

Environmental Engineering II

UNIT – I

SYLLABUS:

Introduction to sanitation – systems of sanitation – relative merits &demerits – collection and conveyance of waste water – sewerage – classification of sewerage systems- Estimation of sewage flow and storm water drainage – fluctuations – types of sewers - Hydraulics of sewers and storm drains– design of sewers – appurtenances in sewerage – cleaning and ventilation of sewers.

Introduction:

Urbanization has encouraged the migration of people from villages to the urban areas. This has given rise to a number of environmental problems such as, water supply with desirable quality and quantity, wastewater generation and its collection, treatment and disposal. In urban areas for domestic and industrial uses the source of water is generally reservoir, river, lake, and wells. Out of this total water supplied, generally 60 to 80% contributes as a wastewater. In most of the cities, wastewater is let out partially treated or untreated and it either percolates into the ground and in turn contaminates the ground water or it is discharged into the natural drainage system causing pollution in downstream water bodies.

The importance of water quality as a factor constraining water use has often gone unacknowledged in the analyses of water scarcity. Water scarcity is a function not only of volumetric supply, but also of quality sufficient to meet the demand. The drinking water demand is perhaps the largest demand for high quality water apart from many industrial uses which also require high quality water. Agriculture, by far the largest consumer of water, also suffers when water supplies become saline. In India, water pollution comes from the main sources such as domestic sewage, industrial effluents, leachates from landfills, and run-off from solid waste dumps and agriculture land. Domestic sewage (black water) and sullage (grey water) is the main source of water pollution in India, especially in and around large urban centers. The regular monitoring of the water quality in the rivers and wells in the country revealed that the total coliform counts far exceeds the desired level in water to be fit for human consumption .

In the past disposal of waste from water closets was carried out manually and wastewater generated from kitchen and bathrooms was allowed to flow along the open drains. This primitive method was modified and replaced by a water carriage system, in which these wastes are mixed with sufficient quantity of water. This waste is carried through closed conduits under the conditions of gravity flow. This mixture of water and waste products is known as sewage.

*The **advantages** offered by the water carriage system are:*

- The carriage of wastes on head or carts is not required.
- Bad smell, which was unavoidable during open transport of sewage, is not occurring due to transport of this polluted water in closed conduits.
- The old system was posing the health hazards to sweepers and to the nearby residents, because of the possibilities of flies and insects transmitting disease germs from the accessible carts to the residents food eatables. This is avoided in water carriage system because of transport of night soil in close conduits.
- The human excreta is washed away as soon as it is produced in water carriage system, thus storing is not required as required in the old system of manual disposal. Thus, no bad smells are produced in closed conduit transport.
- In the old system, the wastewater generated from the kitchen and bathrooms was required to be carried through open roadside drains for disposal. This is avoided in sewerage system as the open drains could generate bad odours when used for disposal of organic wastes.

- The water carriage system does not occupy floor area, as the sewers are laid underground.
- In addition, the construction of toilets one above the other is possible in water carriage system and combining latrine and bathrooms together as water closets is possible. This is one of the important advantages of water carriage system.

*However, this water carriage system also has certain **drawbacks** such as:*

- A large network of pipes is required for collection of the sewage; hence, the capital cost for water carriage system is very high.
- In addition, the operation and maintenance of sewerage system is very expensive.
- Large wastewater volume is required to be treated before disposal.
- Assured water supply is essential for efficient operation of the water carriage system.

DEFINITIONS

Industrial wastewater: It is the wastewater generated from the industrial and commercial areas. This wastewater contains objectionable organic and inorganic compounds that may not be amenable to conventional treatment processes.

Night Soil: It is a term used to indicate the human and animal excreta.

Sanitary sewage: Sewage originated from the residential buildings comes under this category. This is very foul in nature. It is the wastewater generated from the lavatory basins, urinals and water closets of residential buildings, office building, theatre and other institutions. It is also referred as domestic wastewater.

Sewage: It indicates the liquid waste originating from the domestic uses of water. It includes sullage, discharge from toilets, urinals, wastewater generated from commercial establishments, institutions, industrial establishments and also the groundwater and stormwater that may enter into the sewers. Its decomposition produces large quantities of malodorous gases, and it contains numerous pathogenic or disease producing bacteria, along with high concentration of organic matter and suspended solids.

Sewage Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems or land. It is combination of unit operations and unit processes developed to treat the sewage to desirable standards to suit effluent norms defined by regulating authority.

Sewer: It is an underground conduit or drain through which sewage is carried to a point of discharge or disposal.

- **House sewer** (or drain) is used to discharge the sewage from a building to a street sewer. Lateral sewer is a sewer which collects sewage directly from the household buildings.
- **Branch sewer or submain sewer** is a sewer which receives sewage from a relatively small area. Main sewer or trunk sewer is a sewer that receives sewage from many tributary branches and sewers, serving as an outlet for a large territory.
- **Depressed sewer** is a section of sewer constructed lower than adjacent sections to pass beneath an obstacle or obstruction. It runs full under the force of gravity and at greater than atmospheric pressure. The sewage enters and leaves the depressed sewer at atmospheric pressure.
- **Intercepting sewer** is a sewer laid transversely to main sewer system to intercept the dry

weather flow of sewage and additional surface and storm water as may be desirable. An intercepting sewer is usually a large sewer, flowing parallel to a natural drainage channel, into which a number of main or outfall sewers discharge. Outfall sewer receives entire sewage from the collection system and finally it is discharged to a common point.

➤ **Relief sewer or overflow sewer** is used to carry the flow in excess of the capacity of an existing sewer.

Sewerage: The term sewerage refers the infrastructure which includes device, equipment and appurtenances for the collection, transportation and pumping of sewage, but excluding works for the treatment of sewage. Basically it is a water carriage system designed and constructed for collecting and carrying of sewage through sewers.

Stormwater: It indicates the rain water of the locality.

Subsoil water: Groundwater that enters into the sewers through leakages is called subsoil water.

Sullage: This refers to the wastewater generated from bathrooms, kitchens, washing place and wash basins, etc. Composition of this waste does not involve higher concentration of organic matter and it is less polluted water as compared to sewage.

Wastewater: The term *wastewater* includes both organic and inorganic constituents, in soluble or suspended form, and mineral content of liquid waste carried through liquid media. Generally the organic portion of the wastewater undergoes biological decompositions and the mineral matter may combine with water to form dissolved solids.

SOURCES OF SEWAGE

The wastewater generated from the household activities contributes to the major part of the sewage. The wastewater generated from recreational activities, public utilities, commercial complexes, and institutions is also discharged in to sewers. The wastewater discharged from small and medium scale industries situated within the municipal limits and discharging partially treated or untreated wastewater in to the sewers also contributes for municipal wastewater.

SEWAGE DISCHARGE

The quality of sewage and its characteristics show a marked range of hourly variation and hence peak, average and minimum discharge are important considerations. The process loadings in the sewage treatment are based on the daily average characteristics as determined from a 24 hours weighted composite samples. In the absence of any data an average quantity of 150 LPCD may be adopted for design. The hydraulic design load varies from component to component of the treatment plant with all appurtenances, conduits, channels *etc.*, being designed for the maximum discharge, which may vary from 2.0 to 3.5 times the average discharge. Sedimentation tanks are designed on the basis of average discharge, while consideration of both maximum and minimum discharge is important in the design of screens and grit chambers. Secondary treatment is generally designed for average discharge, with sufficient safety margin to accommodate the peak discharge.

EFFECT OF UNTREATED WASTEWATER DISPOSAL

The daily activities of human beings produce both liquid and solid wastes. The liquid portion of the wastewater is necessarily the water supplied by the authority or through private water sources, after it has fouled by variety of uses. The sources of wastewater generation can be defined as a combination of the liquid or water-carried wastes removed from residences, institutions, and commercial and industrial

establishments, together with groundwater, surface water, and storm water as may be present.

If the untreated wastewater is allowed to accumulate, it will lead to highly unhygienic conditions. The organic matter present in the wastewater will undergo decomposition with production of large quantities of malodorous gases. If the wastewater is discharged without treatment in the water body, this will result in the depletion of Dissolved Oxygen (DO) from the water bodies. Due to depletion of DO, the survival of aquatic life will become difficult, finally leading to anaerobic conditions in the receiving waters. The nutrients present in the wastewater can stimulate the growth of aquatic plants, leading to problems like eutrophication. In addition, the untreated domestic wastewater usually contains numerous pathogenic or disease causing microorganisms, that dwell in the human intestinal tract or it may be present in certain industrial wastewaters. Apart from this, the wastewater contains inorganic gritty materials. The continuous deposition of this inorganic material may reduce the capacity of water body considerably over a period. Generally domestic sewage does not contain any inorganic matter or organic compounds in highly toxic concentration. However, depending upon the type of industries discharging into the public sewers and the dilution that is offered by sewage; the municipal wastewater may have these inorganic substances or toxic organic compounds with the concentration more than the discharge limits stipulated by the authorities. Certain compounds, such as sulphates, metals such as chromium, etc., if presents in higher concentration, may disturb the secondary treatment of the sewage.

OBJECTIVES OF SEWAGE COLLECTION AND DISPOSAL

The objective of sewage collection and disposal is to ensure that sewage discharged from communities is properly collected, transported, treated to the required degree so as not to cause danger to human health or unacceptable damage to the natural environment and finally disposed off without causing any health or environmental problems. Thus, efficient sewerage scheme can achieve the following:

- To provide a good sanitary environmental condition of city protecting public health.
- To dispose the human excreta to a safe place by a safe and protective means.
- To dispose of all liquid waste generated from community to a proper place to prevent a favorable condition for mosquito breeding, fly developing or bacteria growing.
- To treat the sewage, as per needs, so as not to endanger the body of water or groundwater or land to get polluted where it is finally disposed off. Thus, it protects the receiving environment from degradation or contamination.

METHODS OF COLLECTION (Systems of Sanitation):

The sanitation of a town or city is done by two methods, which are :

- (a) Conservancy System.
- (b) Water-Carriage System.

CONSERVANCY SYSTEM

Sometimes this system is also called dry—system. This system is in practice from very ancient times. Actually this is out of date system even though it is prevailing in small towns, village and undeveloped portions of the large cities. Various types of refuse and storm water are collected, conveyed and disposed of separately by different methods in this system, therefore it is called conservancy system.

Garbage or dry refuse of a town is collected in dust-bins placed along the roads and streets, from where it is conveyed by trucks or covered carts once or twice in a day to the point of disposal. All the noncombustible portions of the garbage such as sand, dust, Clay, ashes etc, are used for filling the low level areas to reclaim land for the further development of the town. The combustible portion of garbage such as dry leaves, waste paper, broken furniture etc. are burnt. The decaying fruits and vegetables, grass and other such things In first dried and then disposed of by burning or in the manufacture of manure.

Human Excreta or Night Soil is collected separately in privies or conservancy Latrines. The liquid and semi-liquid wastes are collected in separate drains of the same latrine, from where they are removed through human agency. After removal of night soil is taken outside the town in closed animal drawn carts, trucks or tanks mounted on the tractor trailers. The night-soil is buried in trenches. After 2-3 years the buried night soil is converted excellent manure which can be used for growing crops.

Merits of Conservancy System:

The following are the merit of the conservancy system:

- a) It is cheaper in initial cost because storm water can pass in open drains and conservancy latrines are much economical.
- b) The quantity of sewage reaching the treatment plant before disposal is low.
- c) As the storm water goes in open drains, the sewer section will be small and will run full for the major portion of the year, due to which there will be no silting and deposits in sewer lines.
- d) In floods if the water level of the river at the outfall, It will not be costly to pump the sewage for the disposal.

Demerits:

The following are the demerits of conservancy system :

- (i) It is possible that storm water may go in sewers causing heavy load on treatment plants, therefore it is to be watched.
- (ii) In crowded lanes it is very difficult to lay the sewers or construct road-side drains, causing great inconvenience to the traffic.
- (iii) For burying human excreta more space of land is required.
- (iv) Buildings cannot be designed as one compact unit, because latrines are to be provided away from the living rooms due to foul smell, which are also inconvenient.
- (v) There is every possibility that liquid refuse may get an access in the subsoil and pollute the underground water.
- (vi) In the presence of conservancy system, the aesthetic appearance of the city cannot be increased.
- (vii) Decomposition of sewage causes insanitary conditions which are dangerous to the public health.
- (viii) This system completely depends on the mercy of sweepers at every time. If the sweepers go on strike, there is every possibility of the spreading of diseases in the town due to decomposition of foul matters.

Water carriage system:

With the development and advancement of the cities, urgent need was felt to replace conservancy system With some more improved type of system in which human agency should not be used for the collection and conveyance of the sewage. After large numbers of experiments, it was found that the water is the only cheapest substance, which can be easily used for the collection and conveyance of sewage. As in this system water is the main substance, therefore it is called Water-Carriage System. In this system the excremental matters are mixed up in large quantity of water and are taken out from the city through properly designed sewerage systems, where they are disposed off after necessary treatment in a satisfactory manner.

The sewage so formed in water carriage system consists of 99.9 per cent of water and the remaining 0.1 per cent of solid matters. All these solids remain in suspension in the sewage and do not change the specific gravity of the water, therefore all the hydraulic formulae can be directly used in the designing of sewerage systems and the treatment plants.

MERITS AND DEMERITS OF WATER CARRIAGE SYSTEM:

The following are the merits of water carriage system :

- (i) It is hygienic method, because all the excremental matters are collected and conveyed by water only and no human agency is employed for it.
- (ii) There is no nuisance in the streets of the towns due to offensive matters, because all the sewage goes in closed sewers under the ground. The risk of epidemics is reduced.
- (iii) As only one sewer is laid, therefore it occupies less space in crowded lane.

- (iv) Due to more quantity of sewage, self-cleansing velocity can be obtained even at less gradients.
- (v) Buildings can be designed compact as one unit.
- (vi) The land required for the disposal work is less as compared with conservancy system in which more area is required for burying the excremental matters.
- (vii) The usual water supply is sufficient and no additional water is required in water carriage system.
- (viii) This system does not depend on manual labour at every time except when sequ get choked.
- (ix) Sewage after proper treatment can be used for various purposes.

Demerits

The following are the demerits of water carriage system :

- (I) This system is very costly in initial cost.
- (ii) The maintenance of this system is also costly.
- (iii) During monsoon large volume of sewage is to be treated whereas very small volume is to be treated in the remaining period of the year.

If both the merits and demerits of the water-carriage system are considered, we will reach at the result that this system is an essential amenity, which every city must have.

SEWERAGE SYSTEMS :

For safe disposal of the sewage generated from a locality efficient collection, conveyance, adequate treatment and proper disposal of treated sewage is necessary. To achieve this, following conditions should be satisfied:

1. Sewage should not pollute the drinking water source, either surface or groundwater, or water bodies that are used for bathing or recreational purposes.
2. The untreated sewage during conveyance should not be exposed so as to have access to human being or animals and should not give unsightly appearances or odour nuisance, and should not become a place for breeding flies.
3. It should not cause harm to public health and adversely affect the receiving environment.

The collection system is meant for collection of the sewage generated from individual houses and transporting it to a common point where it can be treated as per the needs before disposal. In olden days, waste generated from water closets was collected by conservancy methods and other liquid waste was transported through open drain to finally join natural drains. Since, the excreta was carried through carts, it was not hygienic method for transportation to the disposal point. Now, collection and conveyance of sewage is done in water carriage system, where it is transported in closed conduit using water as a medium.

TYPES OF SEWERAGE SYSTEM

The sewerage system can be of following three types:

Combined system: In combined system along with domestic sewage, the run-off resulting from storms is carried through the same conduit of sewerage system. In countries like India where actual rainy days are very few, this system will face the problem of maintaining self cleansing velocity in the sewers during dry season, as the sewage discharge may be far lower as compared to the design discharge after including storm water.

Separate System: In separate system, separate conduits are used; one carrying sewage and other carrying storm water run-off. The storm water collected can be directly discharged into the water body since the run-off is not as foul as sewage and no treatment is generally provided. Whereas, the sewage collected from the city is treated adequately before it is discharged into the water body or used for irrigation to meet desired standards. Separate system is advantageous and economical for big towns.

Partially separate system: In this system part of the storm water especially collected from roofs and paved courtyards of the buildings is admitted in the same drain along with sewage from residences and

institutions, etc. The storm water from the other places is collected separately using separate storm water conduits.

Advantages and disadvantages of combined system Advantages:

- In an area where rainfall is spread throughout a year, there is no need of flushing of sewers, as self cleansing velocity will be developed due to more quantity because of addition of storm water.
- Only one set of pipe will be required for house plumbing.
- In congested areas it is easy to lay only one pipe rather than two pipes as required in other systems.

Disadvantages

- Not suitable for the area with small period of rainfall in a year, because dry weather flow will be small due to which self cleansing velocity may not develop in sewers, resulting in silting.
- Large flow is required to be treated at sewage treatment plant before disposal, hence resulting in higher capital and operating cost of the treatment plant.
- When pumping is required this system is uneconomical.
- During rains overflowing of sewers will spoil public hygiene.

Advantages and disadvantages of separate system Advantages:

- As sewage flows in separate pipe, hence the quantity to be treated at sewage treatment plant is small, resulting in economy of treatment.
- This system may be less costly as only sanitary sewage is transported in closed conduit and storm water can be collected and conveyed through open drains.
- When pumping is required during disposal, this system is economical due to less flow.

Disadvantages

- Self cleansing velocity may not developed at certain locations in sewers and hence flushing of sewers may be required.
- This system requires laying two sets of pipe, which may be difficult in congested area.
- This system will require maintenance of two sets of pipelines and hence maintenance cost is more.

Advantages and disadvantages of partially separate system Advantages

- Economical and reasonable size sewers are required.
- Work of house plumbing is reduced as rain water from roofs, sullage from bathrooms and kitchen, etc. are combined with discharge from water closets.
- Flushing of sewers may not be required as small portion of storm water is allowed to enter in sanitary sewage.

Disadvantages

- Increased cost of pumping as compared to separate system at treatment plants and intermediate pumping station wherever required.
- In dry weather self-cleansing velocity may not develop in the sewers.

CONSIDERATIONS FOR THE TYPE OF SYSTEM

Following points are considered before finalizing the type of collection system.

- The separate system requires laying of two sets of conduits whereas in combined system only one bigger size conduit is required.

- Laying of two separate conduits may be difficult in the congested streets.
- In combined system sewers are liable for silting during non-monsoon season, hence they are required to be laid at *steeper gradients*. Steeper gradients for the sewers may *require more number of pumping stations*, particularly for flat terrain, which may make the system costly.
- Large quantity of wastewater is required to be treated before discharge in case of combined system. Hence, large capacity treatment plant is required.
- In separate system, only sewage is treated before it is discharged into natural water body or used for irrigation. No treatment is generally given to the rainwater collected before it is discharge in to natural water body.
- In case of separate system pumping is only required for sewage. Pumping can be avoided for storm water lines, as they are not very deep and normally laid along the natural slopes.
- In combined system large capacity pumping station is required to safely handle the flow that is likely to be generated during highest design storm considered.
- Based on site conditions the economy of the system needs to be evaluated and selection is made accordingly.

PATTERNS OF COLLECTION SYSTEM

The network of sewers consists of house sewers discharging the sewage to laterals. The lateral discharges the sewage into branch sewers or sub-mains and sub-mains discharge it into main sewer or trunk sewer. The trunk sewer carries sewage to the common point where adequate treatment is given to the sewage and then it is discharged. The patterns of collection system depend upon:

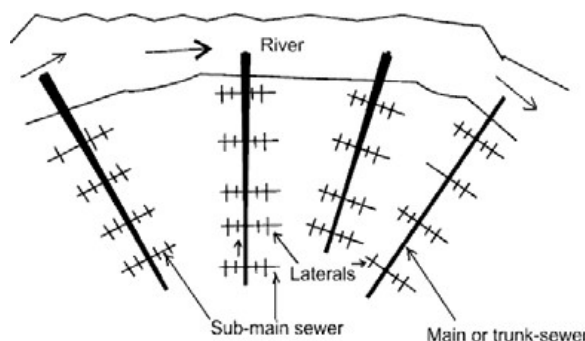
1. The topographical and hydrological features of the area.
2. The location and methods of treatment and disposal works.
3. The type of sewerage system employed, and
4. Extent of area to be served.

Following patterns can be adopted for collection systems as per the suitability:

a. Perpendicular pattern

- The shortest possible path is maintained for the rains carrying storm water and sewage (Figure).
- It is suitable for separate system and partially separate system for storm water drains.
- This pattern is not suitable for combined system, because treatment plant is required to be installed at many places; otherwise it will pollute the water body where the sewage is discharged.

Figure : Perpendicular pattern of collection system



b. Interceptor pattern

- Sewers are intercepted with large size sewers (Figure).
- Interceptor carries sewage to a common point, where it can be disposed off with or without treatment.
- Overflows should be provided to handle very large flow.

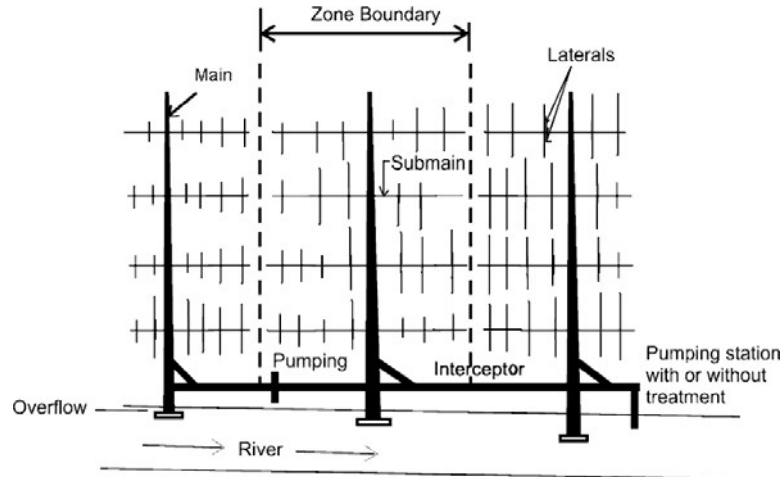
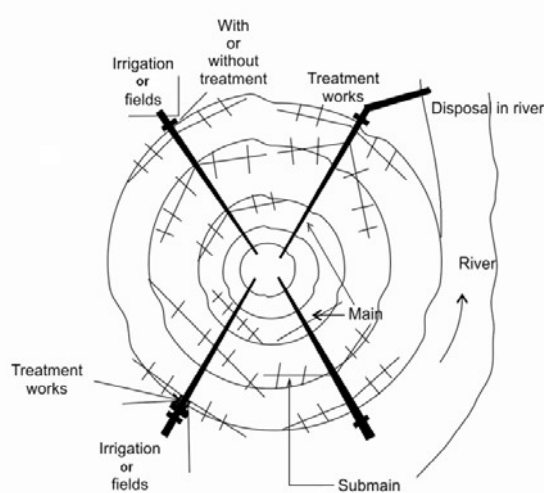


Figure: Interceptor pattern of collection system

c. Radial Pattern

- It is suitable for land disposal.
- In this pattern sewers are laid radially outwards from the centre, hence this pattern is called as radial pattern (Figure).
- The drawback in this pattern is more number of disposal works are required.



d) Fan Pattern

- This pattern is suitable for a city situated at one side of the natural water body, such as river.
- The entire sewage flows to a common point where one treatment plant is located (Figure).
- In this number of converging main sewers and sub-mains are used forming a fan shape.
- Single treatment plant is required in this pattern.

- The drawback in this pattern is that larger diameter sewer is required near to the treatment plant as entire sewage is collected at a common point.
- In addition, with new development of the city the load on existing treatment plant increases.

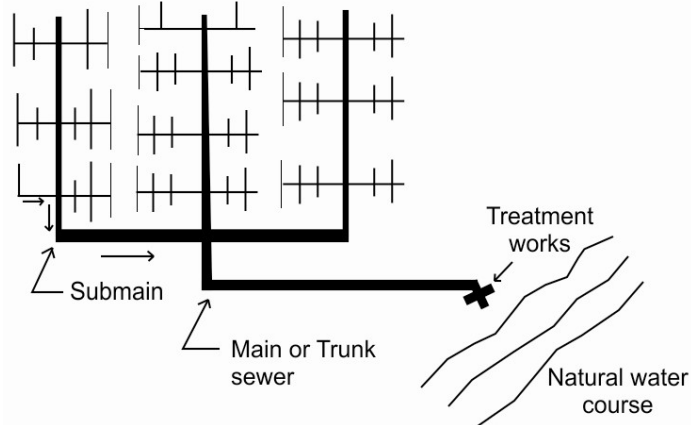


Figure: Fan pattern of collection system

d. Zone Pattern

- More numbers of interceptors are provided in this pattern (Figure).
- This pattern is suitable for sloping area than flat areas.

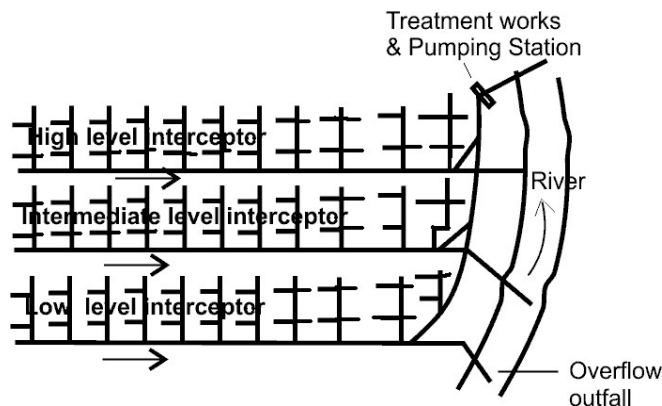


Figure Zone pattern of collection system

Important Factors Considered for Selecting Material for Sewer

Following factors should be considered before selecting material for manufacturing sewer pipes:

a. Resistance to corrosion

Sewer carries wastewater that releases gases such as H_2S . This gas in contact with moisture can be converted into sulfuric acid. The formation of acids can lead to the corrosion of sewer pipe. Hence, selection of corrosion resistance material is must for long life of pipe.

b. Resistance to abrasion

Sewage contain considerable amount of suspended solids, part of which are inorganic solids such as sand or grit. These particles moving at high velocity can cause wear and tear of sewer pipe internally. This abrasion can reduce thickness of pipe and reduces hydraulic efficiency of the sewer by making the interior surface rough.

c. Strength and durability

The sewer pipe should have sufficient strength to withstand all the forces that are likely to come on them. Sewers are subjected to considerable external loads of backfill material and traffic load, if any. They are not subjected to internal pressure of water. To withstand external load safely without failure, sufficient wall thickness of pipe or reinforcement is essential. In addition, the material selected should be durable and should have sufficient resistance against natural weathering action to provide longer life to the pipe.

d. Weight of the material

The material selected for sewer should have less specific weight, which will make pipe light in weight. The lightweight pipes are easy for handling and transport.

e. Imperviousness

To eliminate chances of sewage seepage from sewer to surrounding, the material selected for pipe should be impervious.

f. Economy and cost

Sewer should be less costly to make the sewerage scheme economical.

g. Hydraulically efficient

The sewer shall have smooth interior surface to have less frictional coefficient.

Materials for Sewers***Asbestos Cement Sewers***

- These are manufactured from a mixture of asbestos fibers, silica and cement. Asbestos fibers are thoroughly mixed with cement to act as reinforcement.
- These pipes are available in size 10 to 100 cm internal diameter and length up to 4.0 m.
- These pipes can be easily assembled without skilled labour with the help of special coupling, called 'Ring Tie Coupling' or Simplex joint.
- The pipe and joints are resistant to corrosion and the joints are flexible to permit 12° deflection for curved laying.
- These pipes are used for vertical transport of water. For example, transport of rainwater from roofs in multistoried buildings, for transport of sewage to grounds, and for transport of less foul sullage i.e., wastewater from kitchen and bathroom.

Advantages

- These pipes are light in weight and hence, easy to carry and transport.
- Easy to cut and assemble without skilled labour.
- Interior is smooth (Manning's $n = 0.011$) hence, can make excellent hydraulically efficient sewer.

Disadvantages

- These pipes are structurally not very strong.

- These are susceptible to corrosion by sulphuric acid. When bacteria produce H_2S , in presence of water, H_2SO_4 can be formed leading to corrosion of pipe material.

Plain Cement Concrete or Reinforced Cement Concrete

Plain cement concrete (1: 1.5: 3) pipes are available up to 0.45 m diameter and reinforcement cement pipes are available up to 1.8 m diameter. These pipes can be cast in situ or precast pipes. Precast pipes are better in quality than the cast in situ pipes. The reinforcement in these pipes can be different such as single cage reinforced pipes, used for internal pressure less than 0.8 m; double cage reinforced pipes used for both internal and external pressure greater than 0.8 m; elliptical cage reinforced pipes used for larger diameter sewers subjected to external pressure; and Hume pipes with steel shells coated with concrete from inside and outside. Nominal longitudinal reinforcement of 0.25% is provided in these pipes.

Advantages of concrete pipes

- Strong in tension as well as compression.
- Resistant to erosion and abrasion.
- They can be made of any desired strength.
- Easily molded, and can be in situ or precast pipes.
- Economical for medium and large sizes.
- These pipes are available in wide range of size and the trench can be opened and backfilled rapidly during maintenance of sewers.

Disadvantages

- These pipes can get corroded and pitted by the action of H_2SO_4 .
- The carrying capacity of the pipe reduces with time because of corrosion.
- The pipes are susceptible to erosion by sewage containing silt and grit.

The concrete sewers can be protected internally by vitrified clay linings. With protection lining they are used for almost all the branch and main sewers. Only high alumina cement concrete should be used when pipes are exposed to corrosive liquid like sewage.

Vitrified Clay or Stoneware Sewers

These pipes are used for house connections as well as lateral sewers. The size of the pipe available is 5 cm to 30 cm internal diameter with length 0.9 to 1.2 m. These pipes are rarely manufactured for diameter greater than 90 cm. These are joined by bell and spigot flexible compression joints.

Advantages

- Resistant to corrosion, hence fit for carrying polluted water such as sewage.
- Interior surface is smooth and is hydraulically efficient.

- The pipes are highly impervious.
- Strong in compression.
- These pipes are durable and economical for small diameters.
- The pipe material does not absorb water more than 5% of their own weight, when immersed in water for 24 h.

Disadvantages

- Heavy, bulky and brittle and hence, difficult to transport.
- These pipes cannot be used as pressure pipes, because they are weak in tension.
- These require large number of joints as the individual pipe length is small.

Brick Sewers

This material is used for construction of large size combined sewer or particularly for storm water drains. The pipes are plastered from outside to avoid entry of tree roots and groundwater through brick joints. These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient. Lining also makes the pipe resistant to corrosion.

Cast Iron Sewers

These pipes are stronger and capable to withstand greater tensile, compressive, as well as bending stresses. However, these are costly. Cast iron pipes are used for outfall sewers, rising mains of pumping stations, and inverted siphons, where pipes are running under pressure. These are also suitable for sewers under heavy traffic load, such as sewers below railways and highways. They are used for carried over piers in case of low lying areas. They form 100% leak proof sewer line to avoid groundwater contamination. They are less resistant to corrosion; hence, generally lined from inside with cement concrete, coal tar paint, epoxy, etc. These are joined together by bell and spigot joint. IS:1536-1989 and IS:1537-1976 provides the specifications for spun and vertically cast pipes, respectively.

Steel Pipes

These are used under the situations such as pressure main sewers, under water crossing, bridge crossing, necessary connections for pumping stations, laying pipes over self supporting spans, railway crossings, etc. They can withstand internal pressure, impact load and vibrations much better than CI pipes. They are more ductile and can withstand water hammer pressure better. These pipes cannot withstand high external load and these pipes may collapse when negative pressure is developed in pipes. They are susceptible to corrosion and are not generally used for partially flowing sewers. They are protected internally and externally against the action of corrosion.

Ductile Iron Pipes

Ductile iron pipes can also be used for conveying the sewers. They demonstrate higher capacity to withstand water hammer. The specifications for DI pipes is provided in IS:12288-1987.

The predominant wall material is ductile iron, a spheroidized graphite cast iron. Internally these pipes are coated with cement mortar lining or any other polyethylene or poly wrap or plastic bagging/ sleeve lining to inhibit corrosion from the wastewater being conveyed, and various types of external coating are used to inhibit corrosion from the environment. Ductile iron has proven to be a better pipe material than cast iron but they are costly. Ductile iron is still believed to be stronger and more fracture resistant material. However, like most ferrous materials it is susceptible to corrosion. A typical life expectancy of thicker walled pipe could be up to 75 years, however with the current thinner walled ductile pipe the life could be about 20 years in highly corrosive soils without a corrosion control program like cathodic protection.

Plastic sewers (PVC pipes)

Plastic is recent material used for sewer pipes. These are used for internal drainage works in house. These are available in sizes 75 to 315 mm external diameter and used in drainage works. They offer smooth internal surface. The additional advantages they offer are resistant to corrosion, light weight of pipe, economical in laying, jointing and maintenance, the pipe is tough and rigid, and ease in fabrication and transport of these pipes.

High Density Polyethylene (HDPE) Pipes

Use of these pipes for sewers is recent development. They are not brittle like AC pipes and other pipes and hence hard fall during loading, unloading and handling do not cause any damage to the pipes. They can be joined by welding or can be jointed with detachable joints up to 630 mm diameter (IS:4984-1987). These are commonly used for conveyance of industrial wastewater. They offer all the advantages offered by PVC pipes. PVC pipes offer very little flexibility and normally considered rigid; whereas, HDPE pipes are flexible hence best suited for laying in hilly and uneven terrain. Flexibility allows simple handling and installation of HDPE pipes. Because of low density, these pipes are very light in weight. Due to light in weight, they are easy for handling, this reduces transportation and installation cost. HDPE pipes are non corrosive and offer very smooth inside surface due to which pressure losses are minimal and also this material resist scale formation.

Glass Fiber Reinforced Plastic Pipes

This material is widely used where corrosion resistant pipes are required. Glass fiber reinforced plastic (GRP) can be used as a lining material for conventional pipes to protect from internal or external corrosion. It is made from the composite matrix of glass fiber, polyester resin and fillers. These pipes have better strength, durability, high tensile strength, low density and high corrosion resistance. These are manufactured up to 2.4 m diameter and up to 18 m length (IS:12709-1989). Glass reinforced plastic pipes represent the ideal solution for transport of any kind of water, chemicals, effluent and sewage, because they combine the advantages of corrosion resistance with a mechanical strength which can be compared with the steel pipes. Typical properties that result in advantages in GRP pipes application can be summarized as follows:

- Light weight of pipes that allows for the use of light laying and transport means.
- Possibility of nesting of different diameters of pipe thus allowing additional saving in transport cost.
- Length of pipe is larger than other pipe materials.

- Easy installation procedures due to the kind of mechanical bell and spigot joint.
- Corrosion resistance material, hence no protections such as coating, painting or cathodic are then necessary.
- Smoothness of the internal wall that minimizes the head loss and avoids the formation of deposits.
- High mechanical resistance due to the glass reinforcement.
- Absolute impermeability of pipes and joints both from external to internal and vice- versa.
- Very long life of the material.

Lead Sewers

- They are smooth, soft and can take odd shapes.
- This pipe has an ability to resist sulphide corrosion.
- However, these pipes are very costly.
- These are used in house connection.

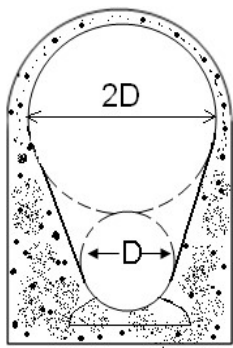
Shapes of Sewer Pipes

Sewers are generally circular pipes laid below ground level, slopping continuously towards the outfall. These are designed to flow under gravity. Shapes other than circular are also used.

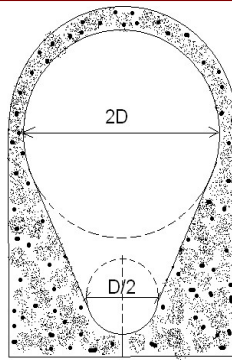
Other shapes used for sewers are (Figure a through i):

- a. Standard Egg-shaped sewer
- b. New egg-shaped sewer
- c. Horse shoe shaped sewer
- d. Parabolic shaped sewer
- e. Semi-elliptical section
- f. Rectangular shape section
- g. U-shaped section
- h. Semi-circular shaped sewer
- i. Basket handled shape sewer

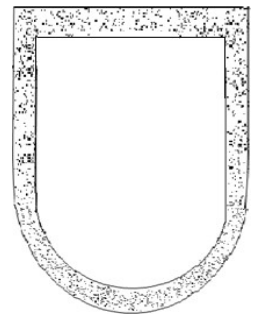
Standard egg-shaped sewers, also called as ovoid shaped sewer, and new or modified egg-shaped sewers are used in combined sewers. These sewers can generate self cleansing velocity during dry weather flow. Horse shoe shaped sewers and semi-circular sections are used for large sewers with heavy discharge such as trunk and outfall sewers. Rectangular or trapezoidal section is used for conveying storm water. U-shaped section is used for larger sewers and especially in open cuts. Other sections of the sewers have become absolute due to difficulty in construction on site and non availability of these shapes readily in market.



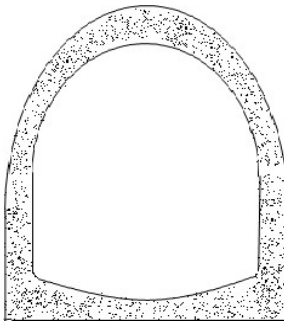
a) Standard Egg-shaped sewer



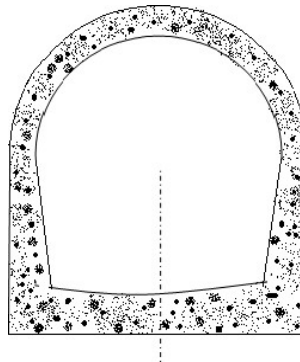
b) New egg-shaped sewer



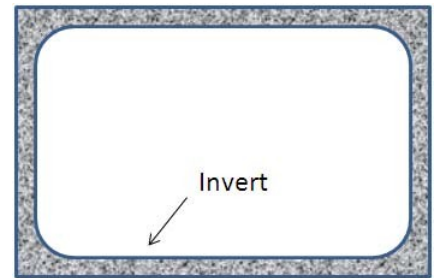
c) U-shaped section



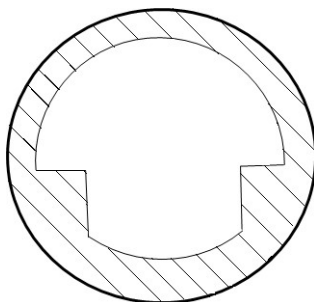
d) Semi-elliptical section



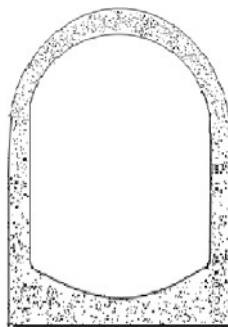
e) Horse shoe shaped sewer



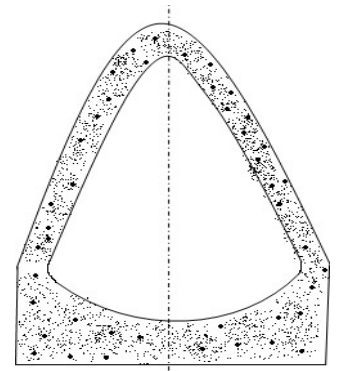
f) Rectangular shape section



g) Basket handled shape sewer



h) U-shaped section



i) Parabolic shaped sewer

Figure : Different shapes used for construction of sewer other than circular

Sewage Discharge

The sewage collected from the municipal area consists of wastewater generated from the residences, commercial centers, recreational activities, institutions and industrial wastewaters discharge into sewer network from the permissible industries located within the city limits. Before designing the sewer, it is necessary to know the discharge i.e., quantity of sewage, which will flow in it after completion of the project.

Sources of Sanitary Sewage

1. Water supplied by water authority for domestic usage, after desired use it is discharged in to sewers as sewage.
2. Water supplied to the various industries for various industrial processes by local authority. Some quantity of this water after use in different industrial applications is discharged as wastewater.
3. The water supplied to the various public places such as, schools, cinema theaters, hotels, hospitals, and commercial complexes. Part of this water after desired use joins the sewers as wastewater.
4. Water drawn from wells by individuals to fulfill domestic demand. After uses this water is discharged in to sewers.
5. The water drawn for various purposes by industries, from individual water sources such as, wells, tube wells, lake, river, etc. Fraction of this water is converted into wastewater in different industrial processes or used for public utilities within the industry generating wastewater. This is discharged in to sewers.
6. Infiltration of groundwater into sewers through leaky joints.
7. Entrance of rainwater in sewers during rainy season through faulty joints or cracks in sewers.

Dry Weather Flow

Dry weather flow is the flow that occurs in sewers in separate sewerage system or the flow that occurs during dry seasons in combined system. This flow indicates the flow of sanitary sewage. This depends upon the rate of water supply, type of area served, economic conditions of the people, weather conditions and infiltration of groundwater in the sewers, if sewers are laid below groundwater table.

Evaluation of Sewage Discharge

Correct estimation of sewage discharge is necessary; otherwise sewers may prove inadequate resulting in overflow or may prove too large in diameter, which may make the system uneconomical and hydraulically inefficient. Hence, before designing the sewerage system it is important to know the discharge / quantity of the sewage, which will flow in it after completion of the project and at the end of

design period.

Apart from *accounted water supplied* by water authority that will be converted to wastewater, following quantities are considered while estimating the sewage quantity:

a. *Addition due to unaccounted private water supplies*

People using water supply from private wells, tube wells, etc. contribute to the wastewater generation more than the water supplied by municipal authority. Similarly, certain industries utilize their own source of water. Part of this water, after desired uses, is converted into wastewater and ultimately discharged into sewers. This quantity can be estimated by actual field observations.

b. *Addition due to infiltration*

This is additional quantity due to groundwater seepage in to sewers through faulty joints or cracks formed in the pipes. The quantity of the water depends upon the height of the water table above the sewer invert level. If water table is well below the sewer invert level, the infiltration can occur only after rain when water is moving down through soil. Quantity of the water entering in sewers depends upon the permeability of the ground soil and it is very difficult to estimate. While estimating the design discharge, following suggested discharge can be considered (Table 4.1).

Table: Suggested estimates for groundwater infiltration for sewers laid below groundwater table (CPHEEO Manual, 1993)

Unit	Minimum	Maximum
L/ha.d	5000	50000
L/km.d	500	5000
L per day per manhole	250	500

Storm water drainage may also infiltrate into sewers. This inflow is difficult to calculate. Generally, no extra provision is made for this quantity. This extra quantity can be taken care of by extra empty space left at the top in the sewers, which are designed for running $\frac{3}{4}$ full at maximum design discharge.

c. *Subtraction due to water losses*

The water loss, through leakage in water distribution system and house connections, does not reach consumers and hence, not appear as sewage.

d. *Subtraction due to water not entering the sewerage system*

Certain amount of water is used for such purposes, which may not generate sewage, e.g. boiler feed water, water sprinkled over the roads, streets, lawns, and gardens, water consumed in industrial product, water used in air coolers, etc.

Net quantity of sewage: The net quantity of sewage production can be estimated by considering the addition and subtraction as discussed above over the accounted quantity of water supplied by water authority as below:

$$\begin{array}{rclclcl} \text{Net} & & \text{Accounted} & & \text{Addition due to} & & \text{Addition due to} & & \text{Subtraction} & & \text{Subtraction} \\ \text{quantity} & = & \text{quantity of} & + & \text{unaccounted} & + & \text{to infiltration} & - & \text{due to} & - & \text{due to water} \\ \text{of} & & \text{water supplied} & & \text{private water} & & & & \text{water} & & \text{not entering} \\ \text{sewage} & & \text{from the water} & & \text{supplies} & & & & \text{losses} & & \text{the sewerage} \\ & & \text{works} & & & & & & & & \text{system} \end{array}$$

Generally, 75 to 80% of accounted water supplied is considered as quantity of sewage produced.

Variation in Sewage Flow

Variation occurs in the flow of sewage over annual average daily flow. Fluctuation in flow occurs from hour to hour and from season to season. The typical hourly variation in the sewage flow is shown in the Figure. If the flow is gauged near its origin, the peak flow will be quite pronounced. The peak will defer if the sewage has to travel long distance. This is because of the time required in collecting sufficient quantity of sewage required to fill the sewers and time required in travelling. As sewage flow in sewer lines, more and more sewage is mixed in it due to continuous increase in the area being served by the sewer line. This leads to reduction in the fluctuations in the sewage flow and the lag period goes on increasing. The magnitude of variation in the sewage quantity varies from place to place and it is very difficult to predict. For smaller township this variation will be more pronounced due to lower length and travel time before sewage reach to the main sewer and for large cities this variation will be less.

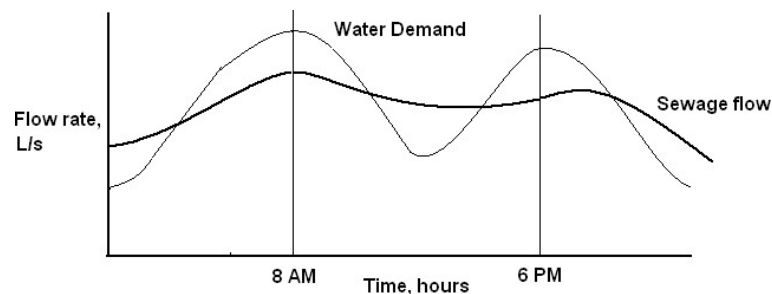


Figure : Typical hourly variations in sewage flow

For estimating design discharge following relation can be considered:

- Maximum daily flow = Two times the annual average daily flow (representing seasonal variations)
- Maximum hourly flow = 1.5 times the maximum daily flow (accounting hourly variations)
- = Three times the annual average daily flow

As the tributary area increases, peak hourly flow will decrease. For smaller population served (less than 50000) the peak factor can be 2.5, and as the population served increases its value reduces. For large cities it can be considered about 1.5 to 2.0. Therefore, for outfall sewer the peak flow can be considered as 1.5 times the annual average daily flow. Even for design of the treatment facility, the peak factor is considered as 1.5 times the annual average daily flow.

The minimum flow passing through sewers is also important to develop self cleansing velocity to avoid silting in sewers. This flow will generate in the sewers during late night hours. The effect of this flow is more pronounced on lateral sewers than the main sewers. Sewers must be checked for minimum velocity as follows:

Minimum daily flow $= \frac{2}{3}$ Annual average daily flow

Minimum hourly flow $= \frac{1}{2}$ minimum daily flow
 $= \frac{1}{3}$ Annual average daily flow

The overall variation between the maximum and minimum flow is more in the laterals and less in the main or trunk sewers. This ratio may be more than 6 for laterals and about 2 to 3 in case of main sewers.

Design Period

The future period for which the provision is made in designing the capacities of the various components of the sewerage scheme is known as the design period. The design period depends upon the following:

- Ease and difficulty in expansion,
- Amount and availability of investment,
- Anticipated rate of population growth, including shifts in communities, industries and commercial investments,
- Hydraulic constraints of the systems designed, and
- Life of the material and equipment.

Following design period can be considered for different components of sewerage scheme.

- | | | | |
|----|-----------------------------------|---|------------------|
| 1. | Laterals less than 15 cm diameter | : | Full development |
| 2. | Trunk or main sewers | : | 40 to 50 years |
| 3. | Treatment Units | : | 15 to 20 years |
| 4. | Pumping plant | : | 5 to 10 years |

Design Discharge of Sanitary Sewage

The total quantity of sewage generated per day is estimated as product of forecasted population at the end

of design period considering per capita sewage generation and appropriate peak factor. The per capita sewage generation can be considered as 75 to 80% of the per capita water supplied per day. The increase in population also result in increase in per capita water demand and hence, per capita production of sewage. This increase in water demand occurs due to increase in living standards, betterment in economical condition, changes in habit of people, and enhanced demand for public utilities.

Problem :

A city has a projected population of 60,000 spread over area of 50 hectare. Find the design discharge for the separate sewer line by assuming rate of water supply of 250 LPCD and out of this total supply only 75 % reaches in sewer as wastewater. Make necessary assumption whenever necessary.

Solution:

Given data

$$Q = 250 \text{ lit/capita/day}$$

$$\begin{aligned} \text{Sewage flow} &= 75\% \text{ of water supply} \\ &= 0.75 * 250 \\ &= 187.5 \text{ LPCD} \end{aligned}$$

$$\begin{aligned} \text{Total sewage generated} &= 187.5 * 60000 / (24 * 3600) \\ &= 130.21 \text{ lit/sec} \\ &= 0.13 \text{ m}^3/\text{s} \end{aligned}$$

$$* \text{Assume peak factor} = 2$$

$$\text{Total design discharge} = 0.26 \text{ m}^3/\text{s}.$$

Factors Affecting the Quantity of Stormwater

The surface run-off resulting after precipitation contributes to the stormwater. The quantity of stormwater reaching to the sewers or drains is very large as compared with sanitary sewage. The factors affecting the quantity of stormwater flow are asbelow:

- i. Area of the catchment
- ii. Slope and shape of the catchment area
- iii. Porosity of the soil
- iv. Obstruction in the flow of water as trees, fields, gardens, etc.
- v. Initial state of catchment area with respect to wetness.
- vi. Intensity and duration of rainfall
- vii. Atmospheric temperature and humidity
- viii. Number and size of ditches present in the area

Measurement of Rainfall

The rainfall intensity could be measured by using rain gauges and recording the amount of rain falling in unit time. The rainfall intensity is usually expressed as mm/hour or cm/hour. The rain gauges used can be manual recording type or automatic recording rain gauges.

Methods for Estimation of Quantity of Storm Water

1. Rational Method
2. Empirical formulae method

In both the above methods, the quantity of storm water is considered as function of intensity of rainfall, coefficient of runoff and area of catchment.

Time of Concentration: The period after which the entire catchment area will start contributing to the runoff is called as the time of concentration.

- The rainfall with duration lesser than the time of concentration will not produce maximum discharge.
- The runoff may not be maximum even when the duration of the rain is more than the time of concentration. This is because in such cases the intensity of rain reduces with the increase in its duration.
- The runoff will be maximum when the duration of rainfall is equal to the time of concentration and is called as *critical rainfall duration*. The time of concentration is equal to sum of inlet time and time of travel.

$$\text{Time of concentration} = \text{Inlet time} + \text{time of travel}$$

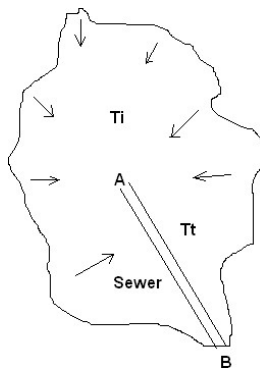


Figure: Runoff from a given catchment

Inlet Time: The time required for the rain in falling on the most remote point of the tributary area to flow across the ground surface along the natural drains or gutters up to inlet of sewer is called inlet time (Figure 6.1). The inlet time 'Ti' can be estimated using relationships similar to following. These coefficients will have different values for different catchments.

$$T_i = [0.885 L^3/H]^{0.385} \quad (1)$$

Where,

T_i = Time of inlet, minute

L = Length of overland flow in Kilometer from critical point to mouth of drain
H = Total fall of level from the critical point to mouth of drain, meter

Time of Travel: The time required by the water to flow in the drain channel from the mouth to the point under consideration or the point of concentration is called as time of travel.

$$\text{Time of Travel (T}_t\text{)} = \text{Length of drain} / \text{velocity in drain} \quad (2)$$

Runoff Coefficient: The total precipitation falling on any area is dispersed as percolation, evaporation, storage in ponds or reservoir and surface runoff. The runoff coefficient can be defined as a fraction, which is multiplied with the quantity of total rainfall to determine the quantity of rain water, which will reach the sewers. The runoff coefficient depends upon the porosity of soil cover, wetness and ground cover. The overall runoff coefficient for the catchment area can be worked out as follows:

$$\text{Overall runoff coefficient, } C = [A_1.C_1 + A_2.C_2 + \dots + A_n.C_n] / [A_1 + A_2 + \dots + A_n] \quad (3)$$

Where, $A_1, A_2, \dots, A_n$ are types of area with $C_1, C_2, \dots, C_n$ as their coefficient of runoff, respectively.

The typical runoff coefficient for the different ground cover is provided in the Table 6.1. Table 6.1 Runoff coefficient for different type of cover in catchment

Type of Cover	Coefficient of runoff
Business areas	0.70 – 0.90
Apartment areas	0.50 – 0.70
Single family area	0.30 – 0.50
Parks, Playgrounds, Lawns	0.10 – 0.25
Paved Streets	0.80 – 0.90
Water tight roofs	0.70 – 0.95

Rational method

Storm water quantity can be estimated by rational method as below:

$$\text{Storm water quantity, } Q = C.I.A / 360 \quad (4)$$

Where,

Q = Quantity of storm water, m³/sec C = Coefficient of runoff

I = intensity of rainfall (mm/hour) for the duration equal to time of concentration,

and A = Drainage area in hectares

(OR)

$$Q = 0.278 C.I.A \quad (5)$$

Where, Q is m³/sec; I is mm/hour, and A is area in square kilometer

Empirical Formulae:

Empirical formulae are used for determination of runoff from very large area. Various empirical relationships are developed based on the past observations on specific site conditions suiting a particular region. These empirical formulae can be used for prediction of storm water runoff for that particular catchment.

A] Burkli – Zeiglar formula

$$Q = \frac{CiA}{141.58} \sqrt[4]{\frac{S}{A}}$$

B) Mc. Math's formula:

$$Q = \frac{CiA}{148.35} \sqrt[5]{\frac{S}{A}}$$

C) Fuller's Formula:

$$Q = \frac{Cm^{5/8}}{13.23}$$

D) Fanning's Formula:

$$Q = 12.8M^{5/8}$$

E) Talbot's Formula:

$$Q = 22.4M^{1/4}$$

Where,

S- Slope of the area in meter per thousand meter,

M- drainage area in sq. km.,

A – drainage area in hectare

i = intensity of rainfall in cm/hr

c = Runoff Coefficient

Empirical formulae for rainfall intensities

These relationships between rainfall intensity and duration are developed based on long term experience in field (Figure). Under Indian conditions, intensity of rainfall in design is usually in the range 12 mm/h to 20 mm/h. In general, the empirical relationship has the following forms:

$$I = a / (t + b) \quad \text{OR} \quad I = b / t^n$$

Where, a, b, and n are constants.

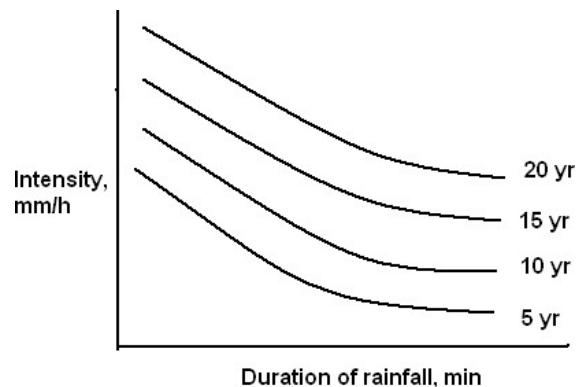


Figure : Relationship of rainfall duration and intensity

British Ministry of Health formula

$$I = 760 / (t + 10) \quad (\text{for storm duration of 5 to 20 minutes}) \quad (10)$$

$$I = 1020 / (t + 10) \quad (\text{for storm duration of 20 to 100 minutes}) \quad (11)$$

Where, I is intensity of rainfall, mm/h and t is duration of storm, minutes.

Examples

Q1. Determine designed discharge for a combined system serving population of 50000 with rate of water supply of 135 LPCD. The catchment area is 100 hectares and the average coefficient of runoff is 0.60. The time of concentration for the design rainfall is 30 min and the relation between intensity of rainfall and duration is $I = 1000/(t + 20)$.

Solution

Estimation of sewage quantity

Considering 80% of the water supplied will result in wastewater generation,

The quantity of sanitary sewage

$$= 50000 \times 135 \times 0.80 = 5400 \text{ m}^3/\text{day}$$

$$= 0.0625 \text{ m}^3/\text{sec}$$

Considering peak factor of 2.5,

$$\begin{aligned}\text{The design discharge for sanitary sewage} &= 0.0625 \times 2.5 \\ &= 0.156 \text{ m}^3/\text{sec}\end{aligned}$$

Estimation of storm water discharge

Intensity of rainfall, $I = 1000/(t + 20)$ Therefore, $I = 1000/(30 + 20) = 20 \text{ mm/h}$ Hence, storm water runoff,

$$\begin{aligned}Q &= C.I.A/360 \\ &= 0.6 \times 20 \times 100/(360) \\ &= 3.33 \text{ m}^3/\text{sec}\end{aligned}$$

Therefore, design discharge for combined sewer = $3.33 + 0.156 = 3.49 \text{ m}^3/\text{sec}$

Q2. The catchment area is of 300 hectares. The surface cover in the catchment can be classified as given below:

Type of cover	Coefficient of runoff	Percentage
Roofs	0.90	15
Pavements and yards	0.80	15
Lawns and gardens	0.15	25
Roads	0.40	20
Open ground	0.10	15
Single family dwelling	0.50	10

Calculate the runoff coefficient and quantity of storm water runoff, if intensity of rainfall is 30 mm/h for rain with duration equal to time of concentration. If population density in the area is 350 persons per hectare and rate of water supply is 200 LPCD, calculate design discharge for separate system, partially separate system, and combined system.

Solution

Estimation of storm water discharge for storm water drain of separate system

Overall runoff coefficient $C = [A_1.C_1 + A_2.C_2 + \dots + A_n.C_n] / [A_1 + A_2 + \dots + A_n]$

$$= \frac{(0.15 \times 0.90 + 0.15 \times 0.80 + 0.25 \times 0.15 + 0.20 \times 0.4 + 0.15 \times 0.1 + 0.10 \times 0.5)}{0.15 + 0.15 + 0.25 + 0.20 + 0.15 + 0.10}$$
$$= 0.44$$

Therefore quantity of storm water, $Q = C.I.A/360$

$$= 0.44 \times 30 \times 300/360$$
$$= 11 \text{ m}^3/\text{sec}$$

Estimation of sewage discharge for sanitary sewer of separate system

Quantity of sanitary sewage = $300 \times 350 \times 200 \times 0.80 = 16800 \text{ m}^3/\text{day}$

$$= 0.194 \text{ m}^3/\text{sec}$$

Considering peak factor of 2, the design discharge for sanitary sewers = 0.194×2

$$= 0.389 \text{ m}^3/\text{sec}$$

Estimation of discharge for partially separate system

Storm water discharge falling on roofs and paved courtyards will be added to the sanitary sewer.

This quantity can be estimated as:

$$\text{Average coefficient of runoff} = (0.90 \times 45 + 0.80 \times 45) / 90$$
$$= 0.85$$

$$\text{Discharge} = 0.85 \times 30 \times 90 / 360 = 6.375 \text{ m}^3/\text{sec}$$

Therefore total discharge in the sanitary sewer of partially separate system = $6.375 + 0.389$

$$= 6.764 \text{ m}^3/\text{sec},$$

$$\text{and the discharge in storm water drains} = 11 - 6.375 = 4.625 \text{ m}^3/\text{sec}$$

General Consideration Design and Planning of Sewerage System

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

area from a rain of design frequency and of duration equal to the time of concentration.

Requirements of Design and Planning of Sewerage System

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

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

Provision of Freeboard in Sewers

Sanitary Sewers

Sewers with diameter less than 0.4 m are designed to run half full at maximum discharge, and sewers with diameter greater than 0.4 m are designed to flow $\frac{2}{3}$ to $\frac{3}{4}$ full at maximum discharge. The extra space provided in the sewers provides factor of safety to counteract against the following factors:

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

Storm Water Drains

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

Hydraulic Formulae for Determining Flow Velocities

Sewers of any shape are hydraulically designed as open channels, except in the case of inverted siphons

and discharge lines of pumping stations. Following formulae can be used for design of sewers.

1. Manning's Formula

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

$$V = \frac{1}{n} m^{2/3} \sqrt{i}$$

Where,

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

m = Hydraulic mean depth of flow, $m = a/p$

a = Cross section area of flow, m^2

p = Wetted perimeter, m

n = Roughness coefficient, depends upon the type of the channel surface i.e., material and lies between 0.011 and 0.015.

For brick sewer it could be 0.017 and 0.03 for stone facing sewers.

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

2. Chezy's Formula

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

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

3. Crimp and Burge's Formula

$$v = 83.5 m^{2/3} \sqrt{i}$$

4. Hazen- Williams Formula

$$V = 0.849 C m^{0.63} i^{0.54}$$

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

Minimum Velocity: Self Cleansing Velocity

The velocity that would not permit the solids to settle down and even scour the deposited particles of a given size is called as self-cleansing velocity. This minimum velocity should at least

develop once in a day so as not to allow any deposition in the sewers. Otherwise, if such deposition takes place, it will obstruct free flow causing further deposition and finally leading to the complete blocking of the sewers. This minimum velocity or self-cleansing velocity can be worked out as below:

$$V_s = \sqrt{\frac{8}{f} \left(\frac{\rho_s - \rho}{\rho} \right) g \cdot d_s}$$

Where,

(5)

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

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

ρ = specific gravity of the liquid, in case of sewage it is water having $\rho=1$

ρ_s = Specific gravity of sediments g = gravity acceleration

d' = diameter of grain.

Hence, for removing the impurities present in sewage i.e., sand up to 1 mm diameter with specific gravity 2.65 and organic particles up to 5 mm diameter with specific gravity of 1.2, it is necessary that a minimum velocity of about 0.45 m/sec and an average velocity of about 0.9 m/sec should be developed in sewers.

Hence, while finalizing the sizes and gradients of the sewers, they must be checked for the minimum velocity that would be generated at minimum discharge, i.e., about 1/3 of the average discharge.

While designing the sewers the flow velocity at full depth is generally kept at about 0.8 m/sec or so. Since, sewers are generally designed for ½ to ¾ full, the velocity at ‘designed discharge’ (i.e., ½ to ¾ full) will even be more than 0.8 m/sec. Thus, the minimum velocity generated in sewers will help in the following ways:

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

Maximum Velocity or Non-scouring Velocity

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

material of sewer. The limiting velocity for different sewer material is provided in Table.

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

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

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

Effect of Flow Variations on Velocities in a Sewer

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

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

Example: 1

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

Solution

$$Q = A.V$$

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

Solving for half full sewer, $m = D/4$

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

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

Design of Storm Water Drains for Separate System

Important points for design

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

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

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

Laying of Sewer Pipes

- Sewers are generally laid starting from their outfall ends towards their starting points. With this advantage of utilization of the tail sewers even during the initial periods of its construction is possible.
- It is common practice, to first locate the points where manholes are required to be constructed as per drawing, i.e., L-section of sewer, and then laying the sewer pipe straight between the two manholes.
- The central line of the sewer is marked on the ground and an offset line is also marked parallel to the central line at suitable distance, about half the trench width plus 0.6 m. This line can be drawn by fixing the pegs at 15 m intervals and can be used for finding out center line of the sewer simply by offsetting.
- The trench of suitable width is excavated between the two manholes and the sewer is laid between them. Further excavation is then carried out for laying the pipes between the next consecutive manholes. Thus, the process is continued till the entire sewers are laid out.
- The width of the trench at the bottom is generally kept 15 cm more than the diameter of the sewer pipe, with minimum 60 cm width to facilitate joining of pipes.
- If the sewer pipes are not to be embedded in concrete, such as for firm grounds, then the

bottom half portion of the trench is excavated to confirm the shape of the pipe itself. In ordinary or softer grounds, sewers are laid embedded in concrete.

- The trench is excavated up to a level of the bottom embedding concrete or up to the invert level of the sewer pipe plus pipe thickness if no embedding concrete is provided. The designed invert levels and desired slope as per the longitudinal section of the sewer should be precisely transferred to the trench bottom.
- After bedding concrete is laid in required alignment and levels. The sewer pipes are then lowered down into the trench either manually or with the help of machines for bigger pipe diameters.
- The sewer pipe lengths are usually laid from the lowest point with their sockets facing up the gradient, on desired bedding. Thus, the spigot end of new pipe can be easily inserted on the socket end of the already laid pipe.

Hydraulic Testing of Sewers

i) Test for Leakage or Water Test

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

ii) 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.

iii) Back filling 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.

SEWER APPURTENANCES:

Sewer systems require various types of appurtenances for the proper functioning and maintenance, because if simply sewers are laid, the sewage cannot flow in it continuously for longer time. After some time, it will be choked up and will require cleaning of sewers.

Manholes

The manhole is masonry or R.C.C. chamber constructed at suitable intervals along the sewer lines, for providing access into them. Thus, the manhole helps in inspection, cleaning and maintenance of sewer. These are provided at every bend, junction, change of gradient or change of diameter of the sewer. The sewer line between the two manholes is laid straight with even gradient. For straight sewer line

manholes are provided at regular interval depending upon the diameter of the sewer. The spacing of manhole is recommended in IS 1742-1960. For sewer up to 0.3 m diameter or sewers which cannot be entered for cleaning or inspection the maximum spacing between the manholes recommended is 30 m, and 300 m spacing for pipe greater than 2.0 m diameter (below table). A spacing allowance of 100 m per 1 m diameter of sewer is a general rule in case of very large sewers (CPHEEO, 1993). The internal dimensions required for the manholes are provided in Table (CPHEEO, 1993). The minimum width of the manhole should not be less than internal diameter of the sewer pipe plus 150 mm benching on both the sides.

Table: Spacing of Manholes

Pipe Diameter	Spacing
Small sewers	45 m
0.9 to 1.5 m	90 to 150 m
1.5 to 2.0 m	150 to 200 m
Greater than 2.0 m	300 m

Table : The minimum internal dimensions for manhole chambers

Depth of sewer	Internal dimensions
0.9 m or less depth	0.90 m x 0.80 m
For depth between 0.9 m and 2.5 m	1.20 m x 0.90 m, 1.2 m dia. for circular
For depth above 2.5 m and up to 9.0 m	For circular chamber 1.5 m dia.
For depth above 9.0 m and up to 14.0 m	For circular chamber 1.8 m dia.

Classification of Manholes

Depending upon the depth the manholes can be classified as:

(a) Shallow Manholes, (b) Normal Manholes, and (c) Deep Manholes

i) **Shallow Manholes:** These are 0.7 to 0.9 m depth, constructed at the start of the branch sewer or at a place not subjected to heavy traffic conditions (Figure). These are provided with light cover at top and called inspection chamber.

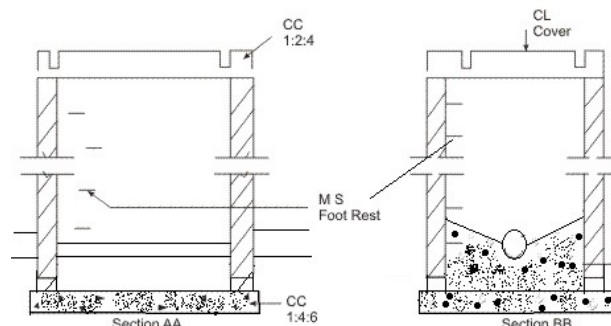


Figure Shallow manhole

ii) **Normal Manholes:** These manholes are 1.5 m deep with dimensions 1.0 m x 1.0 m square or rectangular with 1.2 m x 0.9 m (Figure). These are provided with heavy cover at its top to support the anticipated traffic load.

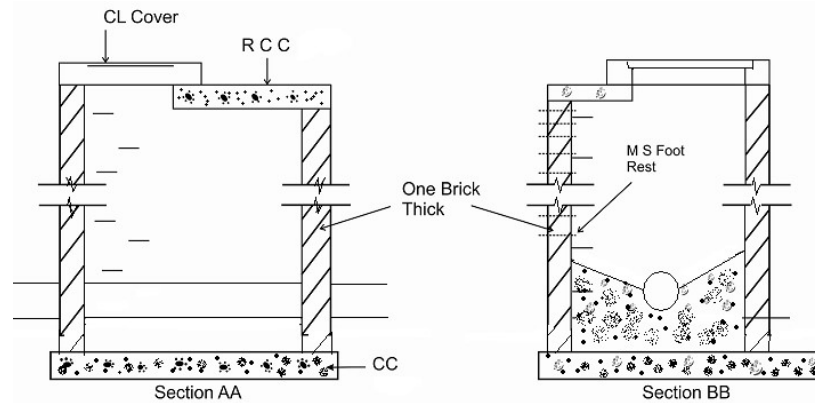
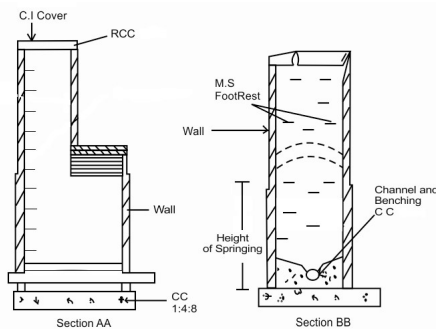
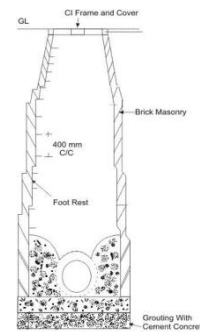


Figure Rectangular manhole for depth 0.9 m to 2.5 m

iii) **Deep Manholes:** The depth of these manholes is more than 1.5 m. The section of such manhole is not uniform throughout (Figure). The size in upper portion is reduced by providing an offset. Steps are provided in such manholes for descending into the manhole. These are provided with heavy cover at its top to support the traffic load.



(a) Rectangular and



(b) Circular deep manhole

→Other Types of Manholes

*Straight – Through Manholes

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

*Junction Manholes

This type of manholes are constructed at every junction of two or more sewers, and on the curved portion of the sewers, with curved portion situated within the manhole. This type of manholes can be constructed with the shape other than rectangular to suit the curve requirement and achieve economy. The soffit of the smaller sewer at junction should not be lower than that of the larger sewer. The gradient of the smaller sewer may be made steeper from the previous manhole to reduce the difference of invert at the point of junction to a convenient amount.

****Side entrance Manholes***

In large sewers where it is difficult to obtain direct vertical access to the sewer from the top ground level due to obstructions such as, other pipe lines like water, gas, etc., the access shaft should be constructed in the nearest convenient position off the line of sewer, and connected to the manhole chamber by a lateral passage. The floor of the side entrance passage which should fall at about 1 in 30 towards the sewer should enter the chamber not lower than the soffit level of the sewer. In large sewers necessary steps or a ladder (with safety chain or removable handrail) should be provided to reach the benching from the side entrance above the soffit.

****Drop Manholes***

When a sewer connects with another sewer, where the difference in level between invert level of branch sewer and water line in the main sewer at maximum discharge is greater than 0.6 m, a manhole may be built either with vertical or nearly vertical drop pipe from higher sewer to the lower one (Figure 8.4). The drop manhole is also required in the same sewer line in sloping ground, when drop more than 0.6 m is required to control the gradient and to satisfy the maximum velocity i.e., non-scouring velocity.

The drop pipe may be outside the shaft and encased in concrete or supported on brackets inside the shaft. If the drop pipe is outside the shaft, a continuation of the sewer should be built through the shaft wall to form a rodding and inspection eye, provided with half blank flange (Figure). When the drop pipe is inside the shaft, it should be of cast iron and provided with adequate arrangements for rodding and with water cushion of 150 mm depth at the end. The diameter of the drop pipe should be at least equal to incoming pipe.

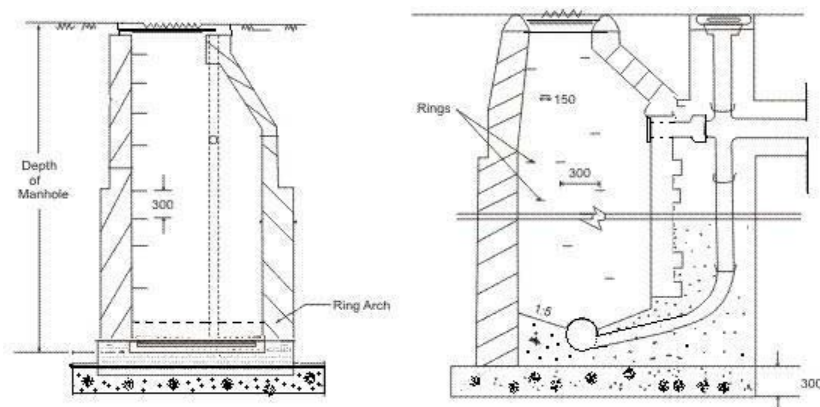


Figure: Drop manhole

****Scraper (service) type manhole***

All sewers above 450 mm in diameter should have one manhole at intervals of 110 to 120 m of

scraper type. This manhole should have clear opening of 1.2 m x 0.9 m at the top to facilitate lowering of buckets.

****Flushing Manholes***

In flat ground for branch sewers, when it is not possible to obtain self cleansing velocity at all flows, due to very little flow, it is necessary to incorporate flushing device. This is achieved by making grooves at intervals of 45 to 50 m in the main drains in which wooden planks are inserted and water is allowed to head up. When the planks are removed, the water will rush with high velocity facilitating cleaning of the sewers. Alternatively, flushing can be carried out by using water from overhead water tank through pipes and flushing hydrants or through fire hydrants or tankers and hose.

Flushing manholes are provided at the head of the sewers. Sufficient velocity shall be imparted in the sewer to wash away the deposited solids. In case of heavy choking in sewers, care should be exercised to ensure that there is no possibility of back flow of sewage into the water supply mains.

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. Inverted siphons are used to pass under obstacles such as buried pipes, subways, etc (Fig.). This terminology 'siphon' is misnomer as there is no siphon action in the depressed sewer. As the inverted siphon requires considerable attention for maintenance, it should be used only where other means of passing an obstacle in line of the sewer are impracticable.

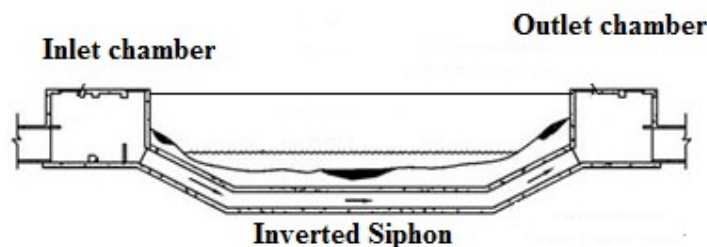


Figure: Inverted siphon

SEWER VENTILATORS

Ventilation to the sewer is necessary to make provision for the escape of air to take care of the exigencies of full flow and to keep the sewage as fresh as possible. In case of stormwater, this can be done by providing ventilating manhole covers. In modern sewerage system, provision of ventilators is not necessary due to elimination of intercepting traps in the house connections allowing ventilation.

LAMP HOLE

It is an opening or hole constructed in a sewer for purpose of lowering a lamp inside it. It consists of

stoneware or concrete pipe, which is connected to sewer line through a T-junction as shown in the Figure. The pipe is covered with concrete to make it stable. Manhole cover of sufficient strength is provided at ground level to take the load of traffic. An electric lamp is inserted in the lamp hole and the light of lamp is observed from manholes. If the sewer length is unobstructed, the light of lamp will be seen. It is constructed when construction of manhole is difficult. In present practice as far as possible the use of lamp hole is avoided. This lamp hole can also be used for flushing the sewers. If the top cover is perforated it will also help in ventilating the sewer, such lamp hole is known as fresh air inlet.

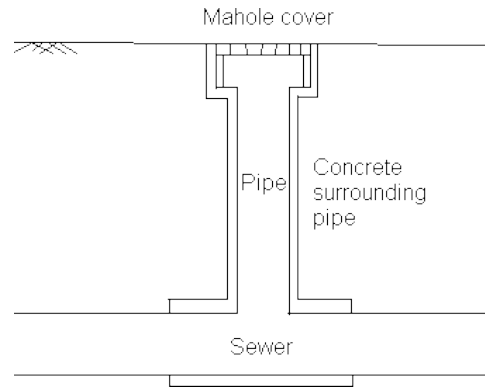


Figure: Lamp hole

UNIT – I

Introduction to sanitation – systems of sanitation – relative merits & demerits – collection and conveyance of waste water – sewerage – classification of sewerage systems- Estimation of sewage flow and storm water drainage – fluctuations – types of sewers - Hydraulics of sewers and storm drains– design of sewers – appurtenances in sewerage – cleaning and ventilation of sewers.

TERMINOLOGY

REFUSE:

This is the most general term to indicate the wastes which include all the rejects left as worthless, sewage, sullage – all these terms are included in this term.

GARBAGE:

It is a dry refuse which includes, waste papers, sweepings from streets and markets, vegetable peelings etc. The quantity of garbage per head per day amounts to be about .14 to .24 kg for Indian conditions. Garbage contains large amount of organic and purifying matter and therefore should be removed as quickly as possible.

RUBBISH:

It consists of sundry solid wastes from the residencies, offices and other buildings. Broken furniture, paper, rags etc are included in this term. It is generally dry and combustible.

SULLAGE:

It is the discharge from the bath rooms, kitchens, wash basins etc., it does not include discharge from the lavatories, hospitals, operation theaters, slaughter houses which has a high organic matter.

SEWAGE:

It is a dilute mixture of the wastes of various types from the residential, public and industrial places. It includes sullage water and foul discharge from the water closets, urinals, hospitals, stables, etc.

STORM WATER:

It is the surface runoff obtained during and after the rainfall which enters sewers through inlet. Storm water is not foul as sewage and hence it can be carried in the open drains and can be disposed off in the natural rivers without any difficulty.

SANITARY SEWAGE:

It is the sewage obtained from the residential buildings & industrial effluents establishments. Being extremely foul it should be carried through underground conduits.

DOMESTIC SEWAGE:

It is the sewage obtained from the lavatory basins, urinals & water closets of houses, offices & institutions. It is highly foul on account of night soil and urine contained in it. Night soil starts putrefying & gives offensive smell. It may contain large amount of bacteria due to the excremental wastes of patients. This sewage requires great handling & disposal.

INDUSTRIAL SEWAGE:

It consists of spent water from industries and commercial areas. The degree of foulness depends on the nature of the industry concerned and processes involved.

SEWERS:

Sewers are underground pipes which carry the sewage to a point of disposal.

SEWERAGE:

The entire system of collecting, carrying & disposal of sewage through sewers is known as sewerage.

DRY WEATHER FLOW (DWF):

Domestic sewage and industrial sewage collectively, is called as DWF. It does not contain storm water. It indicates the normal flow during dry season.

BACTERIA:

These are the microscopic organisms. The following are the groups of bacteria:

- Aerobic bacteria: they require oxygen & light for their survival.
- Anaerobic bacteria: they do not require free oxygen and light for survival.
- Facultative bacteria: they can exist in the presence or absence of oxygen. They grow more in absence of air.

INVERT:

It is the lowest point of the interior of the sewer at any c/s.

SLUDGE:

It is the organic matter deposited in the sedimentation tank during treatment.

CONCEPTS**Necessity for sanitation**

Every community produces both liquid and solid wastes. The liquid portion –waste water– is essentially the water supply of the community after it has been fouled by a variety of uses such as spent water from bathroom kitchen, lavatory basins, house and street washings, from various industrial processes semi solid wastes of human and animal excreta, dry refuse of house and street sweepings, broken furniture, wastes from industries etc are produced daily.

If proper arrangements for the collection, treatment and disposal are not made, they will go on accumulating and create foul condition. If untreated water is accumulating, the decomposition of the organic materials it contains can lead to the production of large quantity of mal odorous gases. It also contains nutrients, which can stimulate the growth of aquatic

plants and it may contain toxic compounds. Therefore in the interest of community of the city or town, it is most essential to collect, treat and dispose of all the waste products of the city in such a way that it may not cause any hazardous effects on people residing in town and environment.

Waste water engineering is defined as the branch of the environmental engineering where the basic principles of the science and engineering for the problems of the water pollution problems. The ultimate goal of the waste water management is the protection of the environmental in manner commensurate with the economic, social and political concerns.

Although the collection of stream water and drainage dates from ancient times the collection of waste water can be treated only to the early 1800s. The systematic treatment of waste water followed in the 1800s and 1900s.

Importance of sewerage system

One of the fundamental principles of sanitation of the community is to remove all decomposable matter, solid waste, liquid or gaseous away from the premises of dwellings as

fast as possible after it is produced, to a safe place , without causing any nuisance and dispose it in a suitable manner so as to make it permanently harmless.

Sanitation though motivated primarily for meeting the ends of preventive health has come to be recognized as a way of life. In this context, development of the sanitation infrastructure of any country could possibly serve as a sensitive index of its level of prosperity. It is needless to emphasize that for attaining the goals of good sanitation, sewerage system is very essential. While provision of potable drinking water takes precedence in the order of provision of Environmental Engineering Services, the importance of sewerage system cannot be last sight and cannot be allowed to lag behind, as all the water used by the community has to flow back as the sewage loaded with the wastes of community living, unless properly collected , treated and disposed off , this would create a serious water pollution problems.

Methods of domestic waste water disposal:

After the waste water is treated it is disposed in the nature in the following two principal methods

- a. Disposal by Dilution where large receiving water bodies area available
- b. Land disposal where sufficient land is available

The choice of method of disposal depends on many factors and is discussed later.

Sanitary engg starts at the point where water supply engg ends.It can be classified as

- Collection works
- Treatment works
- Disposal works

The collection consists of collecting tall types of waste products of town. Refuse is collected separately. The collection works should be such that waste matters can be transported quickly and steadily to the treatment works. The system employed should be self cleaning and economical.

Treatment is required to treat the sewage before disposal so that it may not pollute the atmosphere & the water body in which it will be disposed of .The type of treatment processes depend on the nature of the waste water characteristics and hygiene, aesthetics and economical aspects.

The treated water is disposed of in various ways by irrigating fields or discharging in to natural water courses.

Different Methods of domestic waste water disposal include (Systems of Sanitation):

- 1) CONSERVENCY SYSTEM
- 2) WATER CARRIAGE SYSTEM

CONSERVENCY SYSTEM:

Sometimes the system is also called as dry system. This is out of date system but is prevailing in small towns and villages. Various types of refuse and storm water are collected conveyed and disposed of separately. Garbage is collected in dustbins placed along the roads from where it is conveyed by trucks ones or twice a day to the point of disposal. all the non combustible portion of garbage such as sand dust clay etc are used for filling the low level areas to reclaim land for the future development of the town. The combustible portion of the garbage is burnt. The decaying matters are dried and disposed of by burning or the manufacture of manure.

Human excreta are collected separately in conservancy latrines. The liquid and semi liquid wastes are collected separately after removal of night soil it is taken outside the town in

trucks and buried in trenches. After 2-3 years the buried night soil is converted into excellent manure. In conservancy system sewage and storm water are carried separately in closed drains to the point of disposal where they are allowed to mix with river water without treatment.

WATER CARRIAGE SYSTEM

With development and advancement of the cities urgent need was felt to replace conservancy system with some more improved type of system in which human agency should not be used for the collection and conveyance of sewage. After large number of experiments it was found that the water is the only cheapest substance which can be easily used for the collection and conveyance of sewage. As in this system water is the main substance therefore it is called as WATER CARRIAGE SYSTEM.

In this system the excremental matter is mixed up in large quantity of water their are taken out from the city through properly designed sewerage systems, where they are disposed of after necessary treatment in a satisfactory manner.

The sewages so formed in water carriage system consist of 99.9% of water and .1% solids. All these solids remain in suspension and do not changes the specific gravity of water therefore all the hydraulic formulae can be directly used in the design of sewerage system and treatment plants.

SEWERAGE SYSTEMS:

http://Easyengineering.net SEWAGE SYSTEM	WATER CARRIAGE SYSTEM
Very cheap in initial cost.	It involves high initial cost.
Due to foul smells from the latrines, they are to be constructed away from living room so building cannot be constructed as compact units.	As there is no foul smell latrines remain clean and neat and hence are constructed with rooms, therefore buildings may be compact.
The aesthetic appearance of the city cannot be improved	Good aesthetic appearance of city can be obtained.
For burial of excremental matter large area is required.	Less area is required as compared to conservancy system.
Excreta is not removed immediately hence its decomposition starts before removal.	Excreta are removed immediately with water, no problem of foul smell or hygienic trouble.
This system is fully depended on human agency .In case of strike by the sweepers; there is danger of insanitary conditions in	As no human agency is involved in this system ,there is no such problem as in case of conservancy system

- 1) SEPARATE SYSTEM OF SEWAGE
- 2) COMBINED SYSTEM OF SEWAGE
- 3) PARTIALLY COMINED OR PARTIALLY SEPARATE SYSTEM

SEPARATE SYSTEM OF SEWERAGE

In this system two sets of sewers are laid .The sanitary sewage is carried through sanitary sewers while the storm sewage is carried through storm sewers. The sewage is carried to the treatment plant and storm water is disposed of to the river.

Advantages:

- 1) Size of the sewers are small

- 2) Sewage load on treatment unit is less
- 3) Rivers are not polluted
- 4) Storm water can be discharged to rivers without treatment.

Disadvantage

- 1) Sewerage being small, difficulty in cleaning them
- 2) Frequent choking problem will be their
- 3) System proves costly as it involves two sets of sewers
- 4) The use of storm sewer is only partial because in dry season the will be converted in to dumping places and may get clogged.

COMBINED SYSTEM OF SEWAGE

When only one set of sewers are used to carry both sanitary sewage and surface water. This system is called combined system.

Sewage and storm water both are carried to the treatment plant through combined sewers

Advantages:

- 1) Size of the sewers being large, choking problems are less and easy to clean.
- 2) It proves economical as 1 set of sewers are laid.
- 3) Because of dilution of sanitary sewage with storm water nuisance potential is reduced

Disadvantages:

- 1) Size of the sewers being large, difficulty in handling and transportation.
- 2) Load on treatment plant is unnecessarily increased
- 3) It is uneconomical if pumping is needed because of large amount of combined flow.
- 4) Unnecessarily storm water is polluted

PARTIALLY COMINED OR PARTIALLY SEPARATE SYSTEM

A portion of storm water during rain is allowed to enter sanitary sewer to treatment plants while the remaining storm water is carried through open drains to the point of disposal. **Advantages:-**

1. The sizes of sewers are not very large as some portion of storm water is carried through open drains.
2. Combines the advantages of both the previous systems.
3. Silting problem is completely eliminated.

Disadvantages:-

1. During dry weather, the velocity of flow may be low.
2. The storm water is unnecessary put load on to the treatment plants to extend.
3. Pumping of storm water in unnecessary over-load on the pumps.

Suitable conditions for separate sewerage systems:-

A separate system would be suitable for use under the following situations:

Where rainfall is uneven.

Where sanitary sewage is to be pumped.

The drainage area is steep, allowing to runoff quickly.

Sewers are to be constructed in rocky strata. The large combined sewers would be more expensive.

conditions for combined system:-

Rainfall in even throughout the year.

Both the sanitary sewage and the storm water have to be pumped.

The area to be sewered is heavily built up and space for laying two sets of pipes is not enough.

Effective or quicker flows have to be provided.

After studying the advantages and disadvantages of both the systems, present day construction of sewers is largely confined to the separate systems except in those cities where

combined system is already existing. In places where rainfall is confined to one

SL no.	Separate system	Combined system
1.	The quantity of sewage to be treated is less, because no treatment of storm water is done.	As the treatments of both are done, the treatment is costly.
2.	In the cities of more rainfall this system is more suitable.	In the cities of less rainfall this system is suitable.
3.	As two sets of sewer lines are to laid, this system is cheaper because sewage is carried in underground sewers and storm	Overall construction cost is higher than separate system.
4.	In narrow streets, it is difficult to use this system.	It is more suitable in narrow streets.
5.	Less degree of sanitation is achieved in this system, as storm water is disposed without any treatment.	High degree of sanitation is achieved in this system.

season of the year, like India and even in temperate regions, separate system are most suitable.

Sources of Sewage:-

Sanitary sewage is produced from the following sources:

1. When the water is supplied by water works authorities or provided from private sources, it is used for various purposes like bathing, utensil cleaning, for flushing water closets and urinals or washing clothes or any other domestic use. The spent water for all the above needs forms the sewage.
2. Industries use the water for manufacturing various products and thus develop the sewage.
3. Water supplied to schools, cinemas, hotels, railway stations, etc., when gets used develops sewage.
4. Ground water infiltration into sewers through loose joints.
5. Unauthorized entrance of rain water in sewer lines.

Nature of Sewage:-

Sewage is a dilute mixture of the various types of wastes from the residential, public and industrial places. The characteristics and composition i.e. The nature of sewage mainly depends on this source. Sewage contains organic and inorganic matters which may be dissolved, suspension and colloidal state. Sewage also contains various types of bacteria, Virus, protozoa, etc. sewage may also contain toxic or other similar materials which might have got entry from industrial discharges. Before the design of any sewage treatment plant the knowledge of the nature of sewage is essential.

Quantity of Sanitary Sewage and Storm Water:-

The determination of sanitary sewage is necessary because of the following factors which depend on this:

1. To design the sewerage schemes as well as to dispose a treated sewage efficiently.
2. The size, shape and depth of sewers depend on quantity of sewage.
3. The size of pumping unit depends on the quantity of sewage.

Estimate of Sanitary Sewage:-

Sanitary sewage is mostly the spent water of the community into sewer

system with some groundwater and a fraction of the storm runoff from the area, draining into it. Before designing the sewerage system, it is essential to know the quantity of sewage that will flow through the sewer.

The sewage may be classified under two heads:

1. The sanitary sewage, and
2. Storm water

Sanitary sewage is also called as the Dry Weather Flow (D.W.F), which includes the domestic sewage obtained from residential and residential and industrials etc., and the industrial sewage or trade waste coming from manufacturing units and other concerns.

Quantity of Sewage:-

It is usual to assume that the rate of sewage flow, including a moderate allowance for infiltration equals to average rate of water consumption which is 135 litre/ head /day according to Indian Standards. It varies widely depending on size of the town etc. this quantity is known as Dry Weather Flow (D.W.F). It is the quantity of water that flows through sewer in dry weather when no storm water is in the sewer.

Rate of flow varies throughout 24 hours and is usually the greatest in the fore-noon and very small from midnight to early morning. For determining the size of sewer, the maximum flow should be taken as three times the D.W.F.

Design Discharge of Sanitary Sewage

The total quantity of sewage generated per day is estimated as product of forecasted population at the end of design period considering per capita sewage generation and appropriate peak factor. The per capita sewage generation can be considered as 75 to 80% of the per capita water supplied per day. The increase in population also result in increase in per capita water demand and hence, per capita production of sewage. This increase in water demand occurs due to increase in living standards, betterment in economical condition, changes in habit of people, and enhanced demand for public utilities.

Factors affecting the quantity of sewage flow:-

The quantity of sanitary sewage is mainly affected by the following factors:

1. Population
2. Type of area
3. Rate of water supply
4. Infiltration and exfiltration

In addition to above, it may also be affected by habits of people, number of industries and water pressure etc.

The quantity of sanitary sewage directly depends on the population. As the population increases the quantity of sanitary sewage also increases. The quantity of water supply is equal to the rate of water supply multiplied by the population. There are several methods used for forecasting the population of a community. The quantity of sanitary sewage also depends on the type of area as residential, industrial or commercial. The quantity of sewage developed from residential areas depend on the rate of water supply to that area, which is expressed a litres/ capita/ day and this quantity is obtained by multiplying the population with this factor.

The quantity of sewage produced by various industries depends on their various industrial processes, which is different for each industry. Similarly the quantity of sewage obtained from commercial and public places can be determined by studying the development of other such places.

Rate of water

Truly speaking the quantity of used water discharged into a sewer system should be a little less than the amount of water originally supplied to the community. This is because of the fact that all the water supplied does not reach sewers owing to such losses as leakage in pipes or such deductions as lawn sprinkling, manufacturing processes etc. However, these losses may be largely be made up by such additions as surface drainage, groundwater infiltration, water supply from private wells etc. On an average, therefore, the quantity of sewage maybe considered to be nearly equal to the quantity of water supplied. Ground water infiltration and exfiltration.

The quantity of sanitary sewage is also affected by groundwater infiltration through joints. The quantity will depend on, the nature of soil, materials of sewers, type of joints in sewer line, workmanship in laying sewers and position of

underground water table.

Infiltration causes increase to the —legitimate flows in urban sewerage systems. Infiltration represents a slow response process resulting in increased flows mainly due to seasonally- elevated groundwater entering the drainage system, and primarily occurring through defects in the pipe network.

Exfiltration represents losses from the sewer pipe, resulting in reduced conveyance flows and is due to leaks from defects in the sewer pipe walls as well as overflow discharge into manholes, chambers and connecting surface water pipes. The physical defects are due to a combination of factors including poor construction and pipe joint fittings, root penetration, illicit connections, biochemical corrosion, soil conditions and traffic loadings as well as aggressive groundwater.

It is clear that Infiltration and Exfiltration involve flows passing through physical defects in the sewer fabric and they will often occur concurrently during fluctuations in groundwater levels, and particularly in association with wet weather events; both of which can generate locally high hydraulic gradients. Exfiltration losses are much less obvious and modest than infiltration gains, and are therefore much more difficult to identify and quantify.

However, being dispersed in terms of their spatial distribution in the sewer pipe, exfiltration losses can have potentially significant risks for groundwater quality. The episodic but persistent reverse —pumping effect of hydraulic gain and loss will inevitably lead to long term scouring of pipe surrounds and foundations resulting in pipe collapse and even surface subsidence.

Suggested estimates for groundwater infiltration for sewers laid below

	Minimum	Maximum
Litre/ day/ hectare	5,000	50,000
Lpd/ km of sewer/cm dia.	500	5,000

ground water table are as follows:

Design period

Following design period can be considered for different components of sewerage scheme.

1. Laterals less than 15 cm diameter : Full development
2. Trunk or main sewers : 40 to 50 years

3. Treatment Units : 15 to 20 years

4. Pumping plant : 5 to 10 years

Variations in sewage flow:-

The sewage flow, like the water supply flow, is not constant in practice but varies. The fluctuation may, in a similar way, be seasonal or monthly, daily and hourly.

Variation occurs in the flow of sewage over annual average daily flow. Fluctuation in flow occurs from hour to hour and from season to season. The typical hourly variation in the sewage flow is shown in the Figure. If the flow is gauged near its origin, the peak flow will be quite pronounced. The peak will defer if the sewage has to travel long distance. This is because of the time required in collecting sufficient quantity of sewage required to fill the sewers and time required in travelling. As sewage flow in sewer lines, more and more sewage is mixed in it due to continuous increase in the area being served by the sewer line. This leads to reduction in the fluctuations in the sewage flow and the lag period goes on increasing. The magnitude of variation in the sewage quantity varies from place to place and it is very difficult to predict.

For smaller township this variation will be more pronounced due to lower length and travel time before sewage reach to the main sewer and for large cities this variation will be less. The seasonal variations are due to climatic effect, more water being used in summer than in winter. The daily fluctuations are the outcome of certain local conditions, involving habits and customs of people. Thus, in U.S.A. and other European countries, Monday is the washing day, as such, amount of sewage flow would be much greater than on any other day. In India, however, Sundays or other holidays involve activities which permit greater use of water. Hourly variations are because of varying rates of water consumption in different hours of the day.

The first peak flow generally occurs in the late morning it is usually about 200 percent of the average flow while the second peak flow generally occurs in the early evening between 6 and 9 p.m. and the minimum flow occurring during the night after twelve or early hours of the morning is generally about half of the average flow.

Effects of Flow Variation on Velocity in a Sewer

Due to variation in discharge, the depth of flow varies, and hence the hydraulic mean depth (r) varies. Due to the change in the hydraulic mean depth, the flow velocity (which depends directly on $r^{2/3}$) gets affected from time to time. It is necessary to check the sewer for maintaining a minimum velocity of about 0.45 m/s at the time of minimum flow (assumed to be 1/3rd of average flow). The designer should also ensure that a velocity of 0.9 m/s is developed atleast at the time of maximum flow and preferably during the average flow periods also. Moreover, care should be taken to see that at the time of maximum flow, the velocity generated does not exceed the scouring value.

Quantity of storm water

When rain falls over the ground surface, a part of it percolates into the ground, a part is evaporated in the atmosphere and the remaining part overflows as storm water. This quantity of storm water is very large as compared with sanitary sewage.

Factors affecting storm water:-

The following are factors which affect the quantity of storm water:

1. Rainfall intensity and duration.
2. Area of the catchment.
3. Slope and shape of the catchment area.
4. Nature of the soil and the degree of porosity.
5. Initial state of the catchment.

If rainfall intensity and duration is more, large will be the quantity of storm water available. If the rainfall takes place very slowly even though it continues for the whole day, the quantity of storm water available will be less. Harder surface yield more runoff than soft, rough surfaces. Greater the catchment area greater will be the amount of storm water. Fan shaped and steep areas contribute more quantity of storm water. In addition to the above it also depends on the temperature, humidity, wind etc.

Estimate of quantity of storm water:-

Generally there are two methods by which the quantity of storm water is calculated:

1. Rational method

2. Empirical formulae method

In both the above methods, the quantity of storm water is a function of the area, the intensity of rainfall and the co-efficient of runoff.

Rational method:-

Runoff from an area can be determined by the Rational Method. The method gives a reasonable estimate up to a maximum area of 50 ha (0.5 Km²).

Assumptions and Limitations

Use of the rational method includes the following assumptions and limitations:

- Precipitation is uniform over the entire basin.
- Precipitation does not vary with time or space.
- Storm duration is equal to the time of concentration.
- A design storm of a specified frequency produces a design flood of the same frequency.
- The basin area increases roughly in proportion to increases in length.
- The time of concentration is relatively short and independent of storm intensity. The runoff coefficient does not vary with storm intensity or antecedent soil moisture.
- Runoff is dominated by overland
- Basin storage effects are negligible.

The minimum duration to be used for computation of rainfall intensity is 10 minutes. If the time of concentration computed for the drainage area is less than 10 minutes, then 10 minutes should be adopted for rainfall intensity computations. This method is mostly used in determining the quantity of storm water. The storm water quantity is determined by the rational formula:

$$Q = \frac{AIR}{360}$$

Hydraulic Design of Sewers

4.1. INTRODUCTION

The sewage, to be transported through sewers, is mostly liquid (*i.e.* water), containing hardly 0.1 to 0.2 percent of solid matter in the form of organic matter, sediments and minerals. Hence the general approach for the design of sewers is similar to the design of water mains. However, there are two differences in the designs of the sewers and of the water mains :

(i) *Presence of solid matter* : Water flowing through the water mains is practically free from solid matter, while the sewage flowing thro' sewers contain particles of solid matter (both organic as well as inorganic). These solid particles settle at the bottom and have to be dragged during the sewage transport. In order that the sewers are not clogged, they are to be laid at such a gradient that *self cleansing velocity* is achieved, at all value of discharges. Also the inner surface of the sewers must be resistant to the abrasive action of these solid particles.

(ii) *Pressure* : Water in the water mains flow under pressure. Hence the water mains can be carried, within certain limits, up and down the hill or gradient. The hydraulic gradient line lies very much above the pipe surface. On the other hand in most cases, sewers may be considered as open channels, wherein the sewage runs under gravity. The sewers seldom run full, and the H.G. line falls within the sewer. Hence the sewers must be laid at continuous downward gradient. Sewers run under pressure only when they are designed as force mains and as inverted siphons.

4.2. HYDRAULIC FORMULAE

The design of sewers is done on the basis of the following empirical hydraulic formulae : (1) Chezy's formula (2) Kutter's formula (3) Bazin's formula (4) Manning's formula (5) Crimp and Bruges formula (6) Hazen and Williams's formula.

Apart from these formulae, there are various charts, diagrams, graphs and tables with the help of which the hydraulic design of sewers can be done. The factors that influence the flow of sewage in the sewers are : (1) Slope of sewer (2) Geometry of sewer (3) Roughness of interior surface of sewer (4) Bends, transitions, obstructions etc. (5) Flow conditions and (6) Characteristics of sewage.

1. Chezy's formula. Chezy (1775) gave the following formula:

$$V = C \sqrt{RS} \quad \dots(4.1)$$

where

V = velocity of flow (m/sec.)

S = hydraulic gradient or slope of the sewer

R = hydraulic mean radius (m) = A/P

A = area of cross-section (m^2)

P = wetted perimeter.

C = Chezy's constant

The Chezy's constant C is very complex in nature, and it depends upon several factors, such as roughness of inner surface of sewer, hydraulic mean radius, size and shape of sewer, slope etc. Generally, the value of Chezy's constant C is found either by Kutter's formula or by Bazin's formula. Knowing the velocity of flow V from Eq. 4.1, the channel section is designed by the general formula :

$$Q = A \times V$$

where

Q = discharge in $m^3/sec.$

2. Kutter's formula. Kutter and Ganguillet (1869), two Swiss engineers, gave the following expression for Chezy's coefficient C :

$$C = \frac{23 + \frac{0.00155}{S} + \frac{1}{N}}{1 + \left(23 + \frac{0.00155}{S} \right) \frac{N}{\sqrt{R}}} \quad \dots(4.2)$$

where

R = hydraulic mean radius ; S = slope.

N = rugosity coefficient the value of which depends upon the nature of inside surface of the sewer (Table 4.1).

Usually, the values corresponding to fair condition of the surface are taken in the design. A reduction in the value of N has been reported with the increase in the diameter of the sewer. For cement concrete pipes of dia. 600 mm and above, $N = 0.013$ may be adopted.

TABLE 4.1. VALUES OF KUTTER'S OR MANNING'S COEFFICIENT N

<i>Conduit Material</i>		<i>Condition of interior surface</i>	
		<i>Good</i>	<i>Fair</i>
1.	Salt glazed stoneware	0.012	0.014
2.	Cement concrete	0.013	0.015
3.	Cast Iron	0.012	0.013
4.	Brick, unglazed	0.013	0.015
5.	Asbestos cement	0.011	0.012
6.	Plastic smooth	0.011	0.011

3. Bazin's formula. Bazin (1897) gave the following formula for Chezy's constant:

$$C = \frac{157.6}{1.81 + \frac{K}{\sqrt{R}}} \quad \dots(4.3)$$

where K = Bazin's constant, the value of which may be taken from Table 4.2.

TABLE 4.2 BAZIN'S CONSTANT K

<i>S.N.</i>	<i>Type or Nature of inside surface of sewer or drain</i>	<i>K</i>
1.	Very smooth surface	0.109
2.	Smooth brick or concrete surface	0.29
3.	Rough brick or concrete surface	0.833
4.	Smooth rubble masonry surface	1.54
5.	Good earthen channels	0.50
6.	Rough earthen channel	3.17

4. Manning's Formula. Manning (1890) gave the following expression for velocity of flow. The formula is widely used in U.S.A. as well as in India :

$$V = \frac{1}{N} R^{2/3} S^{1/2} \quad \dots(4.4)$$

where V , N , R , S have the same meanings, as above. The value of rugosity coefficient N is the same as suggested by Kutter, and may be taken from Table 4.1.

5. Crimp and Bruge's formula. This formula is commonly used in England

$$V = 83.47 R^{2/3} S^{1/2} \quad \dots(4.5)$$

where V , R and S have the same meanings, as defined earlier. Comparing this with Manning's formula, we have.

$$V = 83.47 R^{2/3} S^{1/2} = \frac{R^{2/3} S^{1/2}}{N}$$

which gives $N = 1/83.47 = 0.012$. Hence Manning's formula becomes Crimp and Bruges formula when $N = 0.012$.

For a circular pipe, $R = \frac{A}{P} = \frac{\frac{\pi}{4} D^2}{\pi D} = \frac{D}{4}$.

$\therefore V = 83.47 \left(\frac{D}{4} \right)^{2/3} S^{1/2}$

Now, $Q = A \times V = \frac{\pi}{4} D^2 \times 83.47 \left(\frac{D}{4} \right)^{2/3} S^{1/2}$

or $Q = 26.02 D^{8/3} S^{1/2} \dots(4.6)$

6. **Hazen and William's formula.** Allen Hazen and G.S. Williams (1902) gave the following formula, which is mostly used for flow under pressure :

$$V = 0.85 C R^{0.63} S^{0.54} \dots(4.7)$$

The coefficient C may be taken from Table 4.3.

TABLE 4.3. HAZEN AND WILLIAM'S COEFFICIENT C

4.4. MINIMUM VELOCITY OF FLOW

The sewage flowing through a sewer contains organic as well as inorganic solid matter which remains suspended as the sewage flows. In order to keep the solid matter in suspended form, a certain minimum velocity of flow is required, otherwise the solid particles will settle in the sewer, resulting in its clogging. Such a minimum velocity is known as *self-cleansing velocity*.

A *self cleansing velocity* may be defined as that velocity at which the solid particles will remain in suspension, without settling at the bottom of the sewer. Also it is that velocity at which even the scour of the deposited particles of a given size will take place. It is not possible to maintain this self-cleansing velocity throughout the day because of fluctuations in sewage flow. During minimum flow of sewage, the velocity of flow is less than the self cleansing velocity. Hence self cleansing velocity should be maintained at least once in a day.

Shield's expression for self-cleaning velocity. The self-cleansing property of sewage depends upon the scouring action of the flowing sewage. According to Shield, the velocity required to transport water-

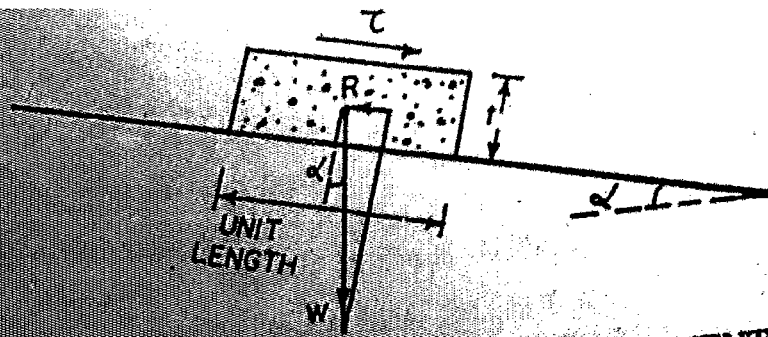


FIG. 4.6. FORCES ACTING ON SEDIMENT.

borne solids is the *self cleansing velocity* which can be determined with reference to Fig. 4.6.

Consider a layer of sediment of unit length, unit width and thickness t , deposited at the invert of the sewer. Let the slope of the sewer be α . The drag force or the intensity of tractive force (τ) exerted by the flowing water on a channel is given by :

$$\tau = \gamma_w \cdot R \cdot S \quad \dots(i) \dots(4.8 a)$$

where γ_w = unit weight of water at the prevailing temperature
 R = hydraulic radius of filled section.
 S = slope of the invert, or head loss per unit length of sewer.

The submerged unit weight of the sediment is given by

$$\gamma_{sub} = \gamma_w \left(\frac{G_s - 1}{1 + e} \right) = \gamma_w (G_s - 1) (1 - n) \quad \dots(ii)$$

where G_s = specific gravity of sediment
 e = voids ratio of sediment deposit.

∴ Weight of sediment of unit length and unit width is given by

$$W = \gamma_{sub} \times 1 \times 1 \times t$$

$$W = \gamma_w (G_s - 1) (1 - n) t \quad \dots(iii)$$

The frictional resistance R is given by

$$R \approx W \sin \alpha = \gamma_w (G_s - 1) (1 - n) t \cdot \sin \alpha \quad \dots(iv) \dots(4.8 b)$$

where α is the friction angle.

When the sediment is just on the point of sliding,

$$\tau = R$$

$$\gamma_w \cdot R \cdot S = \gamma_w (G_s - 1) (1 - n) t \cdot \sin \alpha$$

Putting $(1 - n) \sin \alpha = k$, where k is the important characteristic of the sediment, to be determined by experiments, we get

$$S = \frac{k}{R} (G_s - 1) t \quad \dots(v)$$

For single grains, the volume per unit area t becomes the function of the diameter of the grains d_s as an inverse measure of the surface area of the individual grains exposed to drag or friction.

$$\therefore S = \frac{k}{R} (G_s - 1) d_s \quad \dots(vi)$$

Eq. (vi) gives the invert slope at which the velocity will be self-cleansing.

Now, from Chezy's equation,

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

Denoting $V = V_s$ as self-cleaning velocity, and substituting the value of S from Eq. (vi), we get.

$$V_s = C \sqrt{R} \sqrt{\frac{k}{R} (G_s - 1) d_s}$$

$$\text{or} \quad V_s = C \sqrt{k (G_s - 1) d_s} \quad \dots(vii)$$

In order to get the value of Chezy's constant C , let us use Darcy-Weisbach, formula for head loss H_L :

$$H_L = \frac{f L V^2}{2g D} \quad (\text{where } D = \text{pipe dia.})$$

$$\therefore S = \frac{H_L}{L} = \frac{f V^2}{2g D}$$

$$\text{Now} \quad V = C \sqrt{RS}$$

$$\therefore C \sqrt{R} = \frac{V}{\sqrt{S}} = \sqrt{\frac{2g D}{f}}$$

For circular pipes running full, $R = D/4$

$$\therefore C \sqrt{\frac{D}{4}} = \sqrt{\frac{2g D}{f}}$$

$$\text{or} \quad C = \sqrt{\frac{8g}{f}} \quad \dots(viii)$$

Substituting this value of C , in Eq. (vii),

$$V_s = \sqrt{\frac{8\beta}{f} (G_s - 1) g d_s} \quad \dots(4.8)$$

where V_s = self cleansing velocity.

β = Characteristics of solids flowing in the sewage, in suspension.
This value of β may be taken as 0.04 for initiating scour of clean grit to 0.8 for full removal of sticky grit. Actual magnitude of k has to be found from experiments.

f = Darcy-Weisbach friction factor, the common value of which may be taken as 0.03.

G_s = specific gravity of sediments/solids flowing in the sewage.
Its value may range from 2.65 for inorganic sediments to 1.2 for organic sediments.

g = gravitational acceleration constant.

d_s = diameter of solid particles, to be carried by the liquid.

From Eq. 4.8, it is evident that heavier particles and sticky particles require higher velocity for their transport than lighter and cleaner particles. Table 4.5 gives the value of self-cleansing velocities for various types of particles, as recommended by Beardmore. Similarly, Table 4.6 gives the self-cleansing velocities for sewers of various diameters, as recommended by Badwin Latham.

TABLE 4.5. SELF-CLEANSING VELOCITIES.

S.N.	Nature of material	Self cleansing velocity (cm/sec)
1.	Angular stones	100
2.	Round pebbles (12 mm to 25 mm dia)	50-60
3.	Fine gravel	30
4.	Coarse sand	20
5.	Fine sand and clay	15
6.	Fine clay and silt	7.5

TABLE 4.6. SELF-CLEANSING VELOCITIES.

S.N.	Diameter of sewer (cm)	Self cleansing velocity (cm/sec)
1.	15 to 25	100
2.	30 to 60	75
3.	Above 60	60

4.5. MAXIMUM VELOCITY OF FLOW

Though the minimum velocity of flow of sewage should be equal to the self-cleansing velocity so that particles do not settle and stick to the invert, there is also some upper limit of velocity of flow so that the interior surface of the sewer is not damaged due to wear. At higher velocity, the flow becomes turbulent, resulting in continuous abrasion of the interior surface of the sewer, by the suspended particles. Hence maximum velocity of flow is also limited. The maximum velocity at which no such scouring action or abrasion takes place is known as *non-scouring velocity*. Evidently such a velocity depends upon the material used for the construction of sewers. Of the ceramic materials used in sewers, vitrified tiles and glazed bricks are more resistant to wear while building bricks and concrete are less resistant to wear. Also, abrasion is maximum at the bottom of the sewer, because the grit, sand etc. are heavy and travel along the invert. Due to this reason, the bottom of large sewers of brick or concrete are protected by lining them with vitrified tile, glazed bricks or granite blocks. Table 4.7 gives the non-scouring velocity for various materials used for sewer construction.

TABLE 4.7 NON-SCOURING VELOCITIES.

S.N.	Material of sewer	Non scouring velocity (cm/sec)
1.	Earth channels	60 to 120
2.	Ordinary brick-lined sewers	150—250
3.	Cement Concrete sewers	250—300
4.	Stone ware sewers.	300—450
5.	Cast Iron sewer pipes	350—450
6.	Vitrified tile and glazed bricks	450—500

Effect of variations of discharge on velocity in sewers. As stated earlier, the discharge in a sewer does not remain constant at all times. It varies from time to time. Due to the variation in discharge, the hydraulic mean depth (R) also varies. Since the velocity of flow is a function of $R^{2/3}$, the velocity of flow also varies as the sewage discharge varies. This is more prominent in the case of a combined sewer or in a partially combined sewer.

As the flow decreases in the sewer, the velocity of flow also decreases. When the sewer becomes less than half full, (assumed at one third the average flow), it is essential to check that the velocity of flow is atleast equal to 40 cm/sec. At the same time, the designer should ensure that a velocity of about 90 cm/sec is developed outleat at the time of maximum flow. While designing the sewers, the following points should be observed in connection with the self-cleansing velocity and non-scouring velocity.

1. Before the sewer design is done, the discharge is known. Hence the velocity of flow and gradient of the sewers are to be appropriately determined and correlated, to achieve the desired results.

2. For sewers in flat country, the design of sewers should be done in such a way that self-cleansing velocity is obtained at maximum discharge. However, the section of sewer should be such that even at minimum discharge, the velocity is at least equal to 40 cm/sec.

3. For sewers in roughs country, the design of sewers should be done in such a way that self-cleansing velocity is obtained at minimum discharge while non-scouring velocity is obtained at maximum discharge. If due to steep slopes, the velocity is exceeded during maximum discharge, drop man holes should be provided to bring down the velocity within the non-scouring value.

4. In the case of combined sewer, it may be difficult to achieve self-clearing velocity during minimum flow (D.W.F.). In that case, special form of sewers (such as the one shown in Fig. 4.10) should be adopted.

4.6. HYDRAULIC ELEMENTS OF CIRCULAR SEWERS

Sewers of circular cross-section are more commonly used. However 'egg-shaped' sewers are also used and their hydraulic characteristics have been discussed in § 4.7.

Circular sewers offer the following advantages :

1. They are very easily manufactured.
 2. A circular section gives the maximum area for a given perimeter, and thus gives the greatest H.M.D. when running full or half full. It is therefore the most efficient section at these flow conditions.
 3. It is the most economical section since it utilises minimum quantities of the material.
- The circular section has uniform curvature all round, and hence offers less opportunities for deposits.

A circular sewer may run either full or partially full. However the advantage at S.N. 2 above is obtained when the sewer runs *half-full*. This advantage is lost if the depth of flow becomes less than half full, since both the velocity as well as discharge reduce with the reduction in the depth of flow. It will be seen from other part of this article that minimum grades are enough for circular sewers flow more than half full. However, when the depth of flow is less than half full, grades must be doubled for equal self-cleansing.

Consider a circular section running full. Let D be the internal diameter of the circular sewer.

$$\text{Area of cross-section} \quad A = \frac{\pi}{4} D^2 \quad \dots(4.9 \ a)$$

$$\text{Wetted perimeter} \quad P = \pi D \quad \dots(4.9 \ b)$$

$$\text{Hydraulic mean depth} \quad R = A/P = D/4 \quad \dots(4.9 \ c)$$

Consider a circular sewer running partially full. Fig 4.7 shows a

circular sewer running partially full.

Let d be the depth of flow.

Let θ be the central angle subtended by the water surface.

Let A be the area of the cross-section of the water.

Let P be the wetted perimeter of the water.

Let R be the hydraulic mean depth of the water.

Let h be the height of the water surface above the center of the sewer.

Let h_c be the height of the center of the sewer above the water surface.

Let h_t be the height of the water surface above the sewer bed.

Let h_b be the height of the sewer bed above the water surface.

Let h_s be the height of the sewer surface above the water surface.

Let h_d be the height of the sewer ditch above the water surface.

Let h_e be the height of the sewer exit above the water surface.

Let h_f be the height of the sewer fall above the water surface.

Let h_g be the height of the sewer gate above the water surface.

Let h_h be the height of the sewer head above the water surface.

Let h_i be the height of the sewer inlet above the water surface.

Let h_j be the height of the sewer joint above the water surface.

Let h_k be the height of the sewer key above the water surface.

Let h_l be the height of the sewer lock above the water surface.

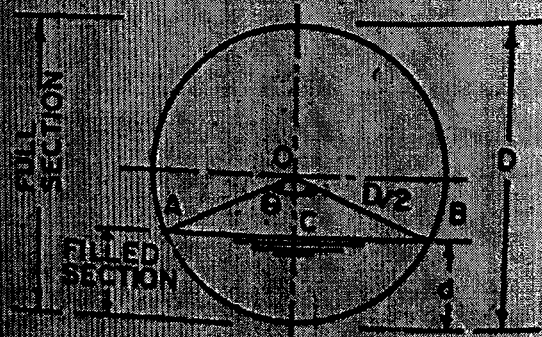


FIG. 4.7

$$\text{Area of water surface} \quad A = \frac{D^2}{2} \left(\theta - \cos \theta \sin \theta \right) \quad \dots(4.11 \ a)$$

$$\text{Wetted perimeter of water surface} \quad P = D \theta \quad \dots(4.11 \ b)$$

$$\text{Hydraulic mean depth of water surface} \quad R = \frac{A}{P} = \frac{D}{2} \left(\frac{\theta - \cos \theta \sin \theta}{\theta} \right) \quad \dots(4.11 \ c)$$

2. Area

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

$$a = \frac{\pi D^2}{4} \left[\frac{\theta}{360^\circ} - \frac{\sin \theta}{2\pi} \right] \quad \dots(4.12 \text{ a})$$

or

$$\therefore \text{Proportional area} = \frac{a}{A} \left[\frac{\theta}{360^\circ} - \frac{\sin \theta}{2\pi} \right] \quad \dots(4.12)$$

3. Wetted perimeter

$$p = \pi D \cdot \frac{\theta}{360} \quad \dots(4.13 \text{ a})$$

$$\therefore \text{Proportional perimeter} = \frac{p}{P} = \frac{\theta}{360^\circ} \quad \dots(4.13)$$

4. H.M.D.

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

$$r = \frac{D}{4} \left[1 - \frac{360^\circ \sin \theta}{2\pi \theta} \right] \quad \dots(4.14 \text{ a})$$

or

$$\therefore \text{Proportional H.M.D. } \frac{r}{R} = \left[1 - \frac{360^\circ \sin \theta}{2\pi \theta} \right] \quad \dots(4.14)$$

5. Velocity of flow

$$v = \frac{1}{n} r^{2/3} S^{1/2} \text{ (Manning's)}$$

where

n = Mannings rugosity coefficient applicable for partial flow condition.

$$\text{Proportional velocity} = \frac{v}{V} = \frac{N}{n} \cdot \left(\frac{r}{R} \right)^{2/3} \quad \dots(4.15 \text{ b})$$

$$\text{If } \frac{N}{n} = 1.0, \frac{v}{V} = \left(\frac{r}{R} \right)^{2/3} = \left[1 - \frac{360^\circ \sin \theta}{2\pi \theta} \right]^{2/3} \quad \dots(4.15)$$

6. Discharge

$q = a \times v$
Taking $N/n = 1.0$, we have

$$\text{Proportionate discharge} = \frac{q}{Q} = \frac{a \cdot v}{A \cdot V} = \frac{a}{A} \times \left(\frac{r}{R} \right)^{2/3} \quad \dots(4.16)$$

$$\frac{q}{Q} = \left[\frac{\theta}{360^\circ} - \frac{\sin \theta}{2\pi} \right] \left[1 - \frac{360^\circ \sin \theta}{2\pi \theta} \right]^{2/3} = \frac{\theta}{360} \left[1 - \frac{360^\circ \sin \theta}{2\pi \theta} \right]^{5/3} \quad \dots(4.16 \text{ a})$$

For variable values of $\frac{N}{n}$, we get

all the joints in the live and looking for air bubbles.

5.12. CLEANING AND MAINTENANCE OF SEWERS

Maintenance of sewers in general relates to the work of keeping any installed sewerage facility in a working condition for the benefit of the people for whom it is intended. Maintenance of sewers consists mainly of the removal or prevention of stoppages, cleaning of sewers and other sewer appurtenances, and repair works. Sewers should be properly cleaned and maintained in good working condition. Sewer maintenance function are two often treated as necessary evil. Maintenance may be *preventive or routine maintenance* which constitutes work executed and precaution taken to prevent any breakdown of sewerage facilities or *corrective maintenance* which constitutes work of repairs after a breakdown has occurred. Preventive maintenance is more economical and provides for reliability in operation of sewerage facilities ; nevertheless, corrective maintenance will also have to be provided for, as the breakdowns are possible inspite of preventive maintenance.

Problems in sewer maintenance. Main problems which are faced in sewer maintenance are : (a) Clogging of sewers, and (b) Hazards.

(a) **Clogging of sewers** : sewer may be clogged because of the following factors :

1. Grit and other detritus may get deposited in the sewer. This will create stagnation resulting in the putrefaction of organic matter present in the sewerage, giving rise to odours and poisonous gases. The grease from hot liquid wastes from kitchen, finding entry into sewers, may get deposited on the sides, on cooling, and thus leading to clogging.

2. Roots from plants and nearby trees may penetrate through the joints or cracks in the sewers, resulting in the eventual clogging of the sewers.

3. The growth of fungi results in the formation of a network of tendrils which start floating, and thus offering an obstruction to the flow in side the sewers.

4. Tarry materials may get deposited. This assists in binding the detritus and leading to their growth.

5. Due to improper working of pumping units, sewerage become stagnant in the sewer, resulting in the settlement of grit and other material and dumping of solid wastes in the man holes indiscriminately.

(b) **Hazards** : Persons engaged in operation and maintenance of sewerage systems, including those at sewage pumping stations, are exposed to different types of occupational hazards like (i) physical injuries (ii) injuries caused by chemicals and radio-active wastes (iii) infections caused by pathogenic organisms in sewage, and (iv) dangers inherent with explosive or noxious vapors and oxygen deficiency. To guard against human error and carelessness, proper *job instructions* and adequate effective supervision by competent personnel are most essential. The most hazardous element during inspection is the presence of gas in sewers. 'Sewer gas' is a mixture of gases in sewers and manholes containing abnormally high percentage of carbon dioxide, varying amounts of methane, hydrogen, hydrogen sulphide and low percentage of oxygen caused by septic action through the accumulation of organic matter in the sewer. The actual hazard is due to the presence of high level of methane forming and explosive mixture or the oxygen deficiency or hydrogen sulphide in excess of permissible levels. Some trade wastes may also contribute to other gases like chlorine, ammonia, sulphur dioxide etc.

Safety precautions against gas hazards. While entering with man holes, the following precautions should be observed :

1. Traffic warning signs should be erected.
2. No smoking or open flames should be allowed and sparks should be guarded against.

3. Only safety, explosion-proof electric lighting equipment or mirrors for reflection of light should be used.

4. The atmosphere should be tested for noxious gas and oxygen deficiency.

5. If the atmosphere is normal, the worker may enter in the manhole or sewer with safety harness attached with two men available at the top.

6. If any noxious gas or oxygen deficiency is found, forced ventilation should be resorted to using portable blower.

7. Frequent tests for noxious gases and oxygen deficiency should be conducted even if initial tests are satisfactory, as conditions may change during the period workers are inside the manhole or sewers.

8. If forced ventilation is not possible or is not satisfactory and men have to enter urgently, such as in saving a life, a gas mask should be worn and extreme care taken to avoid all sources of ignition if inflammable gas is present. Only permissible safety light (not ordinary flash light), rubbers or non-sparking shoes and non-sparking tools should be used.

9. Only personal experienced in line and familiar with the dangers involved in working in a noxious gas environment and fully equipped with the proper protective safety equipment should be allowed to enter.

Safety equipments. Following are various safety equipments normally required in sewer maintenance work :

(i) Gas mask (ii) Oxygen breathing apparatus (iii) Portable lighting equipment (iv) Portable air blowers (v) Non-sparking tools (vi) Safety belts (vii) Inhalators.

(i) **Gas mask** : Gas masks provide respiratory protection from low and moderately high concentrations of all types of toxic gases and vapors present in the atmosphere in which there is insufficient oxygen to support life. A gas mask consists of face piece, a canister containing purifying chemical, a timer for showing duration of service and a harness for support. Gas masks can not be used in oxygen deficient atmosphere or in unventilated locations or area where large concentration of poisonous gases exist.

(ii) **Oxygen breathing apparatus** : This apparatus gives respiratory protection from the atmosphere containing toxic gases or that which is deficient in oxygen. This can be either an air hose respirator type or pure oxygen respirator.

(iii) **Portable lighting equipment** : These consists of permissible type portable electric hand lamps, electric cap lamps and explosion proofs flash lights, for doing work inside the sewer lines.

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(iv) **Portable air blowers** : These blowers, powered by enclosed explosion proof electric motors provide forced ventilation of manholes. Trailer mounted blowers having a capacity of $210 \text{ m}^3/\text{min}$. can ventilate easily many metres of medium sized sewers.

(v) **Non-sparking tools** : These are made of an alloy containing atleast 80% of copper, that will not spark, when struck against other objects and metals, and yet have sufficient strength and resistance to wear and tear.

(vi) **Safety belts** : This consists of a body belt with a buckle and a shoulder harness. It is used along with a life line and both of these should be tested by lifting the wearer clear of ground before each day's work. A life line consists of a high grade spliced manila rope or a steel cable anchored with rings, on each side of the belt and provided with safety straps for anchoring or securing to a stable support. The life line should be about 15 m in length and the overall assembly should withstand a tensile load of 2000 kg.

(viii) **Inhalators** : Inhalators, employing mixture of oxygen and carbon dioxide are used for resuscitating victims of gas collapse, drowning or electric shock. Artificial respiration should be started at once on the patient and an inhalater face piece attached to the victim's mouth as soon as the equipment can be made ready. The carbon dioxide used in small percentages simulates deep breathing so that more oxygen can be inhaled. Pure oxygen should be used only when irritant gases such as hydrogen sulphide or chlorine have caused the victim's collapse.

Sewer clearing equipment and devices. Following equipment is used for sewer cleaning work :

(1) Portable pump set (2) Sectional sewer rods. (3) Flexible sewer rod. (4) Ferret used in conjunction with a fire hose. (5) Sewer cleaning bucket machine. (6) Dredger (7) Rodding machine with flexible sewer rods. (8) Scraper. (9) Hydraulically propelled devices such as (i) flush bags (ii) sewer balls, (iii) sewer scooter.

1. **Portable pump set** : Pumping is resorted to where sewers are blocked completely and sewage has accumulated in manholes. In that case, the collected sewage has to be pumped out to tackle the sewer blockage.

2. **Sectional sewer rods** : Sectional sewer rods are made of bamboo or teakwood or light metal, and are usually of 1 m length having coupling at end. This coupling remains intact in the sewer but can be easily disjointed in the manhole. Sections of the rods are pushed down in the sewer until the obstruction is reached and dislodged. The front or advancing end of the sewer rod is fitted with a cutting edge to cut and dislodge the obstructions. Sewer rods

are used to clean small sewers. They may also be used to locate obstruction in big sewers.

3. *Flexible sewer rods* : These are used for routine cleansing of sewers. The rod is made by sandwiching a manila rope between bamboo strips and tying at short interval.

4. *Ferret used in conjunction with a fire hose* : In this case, a ferret of sufficient strength is attached to a fire hose of sufficient length to reach at least the next manhole. It is used for breaking and removing sand stoppages. The high velocity jet stream of water is used from the those connected sides of the sewer. The forward stream loosens the accumulated debris ahead of the tool and the rear jets of the ferret admit water to wash the sand back down-stream, where it can be removed from the manhole manually.

5. *Sewer cleaning bucket machine* : The machine consists of two powered winches with cable in between. The winches are centred over two adjacent manholes of the sewer section to be cleaned. The cable is threaded through the sewer line by means of sewer rods. The cable from the drum of each winch is fastened to the barrel on each end of an expansion sewer bucket fitted with closing device, so that the bucket can be pulled in either direction by machine on the appropriate end.

6. *Dredger* : A dredger, used to clean larger manholes, consists of a crane and a pulley with the help of which a grab bucket is lowered. The grab bucket scrapes the bottom deposits and brings it to the ground. The disadvantage in this system is that it can not clean the corners of the catchpits of manholes.

7. *Rodding machine with flexible sewer rods* : Rather than operating the flexible sewer rods manually, these can be operated mechanically. The equipment consists of a machine which rotates a flexible rod to which is attached the cleansing tool such as auger, cork screw or hedgehog and sand cups. The flexible rod consists of a series of steel rods with screw couplings. The rod is pulled in and out in quick succession when the tool is engaging the obstruction, so as to dislodge or loosen it.

8. *Scraper* : Scraper, used for clearing sewers of dia. larger than 750 mm, consists of an assembly of wooden planks of slightly smaller size than the sewer to be cleaned. The scraper chains, being attached to a control chain in the manhole where it is lowered, is connected to a winch on the next downstream manhole by means of chains. The heading up of the flow behind the scraper will also assist in pushing it in the forward direction. This ensures that the bottom and the side of the sewer are cleaned thoroughly.

9. **Automatic flushing tanks** : These tanks employ an outside water source with a controlled flow so that required quantity of water is released at predetermined interval. These are used for routine cleaning of sewers.

10. **Hydraulically propelled devices** : Hydraulically propelled devices, such as *flush bags*, *sewer balls* or *sewer scooter* take advantage of force of empounded water to effectively clean sewers.

(i) **Flush bag** : A flush bag or sewer flushed is a canvas bag or rubber bag equipped with a fire hose coupler at one end and a reducer at the other end. The flusher is connected to the fire hose and placed in the downstream end from the point where a choke is located. The bag is allowed to fill up until it expands and seals the sewer. The upstream pressure built up due to this damming effect breaks loose the obstructions.

(ii) **Sewer balls, and sewer pills** : Sewer balls are simple elastic pneumatic type rubber balls, available in different sizes, which can be blown up to varying degree of inflation. The inflated ball of appropriate size is wrapped in a canvass cloth, the edges of which are sewed together, and a trial line, a little longer than the distance between the man holes is attached securely to the covering. Immediately the ball is thrust into the sewer, sewage commences to back up in the manhole and continues to rise until such time as its pressure is great enough to force sewage under the ball and moving it down stream through the pipe. Acting as a compressible floating plug, it affords enough obstruction, so that a continuous high velocity just spurts under and around to some extent around the ball, thereby sluicing all the movable material ahead of the next manhole. A *sewer pill*, which is a wooden ball, can also be used for this purpose, specially for cleaning large outfall sewers.

(iii) **Sewer scooter** : This is an improved version of the scraper and consists of two jacks, a controlling rope and the scooter with a tight fitting shield. The scooter attached to the control rope is lowered into the manhole and then into the downstream sewer line. The downstream manhole jack is lowered into place from the road and the upper manhole jack set across the top of the manhole. When the scooter is lowered into the sewer line, it stops the flow of sewage thus building up a head behind the shield. The resulting pressure causes the scooter to move through the sewer until it accumulates enough debris to stop its movement. The head is then allowed to build up approximately 1 m before the control rope is pulled, causing the shield to fold back, thus allowing the accumulated sewage to gush into the sewer downstream flushing the debris ahead to the next manhole from where it is removed. The control rope

is released, clearing the shield against the sewage and causing the scooter to advance again until the debris stops its movement. This process is repeated till the scooter reaches the downstream manhole.

5.13. VENTILATION OF SEWERS

Sewers are properly ventilated to fulfill the following purposes:

(i) *Continuous flow* : Ventilation relieves air pressure above or below atmospheric caused due to sudden rise or fall of sewage. Due to this, *air locks* will not be formed and continuous flow of sewage inside the sewer will be ensured.

(ii) *Disposal of sewer gases* : Ventilation prevents accumulation of explosive, corrosive or poisonous gases and vapors. The sewer gases include ammonia, carbon monoxide, carbon dioxide, methane (CH_4), nitrogen, sulphuretted hydrogen (H_2S), petrol vapor etc. Methane gas, being explosive, may even blow off the manhole covers, if it is not removed by proper ventilation. These gases also interfere with the natural flow of sewage.

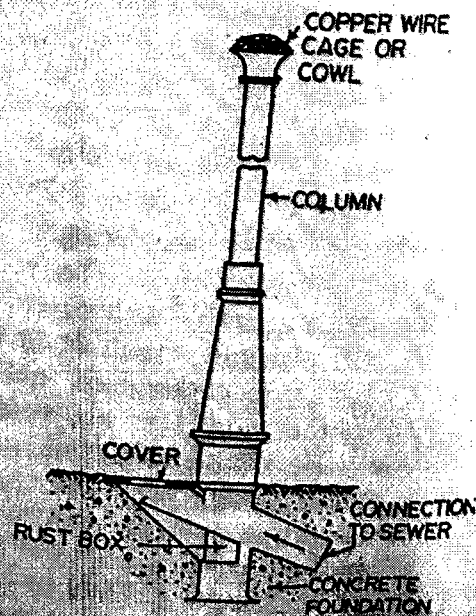
(iii) *Prevention of unpleasant odours* : Ventilation prevents concentration of unpleasant odours, causing nuisance.

Methods of ventilation. Ventilation may be done by adopting the following methods.

1. *Man holes with gratings* : The man hole covers are provided with perforations or gratings through which sewer gases escape. However, this method can not be adopted in residential locality since it will spread foul smell and will cause air pollution. It is adopted only in isolated localities. Another disadvantage of this method is that it permits road dust, large quantities of storm water and other debris.

2. *Ventilating columns or shafts* : Ventilation columns or shafts are provided at the upper end of every branch sewer and also at every change in size of sewers, apart from their regular placement at the interval of about 200 to 300 m along the sewer lines.

Ventilating column (Fig. 5.29) consists of a vertical shaft made by joining cast iron or steel pipe lengths. A foundation block is provided at the bottom end to



keep it steady in the vertical position. At the top, copper wire dome or cowl prevent blockage by nesting birds. Foul gases escape from the cowl. The internal diameter of the column is preferably kept one third the diameter of the sewer served by it. The joints of pipes forming the column should be made air tight. The height of the shaft should be sufficient to effectively discharge the foul gases and to be clear of the flat roof of the nearby buildings. The location of the shaft should be such that it obtains sunshine for the major portion of the day.

3. Proper design and construction of sewer : Sewer should be so designed that they run half or two third full. The space above the flow level will provide ventilation. Also, the flow velocity should be self-cleansing. This can be achieved by laying the sewers at proper gradients.

4. Proper house drainage system : House vent and soil pipes may be used with advantage to ventilate house drain and the lateral sewers into which they drain, particularly where interceptors are not provided on the sewers connecting houses and buildings.

5. Unobstructed outlets : Unobstructed outlets provide partial ventilation to storm water drains and sewers.

6. Use of mechanical devices : Forced draft is provided by exhaust fans to expel out foul gases from sewers.

Sewer Appurtenances

The structures, which are constructed at suitable intervals along the sewerage system to help its efficient operation and maintenance, are called as sewer appurtenances. These include:

- (1) Manholes, (2) Drop manholes, (3) Lamp holes,
- (4) Clean-outs, (5) Street inlets called Gullies, (6) Catch basins,
- (7) Flushing Tanks, (8) Grease & Oil traps, (9) Inverted Siphons, and
- (10) Storm Regulators.

8.1 Manholes

The manhole is masonry or R.C.C. chamber constructed at suitable intervals along the sewer lines, for providing access into them. Thus, the manhole helps in inspection, cleaning and maintenance of sewer. These are provided at every bend, junction, change of gradient or change of diameter of the sewer. The sewer line between the two manholes is laid straight with even gradient. For straight sewer line manholes are provided at regular interval depending upon the diameter of the sewer. The spacing of manhole is recommended in IS 1742-1960. For sewer up to 0.3 m diameter or sewers which cannot be entered for cleaning or inspection the maximum spacing between the manholes recommended is 30 m, and 300 m spacing for pipe greater than 2.0 m diameter (Table 8.1). A spacing allowance of 100 m per 1 m diameter of sewer is a general rule in case of very large sewers (CPHEEO, 1993). The internal dimensions required for the manholes are provided in Table 8.2 (CPHEEO, 1993). The minimum width of the manhole should not be less than internal diameter of the sewer pipe plus 150 mm benching on both the sides.

Table 8.1 Spacing of Manholes

Pipe Diameter	Spacing
Small sewers	45 m
0.9 to 1.5 m	90 to 150 m
1.5 to 2.0 m	150 to 200 m
Greater than 2.0 m	300 m

Table 8.2 The minimum internal dimensions for manhole chambers

Depth of sewer	Internal dimensions
0.9 m or less depth	0.90 m x 0.80 m
For depth between 0.9 m and 2.5 m	1.20 m x 0.90 m, 1.2 m dia. for circular
For depth above 2.5 m and up to 9.0 m	For circular chamber 1.5 m dia.
For depth above 9.0 m and up to 14.0 m	For circular chamber 1.8 m dia.

8.1.1 Classification of Manholes

Depending upon the depth the manholes can be classified as:

(a) Shallow Manholes, (b) Normal Manholes, and (c) Deep Manholes

Shallow Manholes: These are 0.7 to 0.9 m depth, constructed at the start of the branch sewer or at a place not subjected to heavy traffic conditions (Figure 8.1). These are provided with light cover at top and called inspection chamber.

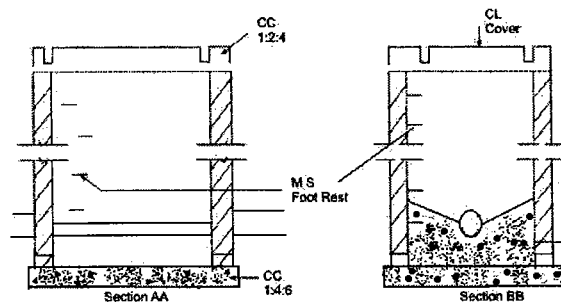


Figure 8.1 Shallow manhole

Normal Manholes: These manholes are 1.5 m deep with dimensions 1.0 m x 1.0 m square or rectangular with 1.2 m x 0.9 m (Figure 8.2). These are provided with heavy cover at its top to support the anticipated traffic load.

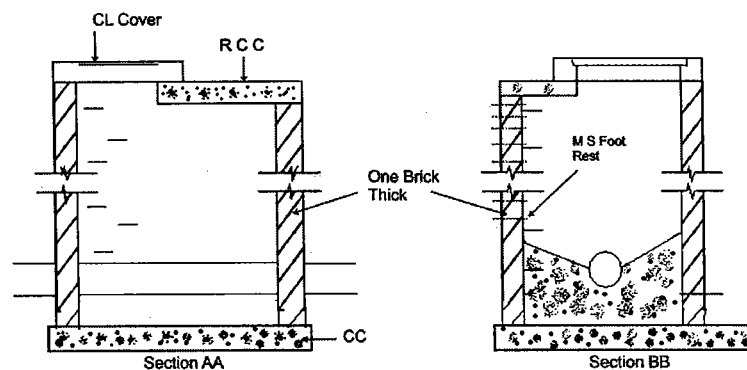
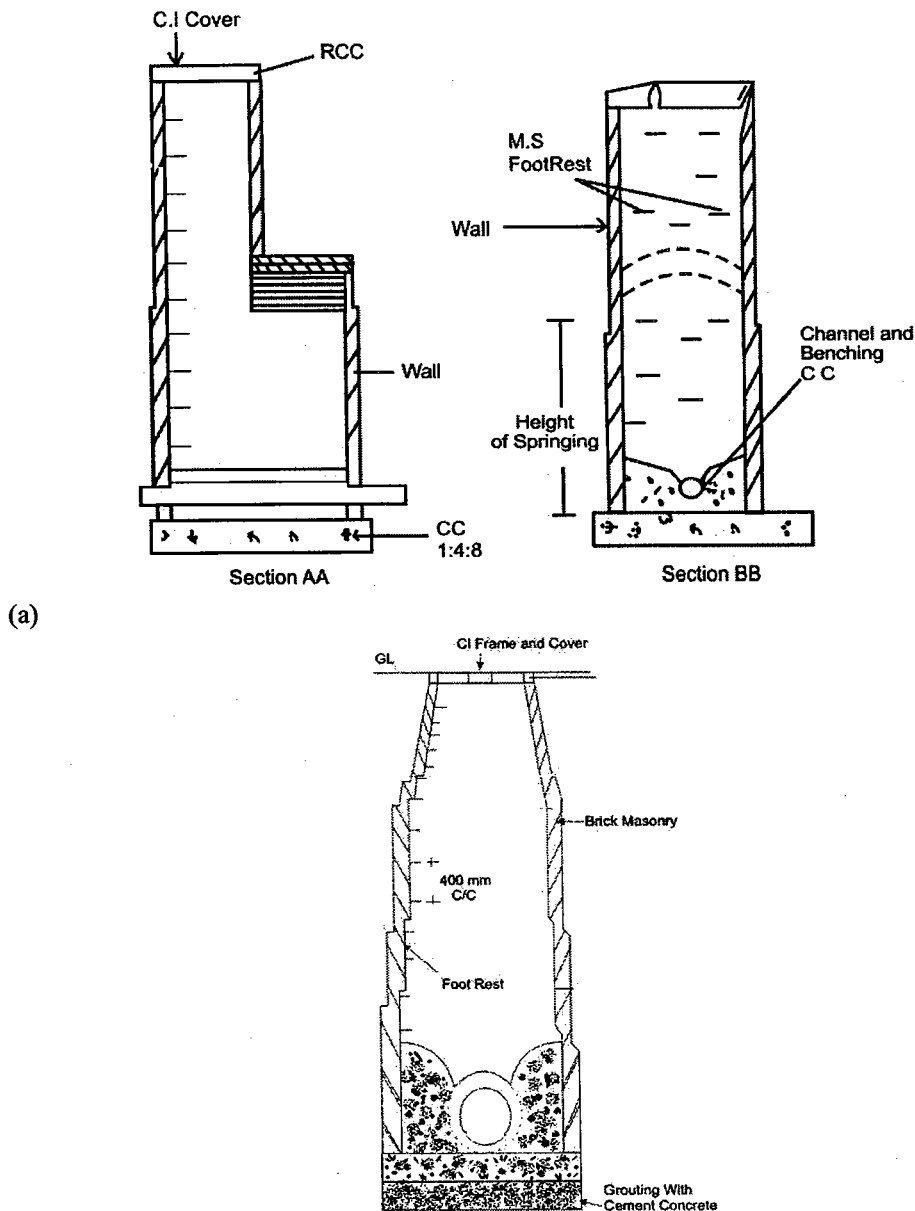


Figure 8.2 Rectangular manhole for depth 0.9 m to 2.5 m

Deep Manholes: The depth of these manholes is more than 1.5 m. The section of such manhole is not uniform throughout (Figure 8.3). The size in upper portion is reduced by providing an offset. Steps are provided in such manholes for descending into the manhole. These are provided with heavy cover at its top to support the traffic load.



(b)

Figure 8.3 (a) Rectangular and (b) Circular deep manhole

8.1.2 Other Types of Manholes

Straight – Through Manholes

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

Junction Manholes

This type of manholes are constructed at every junction of two or more sewers, and on the curved portion of the sewers, with curved portion situated within the manhole. This type of manholes can be constructed with the shape other than rectangular to suit the curve requirement and achieve economy. The soffit of the smaller sewer at junction should not be lower than that of the larger sewer. The gradient of the smaller sewer may be made steeper from the previous manhole to reduce the difference of invert at the point of junction to a convenient amount.

Side entrance Manholes

In large sewers where it is difficult to obtain direct vertical access to the sewer from the top ground level due to obstructions such as, other pipe lines like water, gas, etc., the access shaft should be constructed in the nearest convenient position off the line of sewer, and connected to the manhole chamber by a lateral passage. The floor of the side entrance passage which should fall at about 1 in 30 towards the sewer should enter the chamber not lower than the soffit level of the sewer. In large sewers necessary steps or a ladder (with safety chain or removable handrail) should be provided to reach the benching from the side entrance above the soffit.

Drop Manholes

When a sewer connects with another sewer, where the difference in level between invert level of branch sewer and water line in the main sewer at maximum discharge is greater than 0.6 m, a manhole may be built either with vertical or nearly vertical drop pipe from higher sewer to the lower one (Figure 8.4). The drop manhole is also required in the same sewer line in sloping ground, when drop more than 0.6 m is required to control the gradient and to satisfy the maximum velocity i.e., non-scouring velocity.

The drop pipe may be outside the shaft and encased in concrete or supported on brackets inside the shaft. If the drop pipe is outside the shaft, a continuation of the sewer should be built through the shaft wall to form a rodding and inspection eye, provided with half blank flange (Figure 8.4). When the drop pipe is inside the shaft, it should be of cast iron and provided with adequate arrangements for rodding and with water cushion of 150 mm depth at the end. The diameter of the drop pipe should be at least equal to incoming pipe.

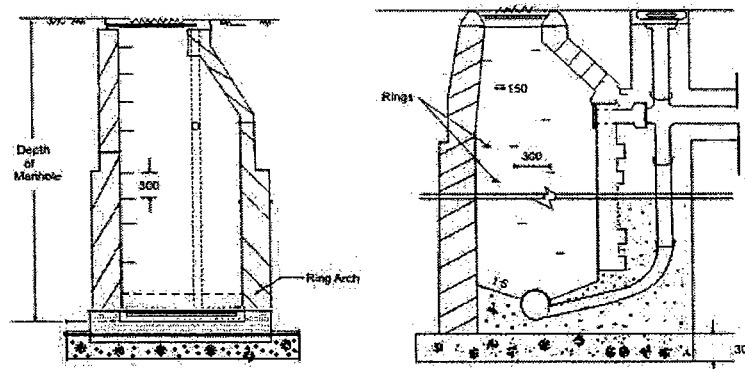


Figure 8.4 Drop manhole

Scraper (service) type manhole

All sewers above 450 mm in diameter should have one manhole at intervals of 110 to 120 m of scraper type. This manhole should have clear opening of 1.2 m x 0.9 m at the top to facilitate lowering of buckets.

Flushing Manholes

In flat ground for branch sewers, when it is not possible to obtain self cleansing velocity at all flows, due to very little flow, it is necessary to incorporate flushing device. This is achieved by making grooves at intervals of 45 to 50 m in the main drains in which wooden planks are inserted and water is allowed to head up. When the planks are removed, the water will rush with high velocity facilitating cleaning of the sewers. Alternatively, flushing can be carried out by using water from overhead water tank through pipes and flushing hydrants or through fire hydrants or tankers and hose.

Flushing manholes are provided at the head of the sewers. Sufficient velocity shall be imparted in the sewer to wash away the deposited solids. In case of heavy chocking in sewers, care should be exercised to ensure that there is no possibility of back flow of sewage into the water supply mains.

8.2 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. Inverted siphons are used to pass under obstacles such as buried pipes, subways, etc (Fig. 8.5). This terminology 'siphon' is misnomer as there

is no siphon action in the depressed sewer. As the inverted siphon requires considerable attention for maintenance, it should be used only where other means of passing an obstacle in line of the sewer are impracticable.

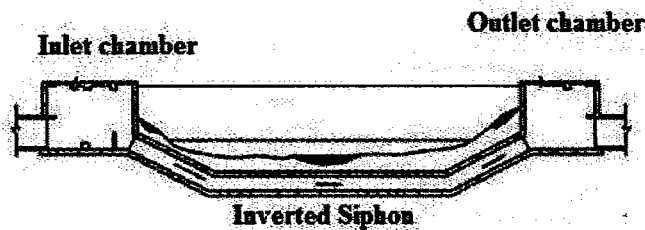


Figure 8.5 Inverted siphon

8.3 STORMWATER INLETS

Storm water inlets are provided to admit the surface runoff to the sewers. These are classified in three major groups viz. curb inlets, gutter inlets, and combined inlets. They are provided either depressed or flush with respect to the elevation of the pavement surface. The structure of the inlet is constructed with brickwork with cast iron grating at the opening conforming to IS 5961. Where the traffic load is not expected, fabricated steel grating can be used. The clear opening shall not be more than 25 mm. The connecting pipe from the street inlet to the sewer should be minimum of 200 mm diameter and laid with sufficient slope. A maximum spacing of 30 m is recommended between the inlets, which depends upon the road surface, size and type of inlet and rainfall.

Curb Inlet: These are vertical opening in the road curbs through which stormwater flow enters the stormwater drains. These are preferred where heavy traffic is anticipated (Figure 8.6a).

Gutter Inlets: These are horizontal openings in the gutter which is covered by one or more grating through which stormwater is admitted (Figure 8.6b).

Combined Inlets: In this, the curb and gutter inlet both are provided to act as a single unit. The gutter inlet is normally placed right in front of the curb inlets.

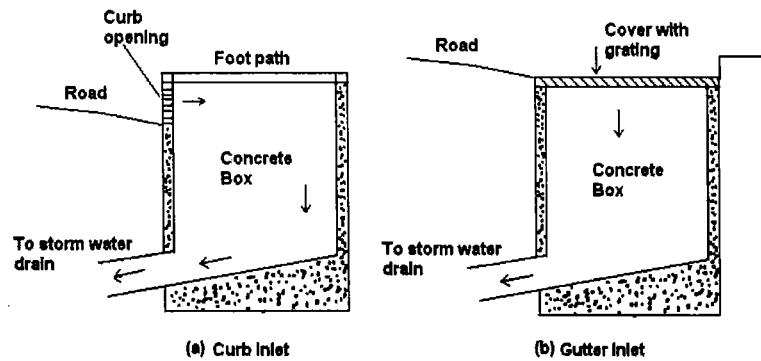


Figure 8.6 (a) Curb inlet and (b) Gutter inlet

8.4 CATCH BASINS

Catch basins are provided to stop the entry of heavy debris present in the storm water into the sewers. However, their use is discouraged because of the nuisance due to mosquito breeding apart from posing substantial maintenance problems. At the bottom of the basin space is provided for the accumulation of impurities. Perforated cover is provided at the top of the basin to admit rain water into the basin. A hood is provided to prevent escape of sewer gas (Figure 8.7).

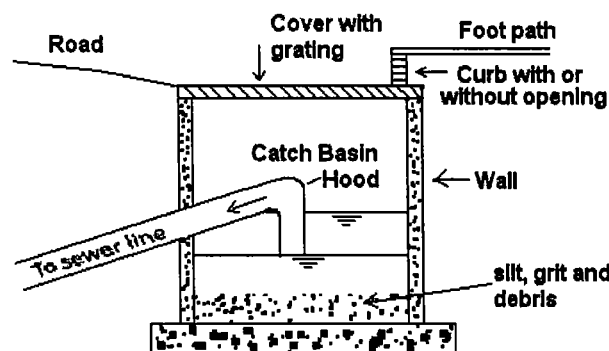


Figure 8.7 Catch basin

8.5 CLEAN-OUTS

It is a pipe which is connected to the underground sewer. The other end of the clean-out pipe is brought up to ground level and a cover is placed at ground level (Figure 8.8). A clean-out is generally provided at the upper end of lateral sewers in place of manholes. During blockage of pipe, the cover is taken out and water is forced through the clean-out pipe to lateral sewers to remove obstacles in the sewer line. For large obstacles, flexible rod may be

inserted through the clean-out pipe and moved forward and backward to remove such obstacle.

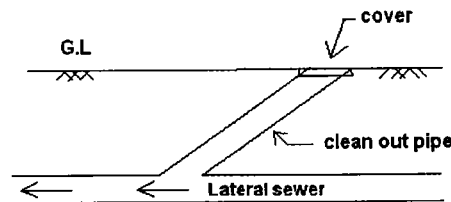


Figure 8.8 Clean-out

8.6 REGULATOR OR OVERFLOW DEVICE

These are used for preventing overloading of sewers, pumping stations, treatment plants or disposal arrangement, by diverting the excess flow to relief sewer. The overflow device may be side flow or leaping weirs according to the position of the weir, siphon spillways or float actuated gates and valves.

8.6.1 Side Flow Weir

It is constructed along one or both sides of the combined sewer and delivers the excess flow during storm period to relief sewers or natural drainage courses (Figure 8.9). The crest of the weir is set at an elevation corresponding to the desired depth of flow in the sewer. The weir length must be sufficient long for effective regulation of the flow.

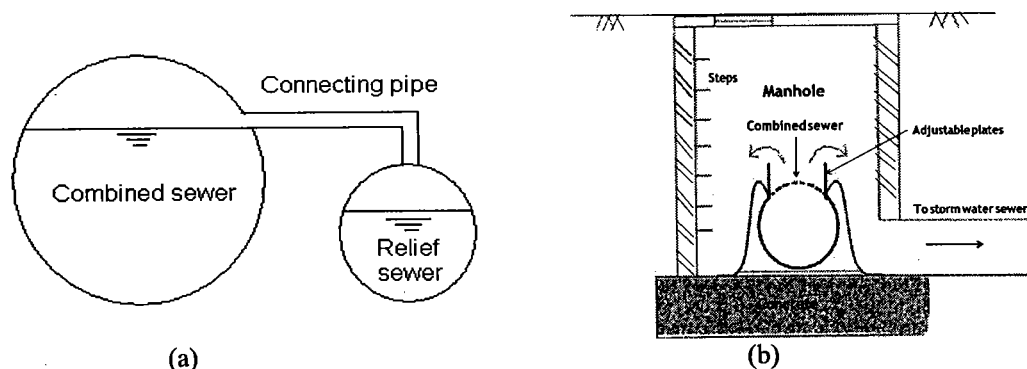


Figure 8.9 (a) Side flow weir (b) Overflow weir arrangement

8.6.2 Leaping Weir

The term leaping weir is used to indicate the gap or opening in the invert of a combined sewer. The leaping weir is formed by a gap in the invert of a sewer through which the dry weather flow falls and over which a portion of the entire storm leaps. This has an advantage

of operating as regulator without involving moving parts. However, the disadvantage of this weir is that, the grit material gets concentrated in the lower flow channel. From practical consideration, it is desirable to have moving crests to make the opening adjustable. When discharge is small, the sewage falls directly into the intercepting sewer through the opening. But when the discharge exceeds a certain limit, the excess sewage leaps or jumps across the weir and it is carried to natural stream or river. This arrangement is shown in the Figure 8.10.

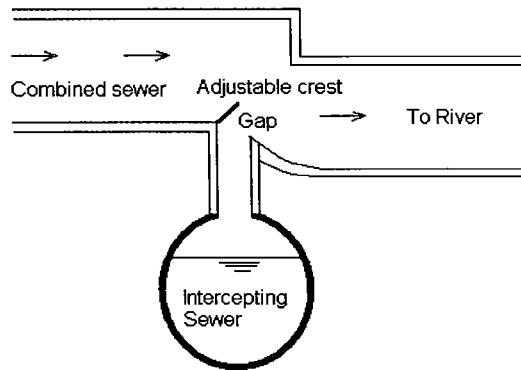


Figure 8.10 Leaping weir with adjustable crest

8.6.3 Float Actuated Gates and Valves

The excess flow in the sewer can also be regulated by means of automatic mechanical regulators. These are actuated by the float according to the water level in the sump interconnected to the sewers. Since, moving part is involved in this, regular maintenance of this regulator is essential.

8.6.4 Siphon Spillway

This arrangement of diverting excess sewage from the combined sewer is most effective because it works on the principle of siphon action and it operates automatically. The overflow channel is connected to the combined sewer through the siphon. An air pipe is provided at the crest level of siphon to activate the siphon when water will reach in the combined sewer at stipulated level (Figure 8.11).

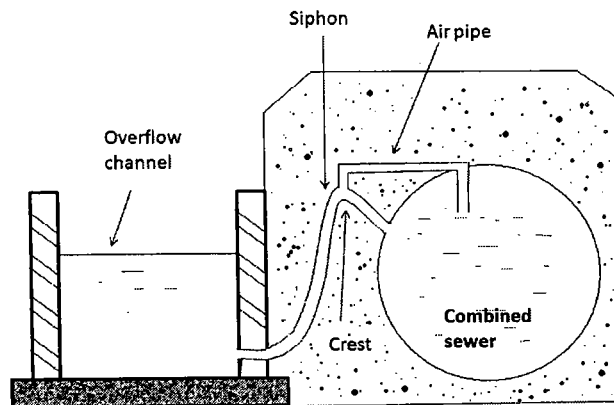


Figure 8.11 Siphon spillway

8.7 FLAP GATES AND FLOOD GATES

Flap gates or backwater gates are installed at or near sewer outlets to prevent back flow of water during high tide, or at high stages in the receiving stream. These gates can be rectangular or circular in shape and made up of wooden planks or metal alloy sheets. Such gates should be designed such that the flap should get open at a very small head difference. Adequate storage in outfall sewer is also necessary to prevent back flow into the system due to the closure of these gates at the time of high tides, if pumping is to be avoided.

8.8 SEWER VENTILATORS

Ventilation to the sewer is necessary to make provision for the escape of air to take care of the exigencies of full flow and to keep the sewage as fresh as possible. In case of stormwater, this can be done by providing ventilating manhole covers. In modern sewerage system, provision of ventilators is not necessary due to elimination of intercepting traps in the house connections allowing ventilation.

8.9 LAMP HOLE

It is an opening or hole constructed in a sewer for purpose of lowering a lamp inside it. It consists of stoneware or concrete pipe, which is connected to sewer line through a T-junction as shown in the Figure 8.12. The pipe is covered with concrete to make it stable. Manhole cover of sufficient strength is provided at ground level to take the load of traffic. An electric lamp is inserted in the lamp hole and the light of lamp is observed from manholes. If the sewer length is unobstructed, the light of lamp will be seen. It is constructed when

construction of manhole is difficult. In present practice as far as possible the use of lamp hole is avoided. This lamp hole can also be used for flushing the sewers. If the top cover is perforated it will also help in ventilating the sewer, such lamp hole is known as fresh air inlet.

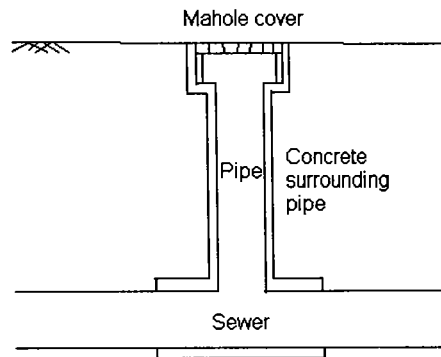


Figure 8.12 Lamp hole

Questions

1. Define sewer appurtenances. What are the appurtenances used in sewerage?
2. Describe different types of Manholes used in collection system.
3. When the drop manhole is used in sewers?
4. Describe different types of storm water inlets used in collection system.
5. Why flow regulator device is used in sewers? Describe different types of regulators used.

