.5 m for storm drainage system.

If the sewer changes direction in a manhole without change of size, a drop of usually 30 mm is provided in the manhole. If the sewer changes size, the crown of inlet and outlet sewers are set at same elevation. The vertical drop may be provided only when the difference between the elevations is more than 600 mm or more. The following invert drops are recommended by *Manual on Sewerage and Sewage Treatment* (CPHEEO, 1993) :

(a) For sewers less than 400 mm : Half the difference in diameter.

(b) 400 mm. to 900 mm : 2/3 the difference in diameter.

(c) Above 900 mm : 4/5 the difference in diameter.

For storm sewer, similar procedure is adopted except lines are considered to run from inlet to inlet. Since inlets are generally at corners, the storm sewer run normally from corner to corner. Area tributary to each inlet is noted according to ground contours in the plan.

Sewers as a design practice are not located in proximity to water supplies. When such situations are unavoidable, the sewers should be encased in sleeve pipes or encased in concrete. Tees or Yees should be provided for all house connections both for present and future locations so as to avoid breaking a hole into the side of a sewer.

Nomenclature

The following procedure is recommended for the nomenclature of manholes and sewers.

(a) First distinct number such as 1, 2, 3 etc., is allotted to the manholes of the trunk sewers commencing from the lower end (outfall end) of the line and finishing at the top end.

(b) Manholes on the mains or sub-mains are again designated as numbers 1, 2, 3, etc., prefixing the number of the manhole on trunk/main sewer where they join. Similar procedure is adopted for the branches to branch main.

(c) If two branches, one on each side meeting the main sewer or the branch sewer, *letter* '*L*' (to represent left) or letter '*R*' (to represent right) is prefixed to the numbering system, depending on the direction of flow.

(d) If there is more than one sewer either from the left or right, they are suitably designated as *L*1, *L*2, *L*3, or *R*1, *R*2, *R*3, the subscripts refer to the line near to the sewer taking away the discharge from the manhole.

For example, in Figure 6.1, *L*2 *R* 3.1.2 represents the second manhole on sub-main (*L*2) through which flow reaches manhole 3.1 of the main sewer, located right side of the manhole number 3 of the trunk sewer. The first numeral (from the left) is the number of the manhole on the trunk sewer. The numerals on the right of this numeral, in order, represent the manhole numbers in the main, sub-main etc., respectively. The first letter immediately preceding the number denotes the main and that it is to the right of the trunk sewer. Letter to the left in their order represent sub-main, branch respectively. The same nomenclature is used for representing the section e.g. Section, *L*2 *R* 3.2.2 identifies the section between the manhole *L*2 *R* 3.2.2 and the adjoining downstream manhole.

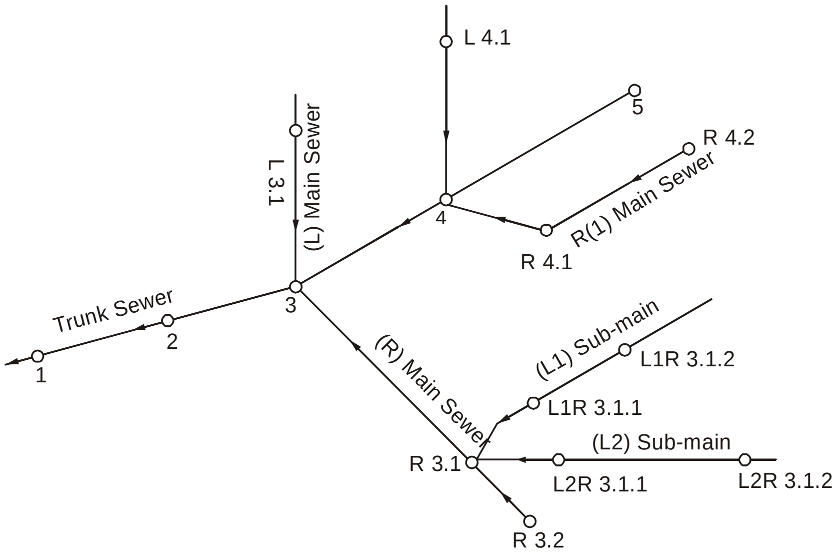


Figure 6.1 : Nomenclature of Sewers

The Profile Design of Sewer System

The vertical profile is drawn from the survey notes for each sewer line. Longitudinal section is indicated with reference to the same datum line. The vertical scale of the longitudinal sections are usually magnified ten times the horizontal scale. The profile shows ground surface, tentative manhole locations, grade, size and material of pipe, ground and invert levels and extent of concrete protection etc. At each manhole the surface elevation, the elevation of sewer invert entering and leaving the manhole, are generally listed. Figure 6.2 describes the profile of a typical sanitary sewer.

Design Approach

For design of sewer network, the slope and diameter of sewers should be decided to meet the following two conditions:

(a) A self-cleansing velocity is maintained at present peak flow.

(b) A sewer runs at 0.80 full at ultimate peak flow.

Since the sewer network design computations are repetitive and hence it can be easily done by tabular form or by using suitable computer software programmes.

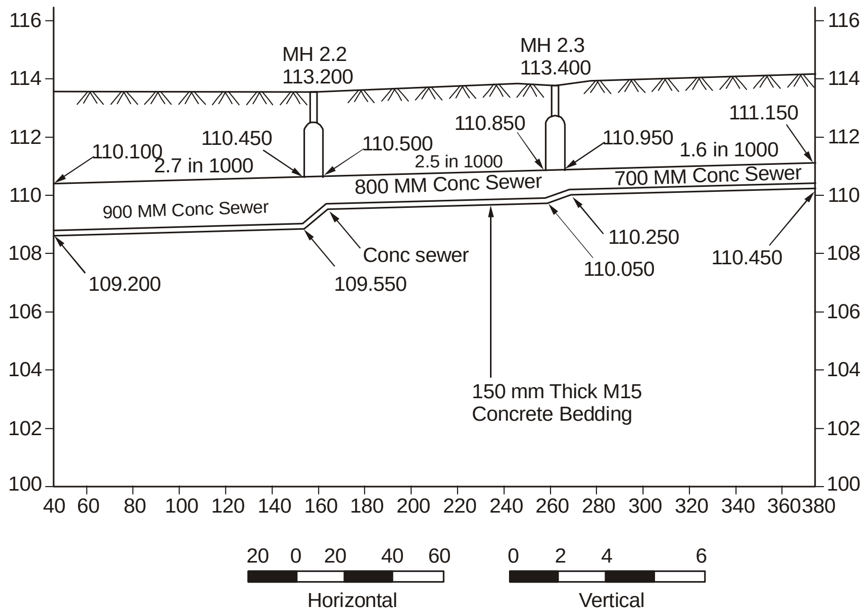


Figure 6.2 : Profile of a Sanitary Sewer

SAQ 3

(a) Which one is correct statement?

(i) Whenever two-sewer meet at one point, main sewer is the smaller incoming sewer.

(ii) In general, sewer does not slope in the same direction in which ground surface slopes.

(iii) Manholes are generally located at all points where sewer transition occurs.

(iv) The vertical scale adopted in plotting of sewer profile is usually 10 times of the horizontal scale.

(v) If a sewer changes direction in manhole without change in size, a drop of 30 mm is usually provided.

(vi) If a sewer changes size, the crowns of inlet and outlet sewers should not have same elevation.

(b) Write two conditions on which design of sewer network is decided.

6.5.4 Illustrative Example on the Design of Sanitary Sewer System

Design a system of sanitary sewers for the given area shown in the Figure 6.3 with the following details :

(a) Population density : 300 persons/hectare.

(b) Water supply : 250 litre per day/head (ultimate).

(c) Maximum rate of infiltration : 20,000 litre per day/hectare.

(d) Minimum depth of cover to be provided over the crown of the sewer : 1.0 m.

(e) Minimum velocity in sewer at peak flow : 0.6 m per second.

(f) Maximum velocity in sewer : 6.0 m per second.

(g) Minimum size of the sewer : 150 mm.

(h) Waste water reaching sewers : 90% of water supply.

(i) Peak flow : 3.5 × Average flow.

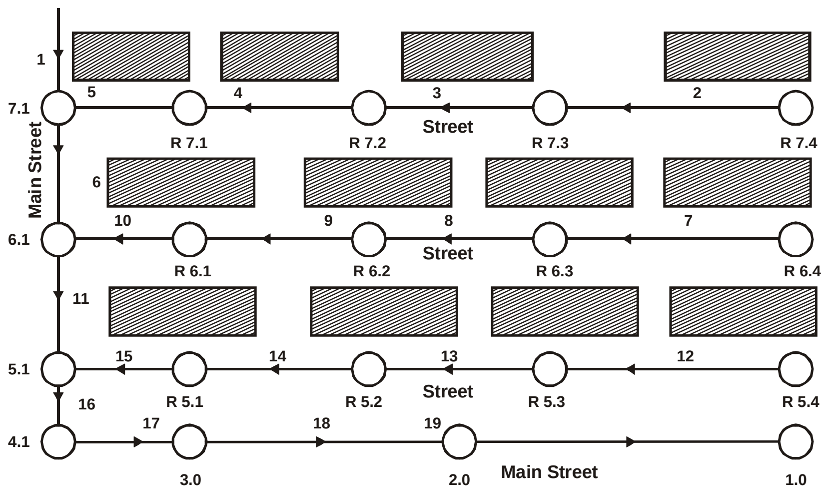


Figure 6.3 : Sanitary Sewer System

Solution

(a) Place the lines on map to represent proposed sewers with arrow indicating assumed direction of flow.

(b) Locate the manholes giving each an identification number as described in the nomenclature of this unit.

(c) Determine the area tributary to each lateral.

(d) Prepare a table showing computational details of each sewer between manholes.

Design Calculations

Design proceeds from the most remote point of the system downward. Where a branch joins a line already designed, a new design is started at the upper end of the completed intersection. Table 6.6 gives the various components of sanitary sewer system design.

Columns 1-6	Describe the location of sewer manholes and length of sewer lines between the manholes for a particular line.
Column 7	Reads the corresponding area increment of sewer section and their sum is entered in column 8, e.g. Tributary Area of line 3 = Tributary Area of Line 2 + Area of Line 3.
Column 9	Gives the population served by each sewer line. This is obtained by multiplying column 8 with population density (300).
Column 10	Gives the sewer flow (million litre per day) through each line, i.e. sewer flow in sewer line = 250 × 0.9 × column 9 × 10^{-6}
Column 11	Shows ground water infiltration for each area in million litre per day = 20,000 × 10^{-6} × column 8
Column 12	Records Peak flow = column 10 × 3.5 + column 11
Column 13	Gives peak flow in litre/second = column 12 × 10^6/(24 × 3600).
Columns 14-15	Indicate the diameter and slope of the pipes determined from Manning's chart for each flow and maintaining a minimum flow velocity of 0.6 m/sec. A number of slopes is to be tried before a satisfactory velocity is obtained.
Columns 16-17	Provide the velocity and discharge through pipe under flowing full condition respectively. This is determined from Manning's chart for selected diameter and slope of pipe.
Column 18	Provides ratio of actual discharge to the full discharge = (Column 13)/(Column 17)
Column 19	Calculates the ratio of actual velocity to the velocity at full discharge with the help of hydraulic element curve for circular pipe given in "*Manual for Sewerage and Sewage Treatment*".
Column 20	Gives actual velocity of flow in metre per second = column 19 × column 16
Column 21	Provides fall for given slope and length of pipe = column 6 × column 15
Columns 22-23	Indicate the invert levels. Please note that invert elevation at lower end of line is same as that at upper end of next line except where there is a change of size or direction. For example, in manhole 7 the lower end of line 5 is upper end of line 6, above the manhole, diameter of line 1 is 200 mm. Trial indicates that a 200 mm pipe would require a slope steeper than ground to carry a flow of 27.67 lps in line 6. Since the sewer invert of line 5 is lower than dictated by minimum cover, a larger sewer pipe of 250 mm diameter is used on a lower slope. Since a change in size occurs the crown of intersecting sewers are matched. The crown of line 5 is 55.755 (Invert elevation + Diameter = 55.605 + 105); that of line 1, is at 56.145. Therefore, crown of line 6 must be at 55.755 giving an invert elevation of 55.505 : Manholes number 6.0 and 5.0 are handled in a similar fashion. At manhole 4.0 there is change in direction but no change in pipe size, the invert is dropped by 30 mm across the manhole.

Table 6.6 : Design of Sanitary Sewer System

6.6 MANHOLES

A manhole is an opening constructed on the alignment of a sewer to facilitate access into the sewer. A typical manhole for a lateral sewer is shown in Figure 6.4. Their principal purpose is to permit inspection (including sampling and flow measurement), cleaning, repair and removal of any obstructions. Manholes are located over the pipe centerline under the circumstances :

(a) when there is a change in the pipeline diameter,

(b) when there is a change in pipeline slope,

(c) when there is a change in pipeline direction,

(d) at all pipe intersections, and

(e) at the uppermost end of each lateral.

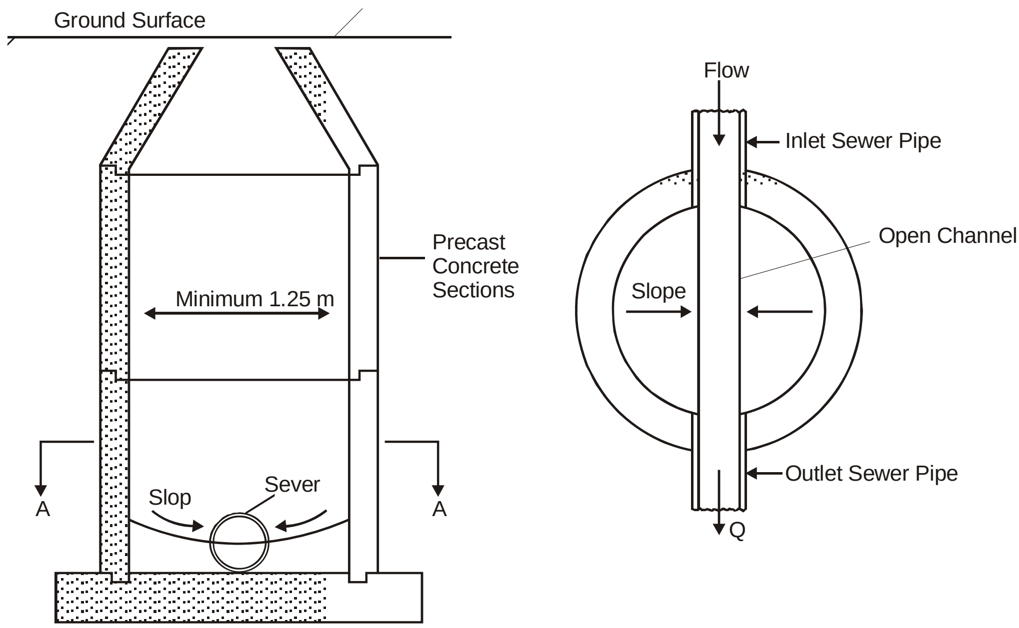


Figure 6.4 : Sectional View of Lateral Sewer Manhole

On sewers, which are to be cleaned manually, which cannot be entered for cleaning or inspection, the maximum distance between the manholes should be 30 m. The spacing of manholes on large sewers above 900 mm diameter is governed by the following for the sewers to be cleaned manually.

(a) The distance upto which silt or other obstruction may have to be conveyed along the sewer to the nearest manhole for removal.

(b) The distance upto which materials for repairs may be conveyed through the sewer.

(c) Ventilation requirements for men working in the sewer.

For sewers, which are to be cleaned with mechanical devices, the spacing of manholes will depend upon the type of equipment to be used for the cleaning. The spacing of manholes above 90 to 150 m may be allowed on straight runs for sewers of diameters 900 to 1500 mm. Spacing of 150 to 200 m may be allowed on straight runs for sewers of 1.5 to 2.0 m diameter, which may be increased upto 300 m for sewers of over 2m diameter. A spacing allowance of 100 m per 1 m diameter of sewer is a general rule in case of very large sewers.

Manholes are directly constructed over the central line of the sewer. They are circular, rectangular or square in shape. Circular manholes are stronger and provide easier access as compared with other types of manholes and hence generally preferred. The inside dimension should be sufficient to perform the necessary operations regarding inspection and cleaning without difficulty. The inside diameter of circular manholes may be kept as given in Table 6.7 below.

Table 6.7 : Inside Diameter of Circular Manholes v/s Depth (CPHEEO, 1993)

Depth (m)	Diameter (mm)
0.90 m – 1.65	900
1.65 m – 2.30	1200
2.30 m – 9.0	1500
9.0 m – 14.0	1800

Note : The dimensions of the manhole should not be less than internal diameter of the sewer + 150 mm benching on both sides (150 mm + 150 mm).

When the width of the sewer does not exceed the width of the manhole, the manhole is usually constructed directly over the centre line of the sewer. For better accessibility, the manhole, for very large sewers, may be centered over the sewer with a landing platform offset from an opening into the sewer itself. Consideration must be given to the need for the introduction of cleaning equipment into the sewer.

The opening into the manhole must enable a man to gain access to the interior without difficulty. Typical manholes of the types used by many municipalities are shown in Figures 6.5 to 6.8.

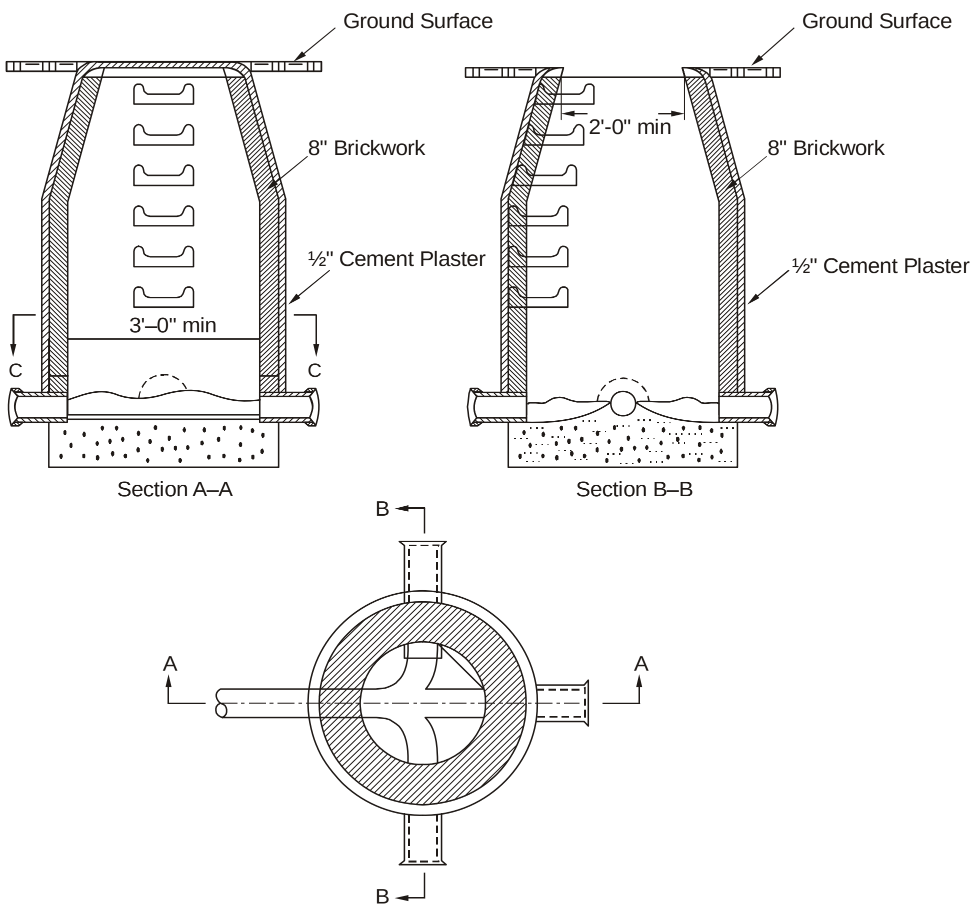


Figure 6.5 : A Typical Manholes

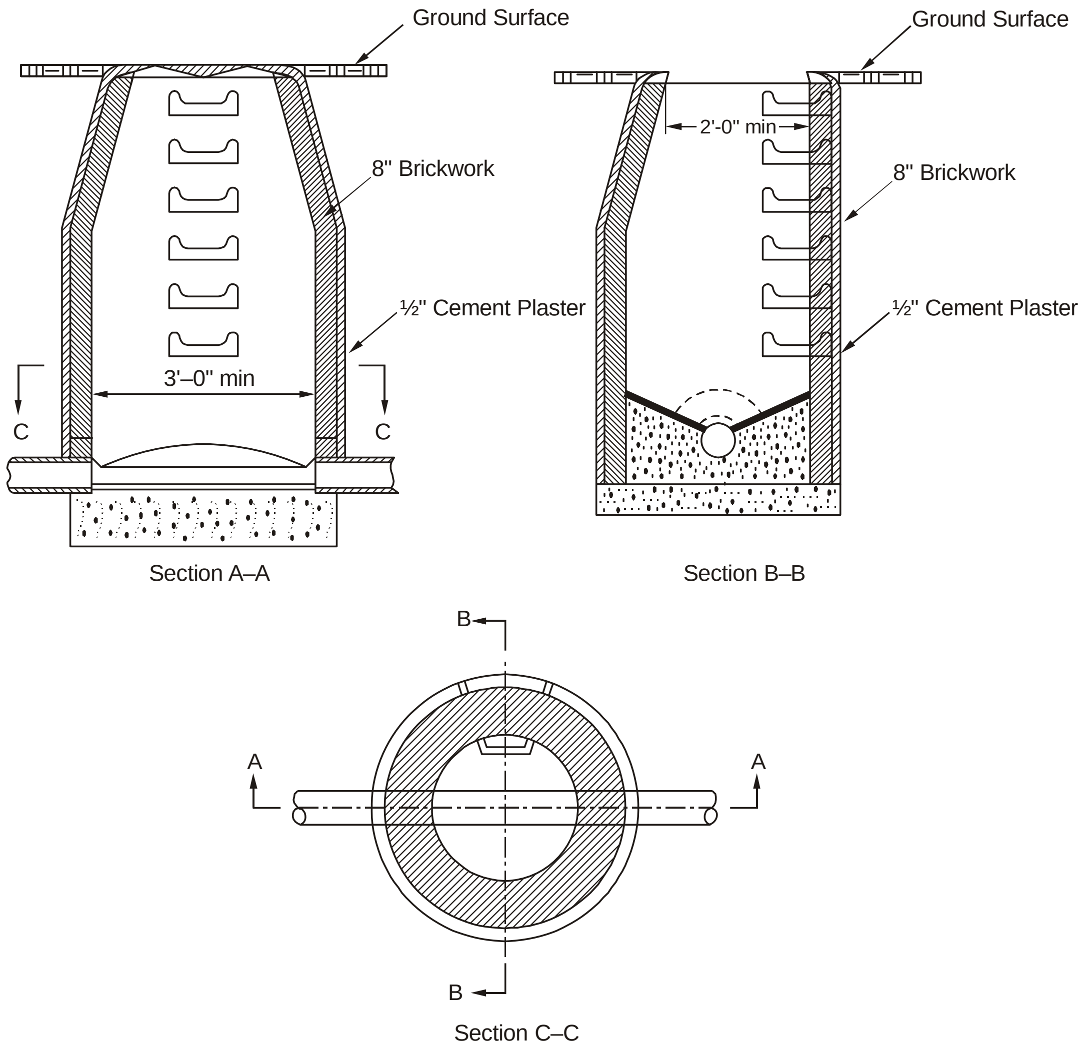


Figure 6.6 : A Typical Manholes with Vertical Side

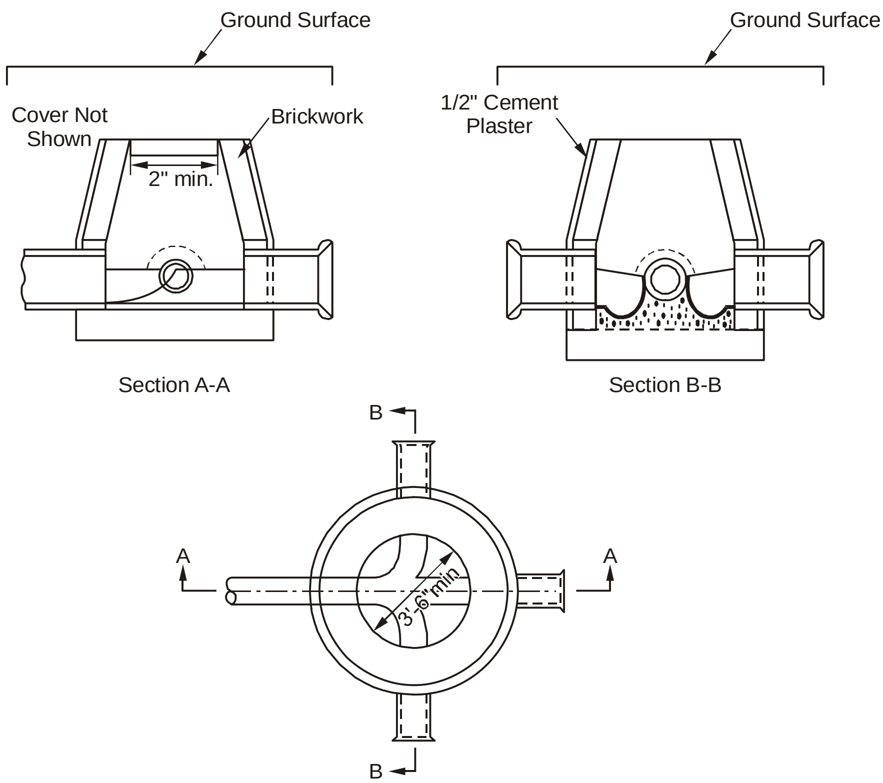


Figure 6.7 : A Shallow Manhole

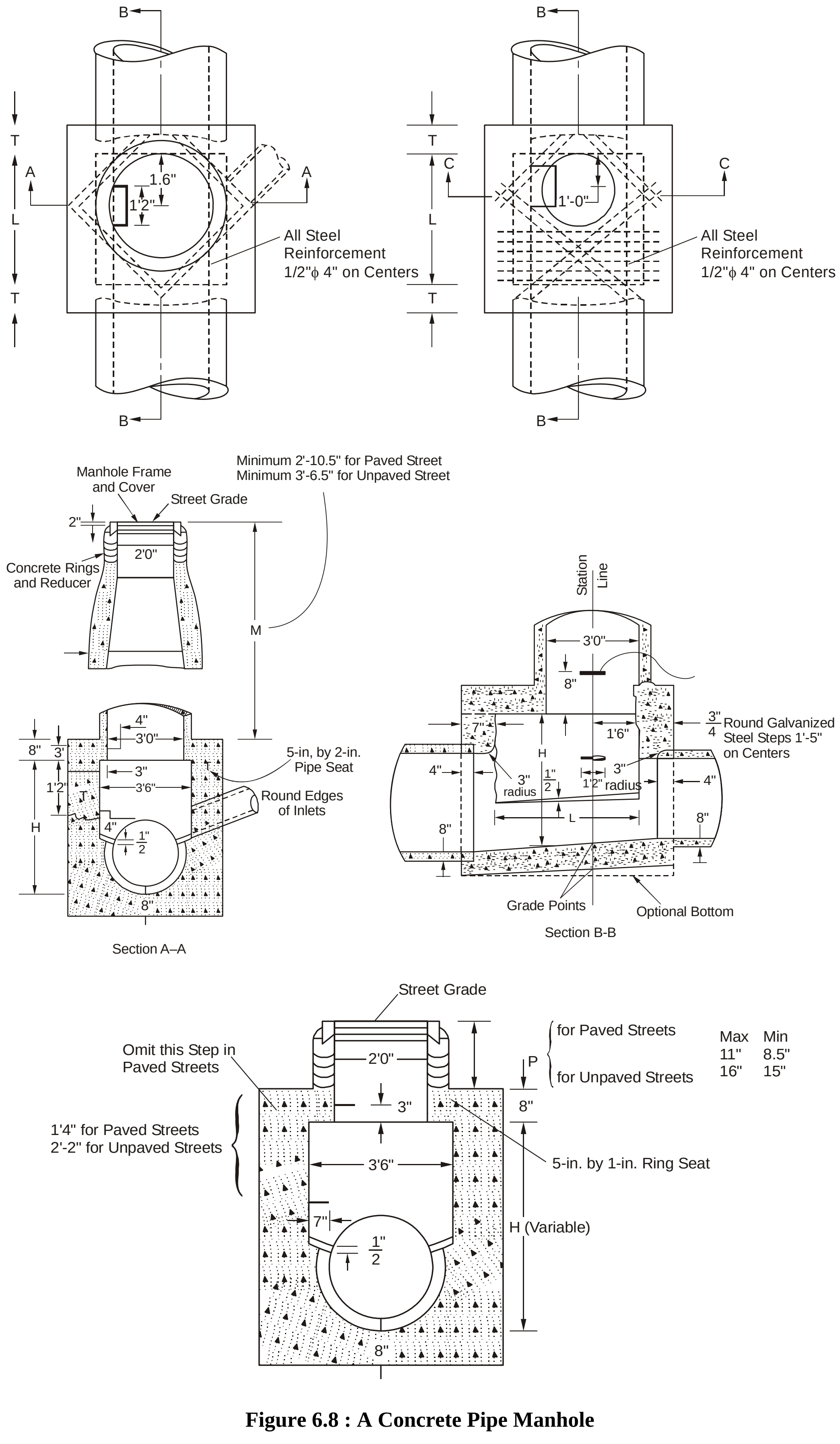


Figure 6.8 : A Concrete Pipe Manhole

A base slab of concrete preferably at least 150 mm thick should be provided on smaller sewers to support the walls of the manhole and to prevent the entrance of ground water. All sanitary flow should be carried in smoothly constructed V-shaped channels, which may be formed integrally with the concrete base or may be constructed separately of concrete or brick. The side height of the channel should be one-half to three fourths of the diameter of the sewer with the higher side height used where conservation of energy is important adjacent floor areas should be sloped to drain to the channel with a slope of 1 in 10. Where more than one sewer enters the manhole, the flowing-through channels should be curved smoothly and should have sufficient capacity to carry the maximum flow. Wherever the sewer changes direction or its size, or a branch sewer is allowed to join the system a manhole needs to be provided.

The materials commonly used for the construction of manhole walls include brick, poured concrete, precast rings and segmental block. The following influences the choice of the material :

(a) Cost in place, including material, labour and equipment.

(b) Durability under all reasonably expected conditions of service.

(c) Adaptability of the material to meet field conditions with particular reference to changes in location, grade or alignment made during construction.

(d) Depth of manhole and characteristics of surrounding material.

The sidewalls of the manhole are usually constructed of cement brickwork 250 mm thick and corbelled suitably to accommodate the frame of the manhole cover. The brickwork should be plastered with cement mortar 1 : 3 (1 cement : 3 coarse sand) and inside finished smooth with coat of neat cement. Where subsoil condition exists, a richer mix may be used and it shall further be waterproofed with addition of approved water proofing compound in a quantity as per manufacturer's specifications.

Manhole frames and covers are generally made of close-grained gray cast iron. All metal-bearing surfaces between the frame and cover, wherever subject to traffic, should be fabricated to insure good seating. Solid covers are preferable to the perforated type on sanitary sewers because they diminish the spread of objectionable odours and the entrance of surface waters. Adequate ventilation can usually be obtained through the house connections. Open-type covers are most common on storm and combined sewers. Locked or specially bolted-down covers may be used to prevent theft, vandalism or unauthorized entrance.

6.6.1 Straight-through Manholes

The simplest type of manhole is that built on a straight run of sewer with no side junctions. Where there is a change in the size of sewer, the crown level of the two sewers should be the same, except where special conditions require otherwise.

6.6.2 Junction Manholes

A manhole should be built at every junction of two or more sewers, and the curved portions of the inverts of tributary sewers should be formed within the manhole.

6.6.3 Drop Manholes

When a sewer connects with another sewer, where the difference in level between water lines (peak flow levels) of main line and the invert level of branch line is more than 600 mm or a drop of more than 600 mm is required to be given in the same sewer line a drop manhole shall be provided. The outside connection is provided for the protection of man entering the manhole and resulting structure is known as drop manhole. Therefore, sometimes when a lateral sewer joins deeper, sub-main sewer, the use of a drop manhole will reduce the amount of excavation needed by allowing the lateral to maintain a shallow slope (Figure 6.9). The wastewater drops into the lower sewer through the vertical pipe at the manhole.

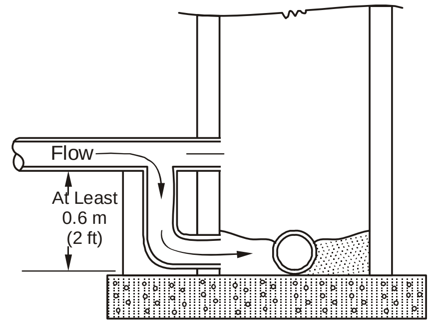


Figure 6.9 : A Typical Drop Manhole Structure

Encasement of the entire outside drop in concrete or brick masonry is needed to protect it against damage during the backfilling of the trench. When such a drop gets plugged, a ball or a chain is dropped down to break any sticks, thereby permitting the plugging material to get washed out. Manholes should be built so as to cause minimum head loss and interference with the hydraulics of the sewer line. One way to maintain a relatively smooth flow transition through the manhole, when a small sewer joins one of a larger diameter, is to match the pipe crown elevations at the manhole (Figure 6.10).

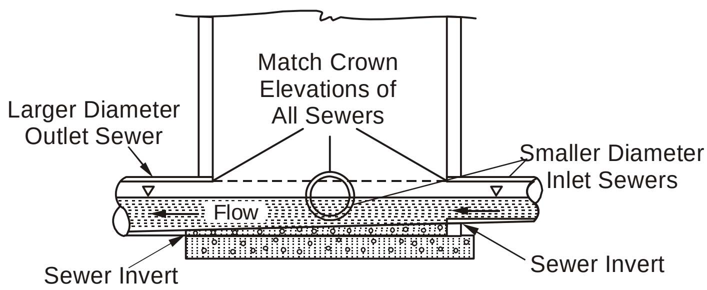


Figure 6.10 : Intersecting Pipes of Different Diameters at a Manhole

6.6.4 Flushing Manholes

Where it is not possible to achieve self-cleansing velocities due to the flatness of the gradient especially at the top ends of the branch sewers, which receive very little flow, it is essential that some form of flushing device be incorporated in the system. This can be done by providing an overhead water tank from which connections are made through pipes and flushing hydrants to rush water to the sewers. Flushing can also be accomplished by the use of a fire hydrant or tanker and hose. Approximate quantities of water needed for flushing are as given in Table 6.8 below.

Table 6.8 : Approximate Quantities of Water Needed for Flushing (CPHEEO, 1993)

Slope	Quantity of Water (Litres)		
	200 mm dia	250 mm dia	300 mm dia
0.0050	2300	2500	3000
0.0075	1500	1800	2300
0.0100	1300	1500	2000
0.0200	500	800	1000
0.0300	400	500	700

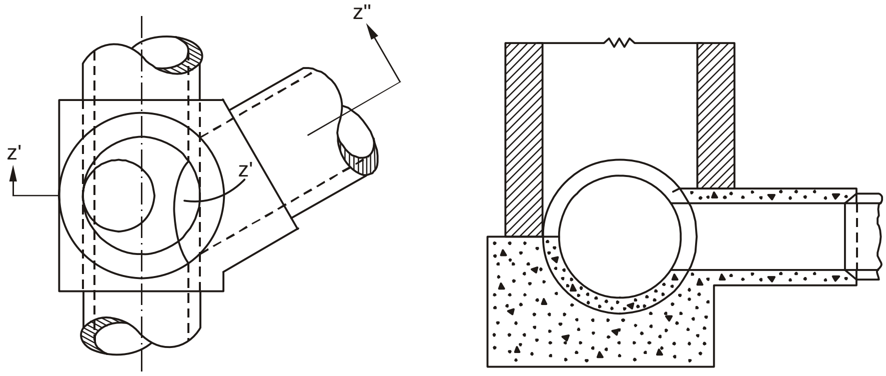
SAQ 4

(a) What are manholes?

(b) Discuss the various types of manholes, and point out their respective advantages.

6.7 JUNCTION CHAMBERS

The junction chamber provides access to the sewers and also allows the flow from the sewers entering the chamber to be combined without excessive turbulence and loss of head. Each junction chamber presents a special design problem necessitating a careful structural and hydraulic consideration. The principal objective in the design is to provide a safe and economical structure, which will combine the flow smoothly without decreasing the velocities appreciably and without causing backwater conditions in the sewers, which enter the chamber. A typical junction chamber is shown in Figure 6.11.



(a) Plan **(b) Section Z'-Z"-Z'''**

Figure 6.11 : A Typical Junction Chamber

SAQ 5

What is a junction chamber? Discuss.

6.8 HOUSE SEWERS

House sewers should not be less than 150 mm in diameter; and should preferably have a minimum longitudinal slope of 1:60, laid to straight line and grade. Slopes of as little as equal to those of the street help minimize infiltration and root penetration. Connections to the main street sewer should not be made with *Y* or *T* branches. The use of *T* is preferred in sanitary sewers where simultaneous discharge of house sewers into the street sewer is not common.

6.9 LAMPHOLE

A lamphole is an opening, constructed in a sewer, slightly larger than necessary to permit the insertion of a light into the sewer. Lampholes are sometimes used as a makeshift substitute for manholes to permit the inspection or the flushing of sewers, or for ventilating purposes.

6.10 CATCH BASINS

Catch basins are used to interrupt the flow of sewage before it enters the sewer, causing deposition of suspended grit and sludge and the detention of floating rubbish, which could enter and clog the sewer. A separate catch basin may be used for each inlet or, to save expense, the pipes from several inlets at a corner may discharge into the same catch basin. Various types of catch basins are successfully used – some holding water in a trap and others discharging directly into the sewer. The construction of the catch and its cover follows the principles given for the construction of manholes. In unusual situations it may be necessary to install a larger basin, but too large a catch basin is undesirable because of the probable production of bad odour.

6.11 SILT BASINS

Basins to interrupt the flow of sewage may be installed on storm sewers to provide a place for the deposition of grit particularly on sewers where there are no catch basins. In order to promote the deposition of grit the velocity of flow should not be greater than 0.6m/s, and to prevent the deposition of organic matter it should not be less than 0.3 m/s. Silt basins are undesirable on separate or on combined sewers because of the inevitable collection of organic matter.

6.12 GREASE AND OIL TRAPS

Grease in sewers results in the formation of incrustations that are difficult to remove and cause a substantial loss in the capacity of the sewer. Some cities have a basin for the removal of these substances at the sewerage-treatment works.

A general feature of grease and oil traps is the provision of a channel, which forces the sewage to flow downwards, beneath a free surface, while passing through the trap. Floating grease and oil rise to the surface on the inlet side of the trap, from which they may be cleaned through removable covers on the structures. It is essential that the cover be tightly sealed to avoid the escape of odours into the building; and it is preferable that the trap, if large, be placed outside the building itself. The capacity of trap should be about double that of the fixtures draining into it.

6.13 REGULATORS

Regulators are commonly used to divert a portion of sewage flow in a combined or storm water in order to prevent to overcharging of the sewer or to regulate the rate of flow to sewage treatment works. Regulators in combined sewers are sometimes designed to divert all flows greater than three to five times the dry weather flow in order to avoid the discharge of too strong a sewage into the overflow or relief sewer. The overflows from intercepting sewers should not be permitted at the points where they will adversely affect the watercourse. Types of automatic regulators include moving part devices and regulators without moving parts such as the leaping weirs and the overflow weirs.

Moving Part Regulator

In this type of regulator, the flow of sewage from a large sewer back into small tributary sewer may be prevented by the closing of the check valve. When the valve is closed sewage accumulates in the smaller sewer. Although undesirable, this action is preferable to backflow from the larger sewer. There are many variations in the details of float-controlled regulators that are available for use.

Leap Weirs

A leaping weir is formed by providing a gap in the invert of a sewer through which the dry weather flow falls and over which a portion or all the storm flow leaps forward. Leaping weirs have the advantages of operating as regulators without moving parts, but they often have disadvantage of concentrating grit in the low-flow channel. During a storm all flow may leap over the gap, stopping the flow in the low-flow channel with an undesirable effect on the sewage treatment plant being fed by that channel. The falling stream may be made to pass through a sloping rack or grating to divert stones and other falling objects from the interceptor. The grating should be sloped steeply to prevent paper and leaves from sticking to it, and a channel should be provided to divert drippings from the grating back to the dry weather interceptor.

Overflow Weirs

These are openings in the side of a sewer high enough to permit the discharge of excess flow into a relief channel and to permit the dry weather flow to continue upto its outlet. It operates successfully as a regulator without moving parts; and, it is simple to construct, and is widely used for regulating the flow in a sewer.

6.14 MEASUREMENT OF FLOW RATE

Standard hydraulic devices and procedures using calibrated constants can measure the rate of sewage flow. However, it is essential that no device shall offer such an obstacle to the flow of sewage so that suspended or floating solids are caught or restrained, obstructing the flow. Devices used for flow measurement include gravimeter and volumetric containers, orifices, weirs, pipe bends, nozzles, velocity meters, and Palmer-Bowlus flumes and Pearshall flumes.

6.15 INVERTED SIPHONS

An inverted siphon or depressed sewer is a sewer that runs full under gravity flow at a pressure above atmosphere in the sewer. Special feature of inverted siphon is that its profile is depressed below the hydraulic grade line. This is very useful when a sewer line has to be laid across a stream, a highway cut, or any other similar obstruction. When the profile laid below the ground, that portion of the sewer is known as **inverted siphon** (or, a depressed sewer) (Figure 6.12).

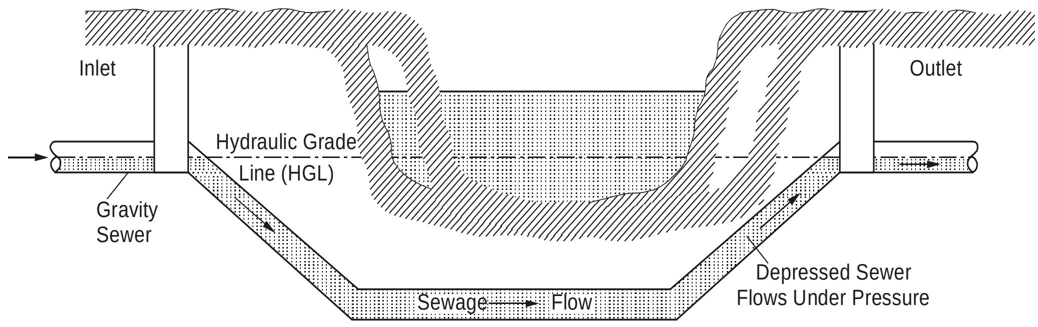


Figure 6.12 : An Inverted Siphon Carrying Gravity Flow under an Obstacle Along the Route

It is obvious that this section of sewer lies below the hydraulic grade line, flowing full and under pressure. In order to maintain appropriately higher velocities to disallow solids settling down in the sewer pipe, generally two or three different sizes of parallel pipes are provided to carry the minimum, average and peak flows. Since the siphon is subject to pressure, while flowing, ductile iron pipes or concrete encasement is provided in order to prevent leakage. The siphon may be constructed as a *U* with vertical or inclined legs.

True siphons are also used in sewerage practices depending upon the ground profile (topography). A true siphon is a sewer that flows full with the flow line above the hydraulic grade line, the pressure in the sewer being less than atmospheric.

6.16 OUTFALL SEWERS

Among the aspects to be considered in the design of a sewer outlet are listed as under :

(a) Location to avoid unpleasant sight and offensive smell.

(b) Protection of the mouth of sewer if it empties into a river against swift currents, water traffic, floating debris, heavy waves, or other hazards which might damage the structure.

(c) Prevention of backing-up of water into the sewer if the outlet is having a flat grade.

The ideal location for an outlet is onto a swiftly running stream with currents that will always carry away floating and settleable matter that has not been removed by treatment processes.

Ventilation

The ventilation of sewers (Figure 6.13) is desirable to prevent the accumulation of dangerous explosive or corrosive gases; the concentration of unpleasant odours that may escape to cause a nuisance in the environment; accumulation of hydrogen sulphide, which corrodes concrete and metal exposed to it in the sewer and in the, plumbing; and, the creation of pressures (above or below atmospheric) that may break water seal in plumbing traps. Pressures in the system are developed by the wind blowing up the outlet; and, also by the trapping of air due to surcharge of sewer; and due to other causes as well.

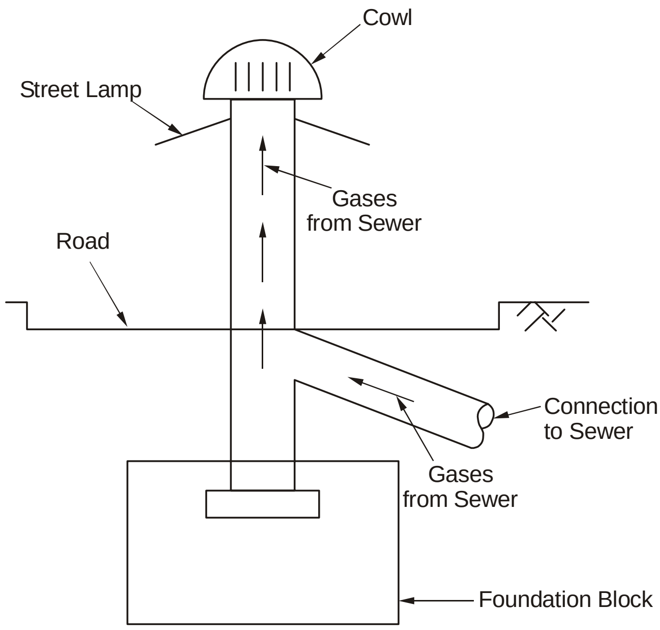


Figure 6.13 : A Ventilating Column Connected to a Sewer

SAQ 6

Draw neat sketches of ventilators that are used in a sewerage system. Are they needed even for storm sewerage system?

6.17 MATERIALS

The following materials are used in the construction of sewers :

(a) Clay or concrete

(b) Cast Iron

(c) Steel

(d) Wood

(e) Asbestos

(f) Bituminized Fibre

(g) Plastic

(h) Other materials.

It is important that the material that is chosen for sewer construction should meet the necessary specifications. Therefore, testing the materials delivered at site assumes special importance for the engineer incharge of the work. Ordinarily, standard specifications of the country should be followed vis-a-vis the quality and testing; but it sometimes happens that the engineer may have to select new materials for which he must write his own specifications based on need-specific considerations.

6.18 SEWER CONSTRUCTION

Prior to taking up the work of sewer construction, engineering drawings and specifications for the whole sewer system should be in place. In sewer construction work, two operations are of special importance, namely, excavation of trenches, and laying of sewer pipes in trenches and tunnels. Most of the trench work involves open cut excavation; and in urban areas it includes :

- removing pavement,
- removal of the material from the ground, and its separation, its classification where necessary, and its final disposal,
- sheeting and bracing the sides of the trench,
- removal of water (if any) from the trench,
- protection of other structures, both underground and on the surface, whose foundations may be affected,
- backfilling, and
- replacement of the pavement.

The most common type of sewer construction practice involves the use of open trenches and prefabricated pipes. However, for larger sewer systems, and unusual situations may require tunnelling, jacking of pipes through the soil, microtunnelling or cast-in-situ concrete sewers.

On all excavation work, safety precautions for the protection of life and property are essential; and measures to avoid too great inconveniences to the public are desirable. Such measures and precautions include the erection and maintenance of signs (to forewarn public), barricades, bridges and detours; the placing and maintenance of lights both for illumination and also as danger signals; provision of watchmen to exclude unauthorized persons, particularly children from trespassing on the work; and such other precautions as local conditions may dictate. In addition, additional requirements are as follows :

(a) Each pipe section should be un-cracked.

(b) Proper placement (i.e., bedding) has to be there for each pipe section that is laid.

(c) There should be proper joining of pipe sections.

(d) There should be proper alignment (direction and longitudinal slope) of the line.

(e) Pipes should be covered properly with clean fill material (backfilled).

It is but obvious, that sewers have to be sturdy enough to sustain the load of the backfill material (dead load) laid over them, as well as the load due to the vehicular traffic (live load) to which it is subjected to (Figure 6.14). Factors like depth of the backfill, type of this material, and width of the trench influence the magnitude of the dead load; while the parameters that determine the load carrying capacity of the sewer line are the *crushing strength of the pipe,* and the characteristics of the pipe bedding (Figure 6.15). Bedding defines the way in which a pipe is placed on the bottom of the trench. Proper bedding distributes the load over the circumference of the pipe, and this increases the supporting strength of the pipe. The ratio of actual field supporting strength to the crushing strength of the pipe is known as *load factor*.

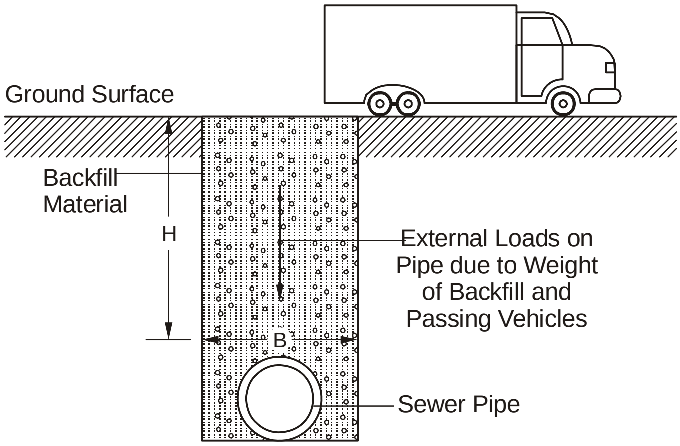


Figure 6.14 : Loads Coming onto Buried Sewer

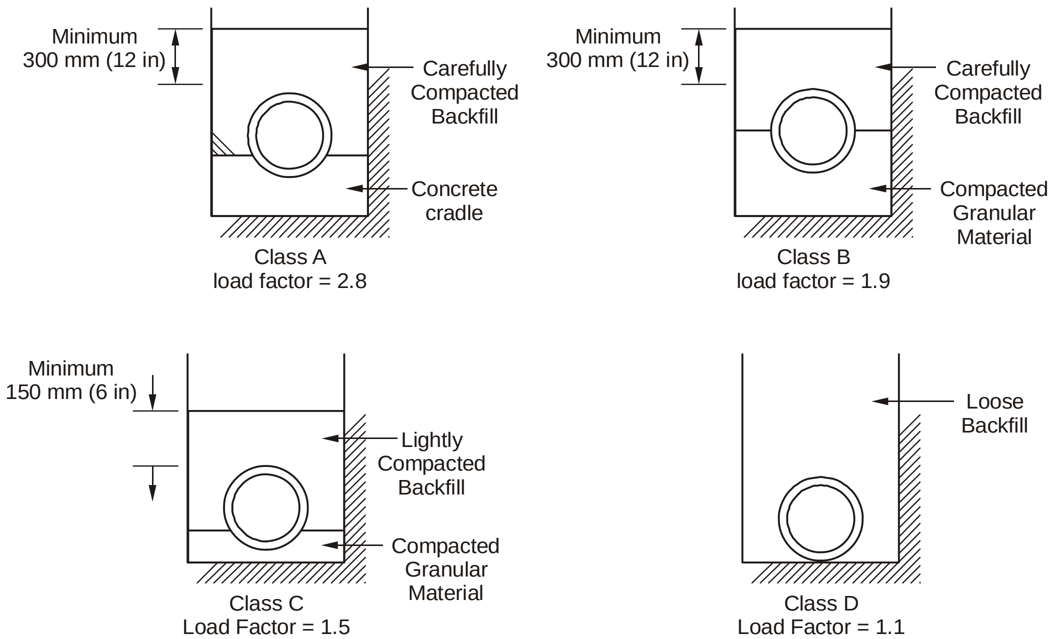


Figure 6.15 : Different Types of Pipe Bedding

With reference to Figure 6.15, it may be pointed out that class D bedding is the weakest of all, and hence is not generally adopted. Here, the trench bed being left flat and bare, the pipe is not fully supported due to its projecting bell-ends. Further, if the backfill is placed loosely over the sewer without the necessary compaction, the bedding may not properly support the barrel. The ordinary bedding (Class C), offers a better support, say, with a load factor of 1.5. In first class bedding (Class B), the granular material extends halfway up the pipe, and a carefully compacted backfill can give a load factor of even 1.9. In Class A bedding, the barrel is supported by a concrete bed (yielding a load factor of 2.8) with a careful compaction of the backfill. It is common, in such engineering constructions, to define a *safety factor* (SF) as well, such as :

$$\text{Safety Factor} = \frac{\text{Field Supporting Strength}}{\text{Safe Supporting Strength}}$$

An SF of 1.5 is normally adopted for clay or unreinforced concrete sewers to address the possibility of using poor quality materials or for faulty construction. With a view to select the best bedding condition, it is to be ensured that the safe supporting strength is equal to or greater than the total expected load over the pipe.

For pipelines situated in shallower trenches (such as, storm sewers or even some water mains) the component of load due to vehicular traffic may be a substantial part of the total load on the line. However, for deeper trenches (such as, sanitary sewers), the proportion of live load may not be significant compared to the dead load. In USA, *Marston's Formula* is commonly used to determine the load due to backfill, and is expressed as follows :

$$W = C\,w\,B^2$$

where, W = Dead load due to backfill (kN/m),

C = A dimensionless coefficient,

w = Unit weight of the backfill soil (kN/m^3), and

B = Width of the trench at the crown of the pipe (m).

In the equation, the value of C is to be selected depending upon the depth of backfill cover (H), width of the trench, and the type of backfill material (Figure 6.16).

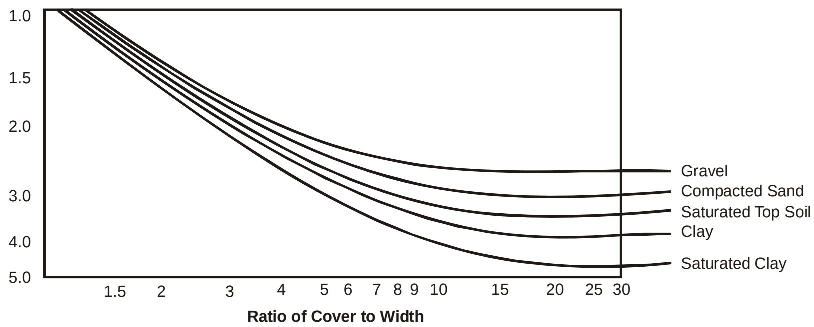


Figure 6.16 : Values of *C* in Marston's Formula

Example 6.1

A 250 mm diameter sewer is placed in a 2.75 m deep rectangular trench that is 0.65 m wide. This trench is backfilled with saturated clay having a unit weight of 20.4-kN/m$^{3.}$ Determine the dead load due to the backfill that the sewer must support. What class of bedding is to be specified if the crushing strength of this pipe is 23.2 kN/m, and the value of safety factor to be used is 1.5?

Solution

Here, $H = 2.75 \text{ m} - 0.25 \text{ m}$

$= 2.50 \text{ m}$

$\therefore$ $H/B = 3.85$

From Figure 6.16, we read $C = 2.65$

We have $W = 2.65 \times 20.4 \times (0.65)^2 = 22.84$ kN/m

$$\text{Safe Supporting Strength} = \frac{\text{Load Factor} \times \text{Crushing Strength}}{\text{Safety Factor}}$$

Load factor = 1.48

Therefore, we specify Class C bedding for the given sewer line.

Field Layout and Installation

It is understood that the line (horizontal alignment) and grade layout of a sewer line as per design has to be carried out meticulously. The horizontal layout determines the location as well as direction of the sewer line, while slope (grade) of the line provides the necessary hydraulic carrying capacity of the sewerage system. The location of the trench is generally laid out first as an offset line running parallel to the proposed sewer centre line. This offset line is demarcated by wooden stakes driven into the ground surface at intervals of, say, 15 m. The offset line, as is clear, is quite away from the sewer centre line with a view not to allow it being disturbed during construction; however, it has to be proximate enough so that the transfer of measurements to the actual trench can readily be done. The wooden stakes are set with their tops at a specific height above the designed trench bottom (horizontal slope line) – thus, the checking of the trench depth during excavation, etc. can be done with ease.

Two procedures are available to lay pipe sections in the open trench, namely, by batter boards, and by laser beams. Better boards are placed across the trench at uniform intervals (Figure 6.17). The tops of these boards can be set at some even height above the designed sewer invert elevation. The centre line of the sewer is traced on the borads by extending a line of sight with a transit level or a theodolite and a string is stretched from board to board along this very line. Later on this line is transferred onto the trench bed by means of a plumb bob. Invert levels are lines that transferred onto the trench bed by means of a plumb bob. Invert levels are indicated by vertical rods marked off in even increments – the lower end of each rod is placed on the pipe invert, and the string over the batter boards helps to check if it matches with the proper elevation mark on the rod, by appropriate adjustment of the pipe placement.

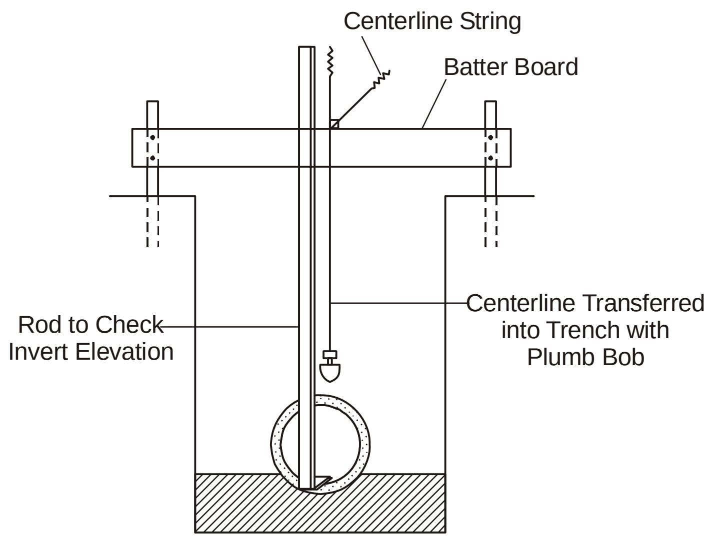


Figure 6.17 : Laying of a Sewer Using Batter Boards

In the laser method, advantage is taken of an intense, narrow beam of light that is projected by the laser instrument, over a long distance. This beam is aligned through a sewer pipe to strike a target held at the other end of the pipe as shown in Figure 6.18. A transit that is placed above a manhole helps establish the alignment of the sewer with reference to field survey points, and transfer it down to the laser instrument that is mounted inside the manhole. Lasers can achieve an accuracy of 0.01 per cent over a distance of upto 300 m.

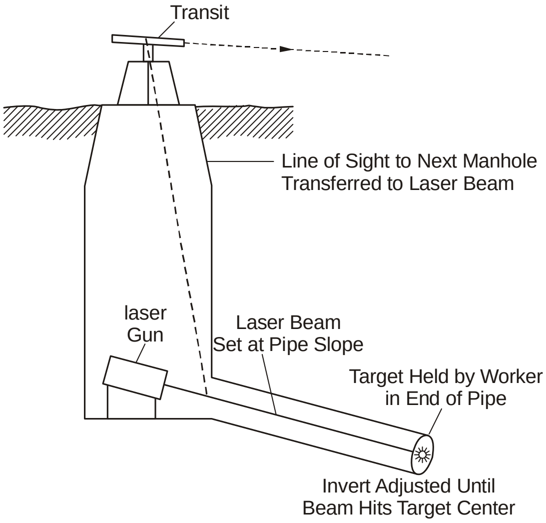


Figure 6.18 : Laser Beam Used to Fix the Longitudinal Slope of a Sewer

6.19 SEWER MANAGEMENT

The principal efforts in the maintenance of sewers are to keep them clean and unobstructed. A sewer system, although buried, cannot be left unattended. It will corrode, erode, clog or otherwise deteriorate with the passage of time. The size of the capital investment in a sewer system justifies its preventive maintenance. Work to be done in the maintenance of sewerage works particularly the sewer system, includes inspection, measurements of rate flow, cleaning, flushing, repairs, supervision of connections, protection of existing sewers, prevention of explosions, valuation and other aspects.

The construction of sewers that are to be connected to the municipal sewer system should be supervised and inspected by the municipal authorities to avoid difficulties that may arise later on through improper design and construction. Connections made to sewers by irresponsible or ignorant persons working without official supervision may cause trouble in sewers because of the weakening of the sewer structure, blockage, foundation collapse, the admission of ground water, etc. Connections should be made only through the openings provided therefor. New building should not be connected to the sewer until construction is complete; the danger from the careless disposal of waste building materials into the sewer is to be guarded against. Since many troubles in sewers arise from improperly built house sewers connected to them, the latter sewer should be constructed with the same care as that given to the public sewer.

Sewer Rehabilitation

Non-repairing of sewers renders them leaky; and, as a result they carry large volumes of infiltration water. They must often get blocked, and sometimes even collapse. The expenditure of excavating and then replacing a portion of badly functioning sewer is prohibitive. It is, therefore, economical to repair and rehabilitate the system as such. Therefore, continuing sewer maintenance efforts have to be designed with a view to prevent unnecessary deterioration of the sewer system. Any maintenance programme that may be adopted depends on the nature of the problem, necessity of maintaining the flow while the repair is being carried out, the expected traffic disruption that may be caused, safety aspects that need to be addressed, and the cost that has to be borne.

It is necessary to clean the sewer lines before embarking on a visual inspection. This is commonly done by flushing the sewer by using a fire hose, connected to a hydrant, that discharges into a manhole. However, caution is to be applied to avoid backups into the surrounding buildings that are connected to the system. There is yet another method to clean the sewers using a soft rubber ball that is inflated to match the diameter of the pipe and later being pulled by a cord via the reach of the line between manholes. Power rodding machines or power winches (to pull a bucket through the line) can also be used. It is essential to ensure that the collected debris is disposed of properly. Inspections (after cleansing operations) are made during low-flow periods using flashlights. Use of closed-circuit television system (even making a photographic or videotape record) gives accurate location of leaks, root intrusions, and any structural problems.

A common method for sealing leaks in otherwise structurally sound pipelines comprises of chemical grouting. The grout is applied internally to joints, holes, and cracks. In smaller or medium sized lines, inflatable rubber sleeves are generally pulled through, while in large sized lines workers place a sealing ring manually over the defective joint, and the grout is pumped through a hand held probe. However, as a safety measure, the air in the sewer must be tested for carbon monoxide, hydrogen sulphide, and explosive gases before allowing entry to workers.

Crown corrosion (Figure 6.19) can cause structural damage to sewers. Large sewers, suffering this damage can be strengthened by applying a *lining of gunite* – a mixture of fine sand, cement, and water. It is applied internally by means of pneumatic spraying. Long lengths of concrete sewers are effectively rehabilitated with gunite lining. To renew an extensively cracked sewer lines, a procedure known as *sliplining* is adopted. It comprises of pulling a flexible plastic liner pipe into the damaged pipe and then reconnecting all the individual service connections to the liner. Sometimes it may be necessary to fill the narrow annular space between the lines and the existing pipe with grount preventing relative movement. However, it may be pointed out that multiple excavations are required to reconnect each service line to the new liner. In a relatively new and sophisticated method, namely, *Inversion lining,* a flexible liner is used. This line expanding to fit over the pipe geometry is thermally hardened. This procedure avoids excavations for service line connections.

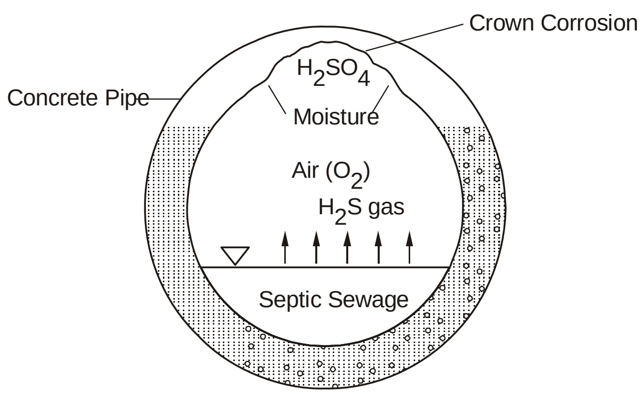


Figure 6.19 : Crown Corrosion in Unlined Concrete Sewer

Concrete manholes may also suffer sulphuric acid corrosion. Severe cases may need total replacement of the manhole. For less severe cases, the deteriorated material is removed using water or sand blasting, or mechanical tools, and then special chemical preparations are applied to stabilize the remaining material. Next, high strength patching mortar is used for filling in the irregularities in the internal surface; and, lastly, a lining or a coating has to be applied.

Manholes are sometimes subject to surface water inflow and/or ground water infiltration. It is an unacceptable situation. This can arise due to holes in the manhole cover, spaces between the cover and the frame, and poor sealing of the frame of the cover. Frames can be resealed using hydraulic cement, and waterproof epoxy coating. Sometimes the manhole frame and cover are raised, and the exposed portion is coated with asphalt or cement. Another method consists of installing a special insert between the frame and the cover. It does not allow water and grit to enter the manhole while allowing gas to escape through a relief valve.

The problem of infiltration of ground water through the sidewall of a manhole and its base, or around pipe entrances is solved by chemical grouting, being a less costly method compared to lining or coating. It needs no preparatory restoration of the surface and the cracks and opening get sealed by pressure injection of the gel or foam (grouting materials).

House (service) connections of smaller diameter pipes, join the lateral sewer line in the street. These house lines are also known as building sewers or service laterals, and can be as long as 30 m. These can develop defects like cracks and open-jointed pipes, causing considerable infiltration of ground water. The total length of service connections can often be greater than the length of the main sewers. Therefore, the maintenance of these lines is also equally important. Chemical grouting and inversion lining procedures are often helpful.

SAQ 7

What is crown corrosion, and how can it be prevented? Explain with the help of sketch.

6.20 SUMMARY

Study of the subject of storm water drainage begins with the consideration of methods to estimate the peak surface runoff due to the storm of a given frequency that occurs over a given catchment. The estimation is mostly done by Rational Method, use of empirical formulae (relevant for particular catchments only), or special procedures applicable to specific areas (such as, Soil Conservation Service Method being used in USA) that may be developed for ease in computations.

The need for estimation of runoff basically arises once an area is proposed to be developed with a view to urbanisation, and the normal peak flow is expected to increase due to increase in the coefficient of runoff of the area because of loss of natural seepage through paved patches of land.

Storm sewer systems, for carrying the flow, comprise suitable inlets in the streets, minor and trunk sewer pipes. The design of the system involves fixing the inlet locations, slope of sewer lines, and working out their diameters. Sewers and drains are designed with all the considerations and formulae applicable for the design of open channels.

Use of stormwater detention basins allows a temporary storage of water that is, later on, released; and it later on helps reduce the peak flow, and so lesser diameter of sewer lines can be adopted to effect economy in the capital cost. Such basins can be designed to cater to many storms falling in the desired range of frequency of occurrence. Hydraulic design of these structures involves the use of flood routing procedures; and a simplified procedure; namely, *simplified storage factor method* comes handy in this context.

In this unit, we have discussed the concepts related with the design of sewer systems. The design of sewer network involves the selection of proper pipe size and slope of pipes so as to transport the sewage to its disposal point. It was pointed out that while designing, it should be ensured that minimum flow velocity is maintained in sewers even during minimum flow conditions, at the same time velocity should not be too excessive to cause erosion in sewers.

Appurtenances are an integral part of a sewer network, and are necessary for proper functioning of the system. These include manholes through catch basins, etc. Manholes are there to permit inspection, cleaning and repair of sewer lines. Their dimensions should be sufficient to allow carrying out these operations. They are provided to accommodate change in pipeline diameter, or slope or alignment. They are also provided at all pipe intersections, uppermost end of each lateral.

Other appurtenances like terminal cleanout structures meant to provide a means for inserting cleaning tools, etc., junction chambers to allow flows from various sewers to be combined smoothly, flush tanks to clean off laterals, house sewers, lampholes to allow inserting light, street inlets, catch basins and sill basins to arrest suspended materials in the flowing sewage.

Stormwater standby tank is also an appurtenance whose function is to serve as a storage basin to even out the excess storm flow or retain the flow during high tides in the receiving water body. Measurement of sewage flow through a given system is an important activity to monitor its functioning. Sewer construction and management of the system is indeed a specialized discipline. Excavation of trenches, preparation of bedding, and laying of sewer pipes to designed alignment and slope are the main jobs to be attended to in the construction of sewers. Management of the system requires inspection and application of appropriate rehabilitation methods wherever required. Leaks need to sealed, cracks and corrosions repaired, and entry of infiltration water into the system (particularly into manholes) prevented.

6.21 ANSWERS TO SAQs

SAQ 1

(a) Refer Section 6.4.

(b) Refer Section 6.4.

SAQ 2

(a) (i) If the velocity of flow is low, the floating and suspended solids will get deposited at the bottom of sewer and keep on accumulating. This will reduce the sectional area of sewer and will cause obstruction in the flow of sewage. Therefore, sewers are designed for self cleansing velocity.

(ii) At high velocity, the interior surface of sewer pipe gets scoured due to continuous abrasion caused by the solids carried in suspension. This scouring and wear and tear is more pronounced at velocities higher than what can be tolerated by pipe material. This causes not only reduction in life span of pipe but also diminishes the carrying capacity of sewers. The limiting velocity mainly depends upon the hardness and also on resistance of sewer material to corrosive action of gases produced in sewer due to decomposition of organic matter.

(b) 92 mm.

(c) At 0.2 proportional depth, Velocity = 0.62 m/second.

At 0.8 proportional depth. Velocity = 1.16 m/second
Discharge = 48.8 litres/second.

SAQ 3

(a) (i) No

(ii) No

(iii) Yes

(iv) Yes

(v) Yes

(vi) No

(b) Refer section 6.5.3.

SAQ 4

Refer Section 6.6.

SAQ 5

Refer Section 6.7.

SAQ 6

Refer Section 6.16.

SAQ 7

Refer Section 6.19.