

Module – 1

Introduction



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1.0 Introduction:

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.

1.1 Objectives

1. Understand sewerage network and influencing parameters.



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.

Definitions of some common terms used in the sanitary engineering.

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 putrefying 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.

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.

1.2 Methods of domestic waste water (Sewage) 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 Engineering starts at the point where water supply Engineering ends.

It can be classified as

- Collection works
- Treatment works
- Disposal works



The collection consists of collecting all 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. Old Conservancy System
2. Modern Water Carriage System

Old Conservancy 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 sullage 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.

Modern 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 Modern Water Carriage System.

In this system the excremental matter is mixed up in large quantity of water their ars 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 0.1% 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.

Conservancy 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 are not removed immediately hence its decomposition starts before removal, causing nuisance smell.	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 city.	As no human agency is involved in this system ,there is no such problem as in case of conservancy system

1.3 Types of Sewerage Systems:

1. Separate System of Sewage
2. Combined System of Sewage
3. Partially Combined 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:

- Size of the sewers are small
- Sewage load on treatment unit is less
- Rivers are not polluted
- Storm water can be discharged to rivers without treatment.



Disadvantage:

- Sewerage being small, difficulty in cleaning them
- Frequent choking problem will be their
- System proves costly as it involves two sets of sewers
- 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:

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

Disadvantages:

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

Partially Combined 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:

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

Disadvantages:

- During dry weather, the velocity of flow may be low.
- The storm water is unnecessary put load on to the treatment plants to extend.
- 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.



Suitable 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 sewerred 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 already exists. In places where rainfall is confined to one season of the year, like India and even in temperate regions, separate system are most suitable.

Separate system	Combined system
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.
In the cities of more rainfall this system is more suitable.	In the cities of less rainfall this system is suitable.
As two sets of sewer lines are to laid, this system is cheaper because sewage is carried in underground sewers and storm water in open drains.	Overall construction cost is higher than separate system.
In narrow streets, it is difficult to use this system.	It is more suitable in narrow streets.
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.

Dry Weather Flow (DWF): Domestic sewage and industrial sewage collectively called as DWF. It does not contain storm water. It indicates the normal flow during dry season of the year.

Wet Weather Flow (WWF): Domestic sewage, industrial sewage and storm water collectively called as WWF. It indicates the maximum flow of sewage during wet season.

Factors Affecting DWF:

The dry weather flow or the quantity of sanitary sewage depends upon the following factors:-

- Rate of water supply
- Population growth
- Type of area served
- Infiltration of ground water

Rate of Water Supply: The rate of water supply to a city or town is expressed so many litres/capita/day. The quantity of waste water entering the sewers would be less than the total quantity of water supplied. This is because of the fact that water is lost in domestic consumption, evaporation, lawn sprinkling, fire fighting, industrial consumption. However, private source of water supply (i.e. water from domestic wells etc.) and infiltration of sub-soil water in the sewers increase the waste water flow rate.

This extra water that enters the sewers can be assumed to approximately equal to the water lost in consumption etc. Due to this reason, the waste water flow rate may be assumed equal to the rate of water supply by the municipal authorities. The sewers should be designed for a minimum of 150 litres per capita per day.

Population Growth: 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 supply multiplied of population. The sewage quantity which will be produced in the town due to future developments of the town and population should be taken into account and as far as possible accurate results should be obtained.

Type of Area Served: The quantity of sanitary sewage also depends on the type of area to be served, whether it is residential, industrial or commercial. The quantity of sewage produced in residential areas directly depends on the quantity of water supply to the area. The quantity is obtained by multiplying the population with this factor. The quantity of sewage produced by various industries depends on their various industrial processes, and it is different for each industry. This quantity can be determined by doing a survey of that area and collecting the data.

Infiltration of Ground Water: Ground water or sub-soil water may infiltrate into the sewers through the leaky joints. Ex-filtration is the reverse process which indicated the flow of waste water from the sewer into the ground. While due to infiltration the quantity of flow through sewer increases, ex-filtration results in decrease in the flow and consequent increase in the pollution of ground water. Both infiltration as well as ex-filtration are undesirable and take place due to imperfect joints. Infiltration unnecessarily increases the load on the treatment works.

1.4 Quantity of storm water flow:

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 flow.
- 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:

$$Q = \frac{C i A}{360}$$

Where,

Q= quantity of storm water in m³/sec

C= coefficient of runoff

i= intensity of rainfall

A= area of drainage in hectare

Runoff coefficient:

In rational method, the value of runoff coefficient, C is required. The whole quantity of rain water that fall over the ground does not reach the sewer line. A portion of it percolates in the ground, a portion evaporates, a portion is stored in ponds and ditches and only remaining portion of rainwater reaches the sewer line. The runoff coefficient depends mainly on characteristics of ground surface as porosity, wetness, ground cover etc., which varies from 0.01 for forest or wooded area to 0.95 for a water tight roof surfaces.

As every locality consists of different types of surface area, therefore for calculating the overall runoff coefficient the following formula is used:

$$C = \frac{A_1 C_1 + A_2 C_2 + \dots + A_n C_n}{A_1 + A_2 + \dots + A_n}$$

Where:

C: Runoff coefficient

A₁, A₂, A₃....are different types of area

C₁, C₂, C₃.....are their runoff coefficient respectively.

Empirical formulae for rainfall intensities:

The empirical formula given by British Ministry of Health is given by:

$$i = \frac{760}{t+10} \quad (\text{For storm duration of 5 to 20 minutes})$$

$$i = \frac{1020}{t+10} \quad (\text{For storm duration of 20 to 100 minutes})$$

Where

I - Intensity of rainfall, mm/h

t - Duration of storm, minutes

Time of concentration of flow:

The time taken for the maximum runoff rate to develop, is known as the time of concentration, and is equal to the time required for a drop of water to run from the farthest point of the watershed to the point for which the runoff is to be calculated.

The time of concentration, t_c , of a watershed is often defined to be the time required for a parcel of runoff to travel from the most hydraulically distant part of a watershed to the outlet. It is not possible to point to a particular point on a watershed and say, the time of

concentration is measured from this point. Neither is it possible to measure the time of concentration. Instead, the concept of t_c is useful for describing the time response of a watershed to a driving impulse, namely that of watershed runoff.

In the context of the rational method then, t_c represents the time at which all areas of the watershed that will contribute runoff are just contributing runoff to the outlet. That is, at t_c , the watershed is fully contributing. We choose to use this time to select the rainfall intensity for application of the rational method. If the chosen storm duration is larger than t_c , then the rainfall intensity will be less than that at t_c . Therefore, the peak discharge estimated using the rational method will be less than the optimal value. If the chosen storm duration is less than t_c , then the watershed is not fully contributing runoff to the outlet for that storm length, and the optimal value will not be realized. Therefore, we choose the storm length to be equal to t_c for use in estimating peak discharges using the rational method.

The time of concentration refers to the time at which the whole area just contributes runoff to a point.

$$t_c = t_e + t_f$$

Where,

t_c = time of concentration

t_e = time of entry to the inlet (usually taken as 5 – 10 min)

t_f = time of flow in the sewer

1.5 Materials of sewers:

Classification or types of sewers with respect to their material of construction:

The sewers may be made of:

1. Asbestos cement
2. Bricks
3. Cast iron
4. Cement concrete plain or reinforced
5. Corrugated iron sewers
6. Stoneware sewers
7. Steel sewers
8. Plastic sewers
9. Wooden sewers

May create beam action in the sewer line. To withstand all such effects, the sewer should be made from strong material.

Types of sewers

Different types of sewers are discussed

Asbestos Cement Sewers

- These are manufactured from a mixture of asbestos fibres, 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 multi-storeyed 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 $n = 0.011$) 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.

Bricks sewers: Brick sewers are made it site. They are used for construction of large size sewers. Now a day's brick sewers are replaced by concrete sewers because lot of labour is involved in the construction of 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 ground water through brick joints. These are lined from inside with stone ware or ceramic block to make them smooth and hydraulically efficient. Lining also make 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 ground water 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.

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 moulded, 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.

Corrugated iron sewers: Corrugated iron sewers are used for storm sewers. The sewers should be protected from the effects of corrosion by galvanization or by bituminous coatings. They are made in varying metal thickness and in diameters upto 450cm.

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.

Steel sewers: These sewers are used where lightness, imperviousness and resistance to high pressure are the prime requirements. These sewers are flexible and can absorb vibrations and shocks efficiently. They are mainly used for trunk or outfall sewers. Riveting should, as far as possible be avoided. 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.

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.

Wooden sewers: In early stages these sewers were put into use. They are difficult to construct and maintain. The life of sewers is short and they are now rarely in use.

1.6 Shapes of Sewers:

Sewers are generally circular pipes laid below ground level, slopping continuously towards the outfall. These are designed to flow under gravity. Mostly sewers of circular shape are used in all the sewerage schemes, because of the following facts:

- i. It affords least perimeter and hence construction material required is minimum.
- ii. They are easy to construct and handle.
- iii. Since it has no corners, there are less chances of deposition of organic matters.
- iv. They possess excellent hydraulic properties.

However, sewers of non circular shapes are used for the following reasons.

- (i) To develop self cleansing velocity in the sewer, when the flow is minimum.
- (ii) To effect economy in the construction.
- (iii) To increase the headway so that a man can enter easily for repairs, and cleaning.

Following are the non-circular shapes of sewers which are commonly used for sewers:

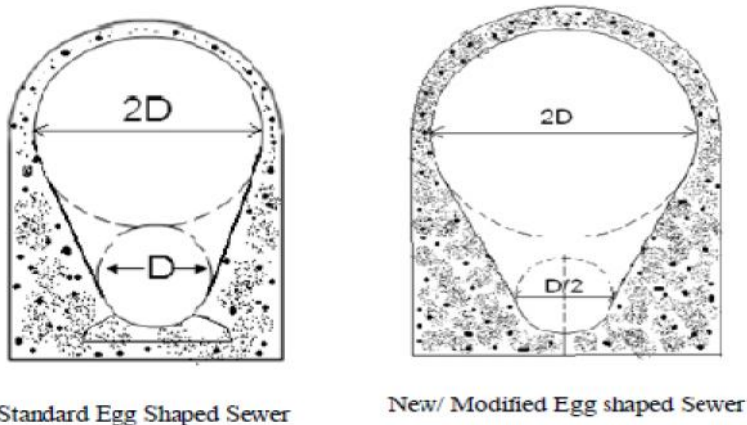
1. Box or rectangular sewers

2. Egg-shaped or avoid sewers
3. Basket-handle sections
4. Horse shoe sewers
5. Parabolic sewers
6. Semi-circular sewers
7. Semi-elliptical sewers
8. U-shaped sewers

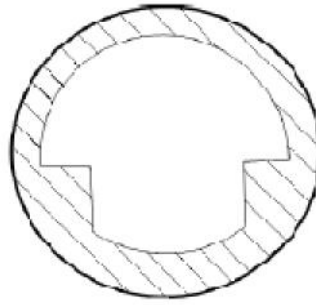
1. Box or rectangular type sewers: In olden days these sewers were constructed by laying concrete at bottom and constructing the sides with masonry. But now a day's masonry has been completely replaced by concrete. These are mainly used for out fall sewers. They have got relatively high hydraulic mean depth at large flows and therefore can have higher velocities when laid to the same slope as that of a circular or egg-shaped sewer. They are therefore most suitable for large size storm sewers.

2. Egg-shaped sewers: These are shown in figure. This shape has got better hydraulic properties, but it is costly. Firstly due to longer perimeter more material for construction is required and secondly because of its odd shapes it is difficult to construct. This sewer requires always a good foundation and proper reinforcement to make structurally stable. In India they are rarely used. They are most suitable in case of combined sewers.

The main advantage of this sewer is that it gives a slightly higher velocity during low flow, than a circular sewer of the same size.

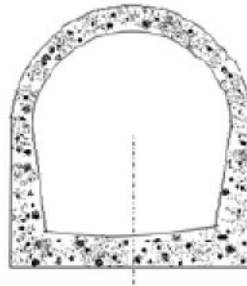


3. Basket-handle sewer: The shape of this sewer resembles the shape of a basket handle. Small discharges flow through the bottom narrower portion. During rainy days, the combined sewage flows in the full section.



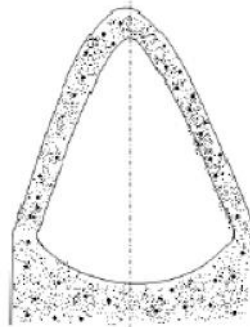
Basket-Handle Section

4. Horse-shoe sewers: Its top is usually semi-circular with sides inclined or vertical. The bottom may be flat, circular or paraboloid. Its height is more than width. It is mostly used for sewers in tunnels. It is used for the construction of large sewers with heavy discharges such as trunk sewers. This shape gives increased head room.



Horse shoe sewer section

5. Parabolic sewers: In this form of sewers, the upper arch takes the shape of parabola as shown in fig. The invert of the sewer may be flat, parabolic or elliptical. They are used for the disposal of relatively small quantities of sewage.



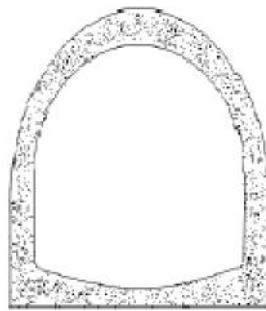
Parabolic section

6. Semi-circular sewers: The semi-circular sewer gives a wider curve at the bottom and hence, it becomes suitable for constructing large sewers with less available headroom. Now a day there are replaced by rectangular sewers.



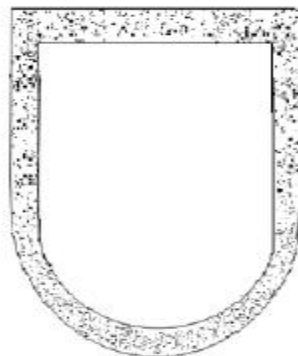
Semi-circular Section

7. Semi-elliptical sewers: This shape of sewer is more suitable for soft soils as they are more stable. This shape is not suitable for carrying low discharges and it is normally adopted for sewers having diameter greater than 180cm or so.



Semi-elliptical section

8. U-shaped sewers: Two sections of U-shaped sewers are shown in fig. Trench provided at the bottom is called cunete. These are easy to construct. Their invert may be flat or semi-circular. The sides are generally vertical and top may be flat or arched.



U-shaped section

1.7 Laying of Sewers:

After the sewer plan has been approved, the next step is to set out the work. The centre line of the trench is first staked out on the ground. The centre line pegs are driven at a distance of 7.5m or 15m. The sight rail and boning rod system is the accepted method for laying the drains accurately to the gradients, indicated on the plans. Sight rails are set at all changes of gradients and at intermediate positions, if the distance for sighting is large. The sight rails are set in such a way that, the line sighted along the top edge of the rails represents, the true fall of the sewer, this gradient is shifted below the ground level by means of a Traveller of fixed length. Sight rails are the horizontal cross rails placed on uprights. They are

usually made up of a good straight piece of timber of 15cm width and 5cm thick and length to extend over the width of the trench. Traveller or boning rod consists of a rod and T-piece. It is most important that boning rod should be cut to the exact length required; otherwise the pipes may not be laid correctly to the required grade. The boning rod may be 8cm by 4cm timber piece of required length. A T-piece of 9cm by 45cm is securely fixed by nails at top (Fig 3.3). Since the work of laying pipes is generally started from the lower end, the sight rails will therefore, be required to fix at this point. After fixing the first set of sight rails at the lower end, a second set of sight rails is similarly set at some distance upstream side. Knowing the reduced level of invert of the sewer at the lower end and the desired gradient of the sewer line, the reduced level of invert at second set of sight rail is calculated. The depth of invert below both the sight rails should be the same to obtain the desired correct gradient, because the top of sight rails are adjusted to the correct reduced levels according to the gradient required.

Testing of sewer line

It is necessary to test the sewer after its laying for water tightness before backfilling of the excavated earth.

Smoke test: This test is performed for soil pipes, vent pipes laid above ground. The test is conducted under a pressure of 2.5m of water and maintained for 15 minutes after all trap real have been filled with water. The smoke is produced by burning oil waste or tar paper in combustion chamber of a smoke machine.

Water test: This test is performed for underground sewer pipes before back filling is done. The test should be carried out by suitably plugging the lower end of the drain and filling the system with water. A knuckle band shall be temporarily jointed at the top end and a sufficient length of vertical pipe is jointed so as to provide the required test head.

Subsidence of test water may be due to (a) Absorption by pipes and joints (b) Leakages at joints etc. Any leakage if visible and defective part of work if any should be made good.

Test for straightness and obstruction: For this test, a mirror is placed in front of one end of sewer and the image of the section is observed. If the sewer line is straight, the image should be circular. If it is not a complete circle, then it is not straight. For testing for obstruction, by inserting a steel call at upper end and if there is no obstruction in the sewer line, the call will emerge out from the

Ventilation of Sewer

Sewage flowing in sewer has got lot of organic and inorganic matters present in it. Some of the matters decompose and produce gases. These gases are foul smelling, corrosive and explosive in nature. If these gases are not disposed of properly they may create a number of difficulties. They may cause air locks in sewers and affect the flow of sewage. They may prove to be dangerous for the maintenance squad working in sewers. They may also cause

explosions and put the sewer line out of commission. For the disposal of these gases, ventilation of sewer line is a must.

Methods of Ventilation

Following are some of the means or fittings which help in the ventilation of sewers,

1. Laying sewer line at proper gradient.
2. Running the sewer at half full or 2/3 depth.
3. Providing manhole with gratings.
4. Proper house drainage.
5. Providing the ventilating columns or shafts.

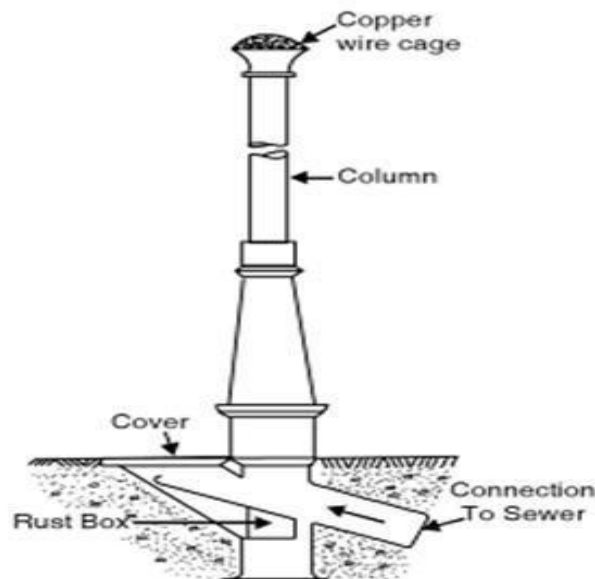


Fig. Ventilation column

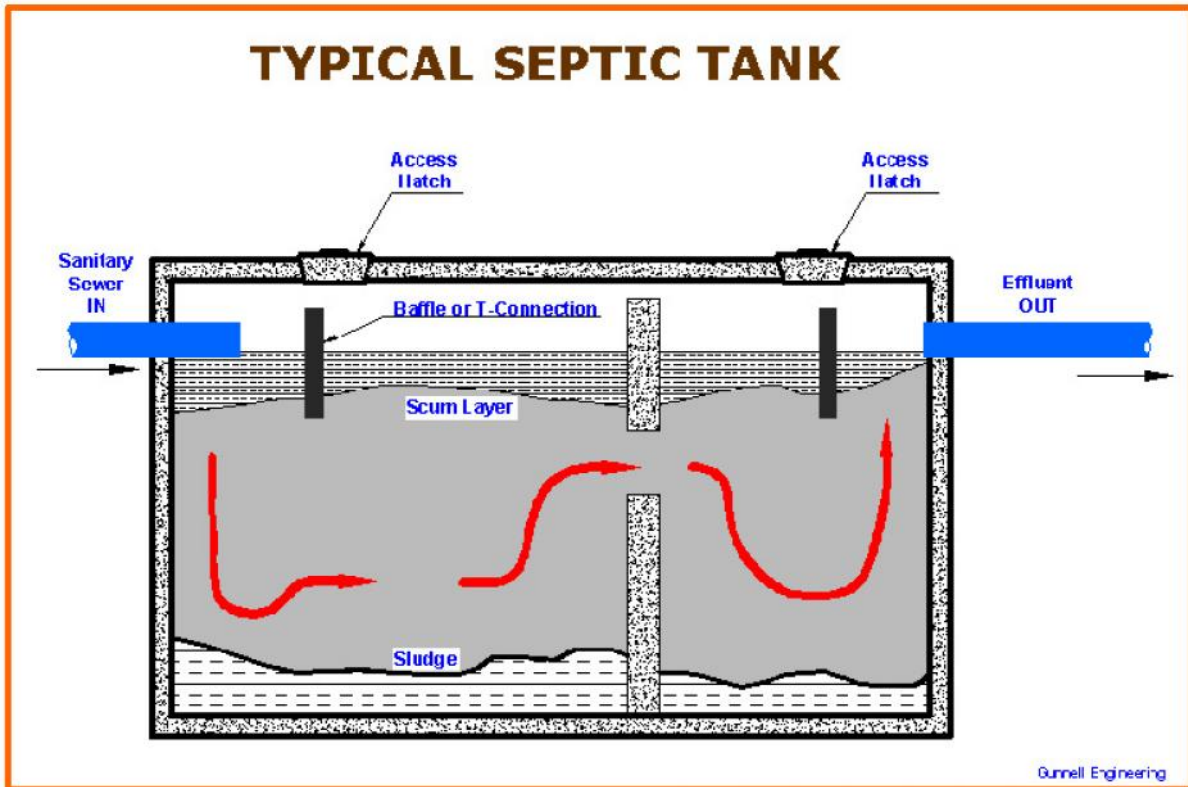
1.8 Low-cost waste treatment:

Oxidation pond: Oxidation ponds, also called lagoons or stabilization ponds, are large, shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae. Algae grow using energy from the sun and carbon dioxide and inorganic compounds released by bacteria in water. During the process of photosynthesis, the algae release oxygen needed by aerobic bacteria. Mechanical aerators are sometimes installed to supply yet more oxygen, thereby reducing the required size of the pond. Sludge deposits in the pond must eventually be removed by dredging. Algae remaining in the pond effluent can be removed by filtration or by a combination of chemical treatment and settling.

Advantages of oxidation Ponds

1. Suitable for hot climate, where 200 sunny days are expected per year
2. Best suited for small cities and towns where land is cheap
3. Capital cost is only 20 to 30% of conventional plant
4. Maintenance cost is minor
5. No skilled supervision is required
6. Flexible and will get upset due to sudden fluctuations in organic loading

Septic tank: A tank, typically underground, in which sewage is collected and allowed to decompose through bacterial activity before draining by means of a soak away.



A septic tank is a watertight tank designed to slow down the movement of raw sewage and wastes passing through so that solids can separate or settle out and be broken down by liquefaction and anaerobic bacteria action. It does not purify the sewage, eliminate odours, or destroy all solid matter. The septic tank simply conditions the sewage so that it can be disposed of normally to a subsurface absorption system without prematurely clogging the system. Suspended solids removal is 50 to 70 percent; five-day BOD removal is about 60 percent.

The detention time for large septic tanks should not be less than 24 to 72 hr. Schools, camps, theatres, factories, and fairgrounds are examples of places where the total or a very large proportion of the daily flow takes place within a few hours. For example, if the total daily flow takes place over a period of 6 hr (one-fourth of 24 hr), the septic tank should have a liquid volume equal to four times the 6-hr flow to provide a detention equivalent to 24 hr over the period of actual use. The larger tank would minimize scouring of septic tank sludge and scum and carryover of solids into the absorption system.

1.9 Sewer Appurtenances:

Sewage flowing in the sewer line contains a large number of impurities in the form of silt, fats, oils, rags etc. Under normal flows they are not likely to settle and choke the sewers, but during small flows self-cleansing velocity is not likely to develop and the chances of choking of the sewers are increased. Choking have to be removed time to time and facilities should be provided on the sewer lines for this purpose. Therefore, for proper functioning and to facilitate maintenance of the sewage system, various additional structures have to be constructed on the sewer lines. These structures are known as sewer appurtenances

Following are the important appurtenances, 1. Manholes 2. Inlets 3. Catch basins 4. Flushing devices 5. Regulators 6. Inverted siphons 7. Grease and oil traps 8. Lamp holes 9. Leaping weirs 10. Junction chambers

Manholes: The manholes are R.C.C or masonry chambers constructed on the sewer line to facilitate a man to enter the sewer line and make the necessary inspection and repairs. These are fitted with suitable cast iron covers. The manholes should be installed at every point where there is a change in direction, change in pipe size, or considerable change in gradient. As far as possible sewer line between two subsequent man holes should be straight. The centre distance between manholes is less for sewers of smaller size while it may behave such a size that man can easily enter in the working chamber. The minimum size is 50cm diameter.

Size of Sewer	Recommended spacing of Manhole
Dia up to 0.3 m	45 m
Dia up to 0.6 m	75 m
Dia up to 0.9 m	90 m
Dia up to 1.2 m	120 m
Dia up to 1.5 m	250 m
Dia greater than 1.5 m	300 m

Classification of Manhole:

Shallow Manholes (Inspection Manholes) are the one which are about 0.75 to 0.9 m in depth. They are constructed at the start of a branch sewer.

Normal Manholes are those which are about 1.5 m in depth. They are constructed either in square (1 m * 1m) or rectangular (0.8 m * 1.2 m) in cross section.

Deep Manholes are those which are deeper than 1.5 m. The size of such a manhole is larger at the bottom, which is reduced at the top to reduce the size of manhole cover.

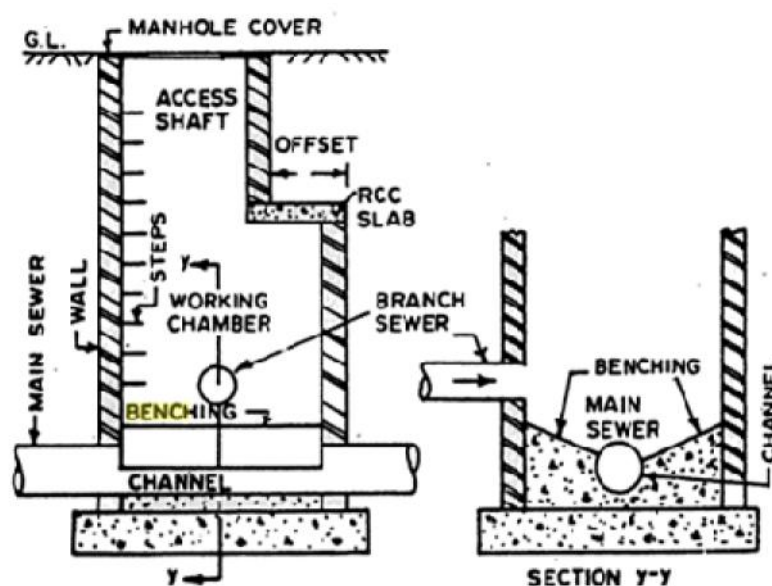
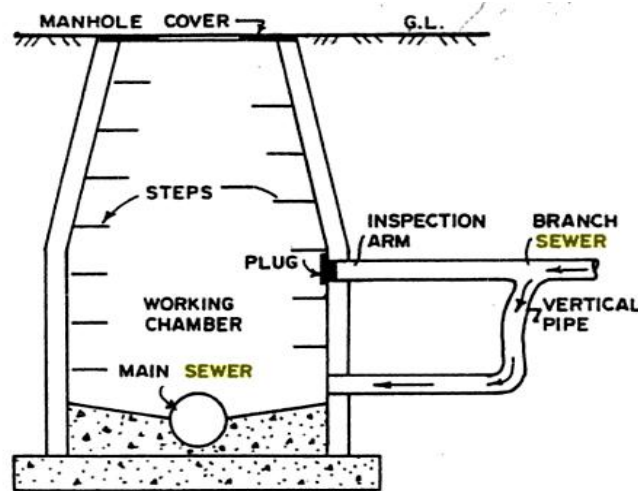


FIG. DEEP MANHOLE

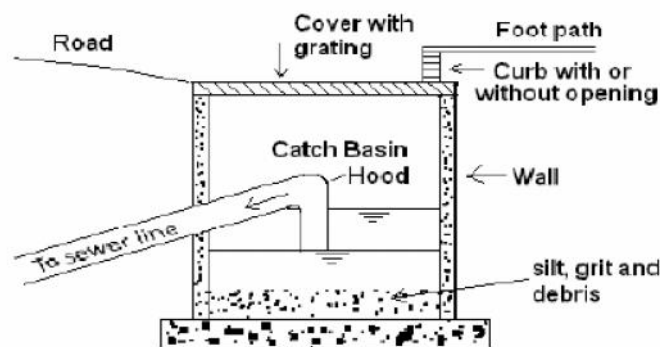
Drop Manhole: It is a measure of connecting high level branch sewer to low level main sewer. They are connected through a vertical pipe. The installation of a drop manhole becomes necessary when there is difference in levels is more than 60cm between branch sewer and the main sewer, which can be avoided by increasing the sewer grade.

Components parts of a Deep Manhole are:

- i) Access shaft ii) Working chamber iii) Bottom or Invert iv) Side walls v) Steps or ladder vi) Top cover



Catch Basins: Catch basins are the structures of pucca chamber and a stout cover. They are meant for the retention of suspended grit, sludge and other heavy debris and floating rubbish from rain water which otherwise might have entered and cause choking problems. The outlet pipe from the catch basin may be submerged in order to prevent the escape of odours from the sewer and provision that also causes retention of floating matter. Their use is not recommended since they are more of a nuisance and a source of mosquito breeding apart from posing substantial maintenance problems.

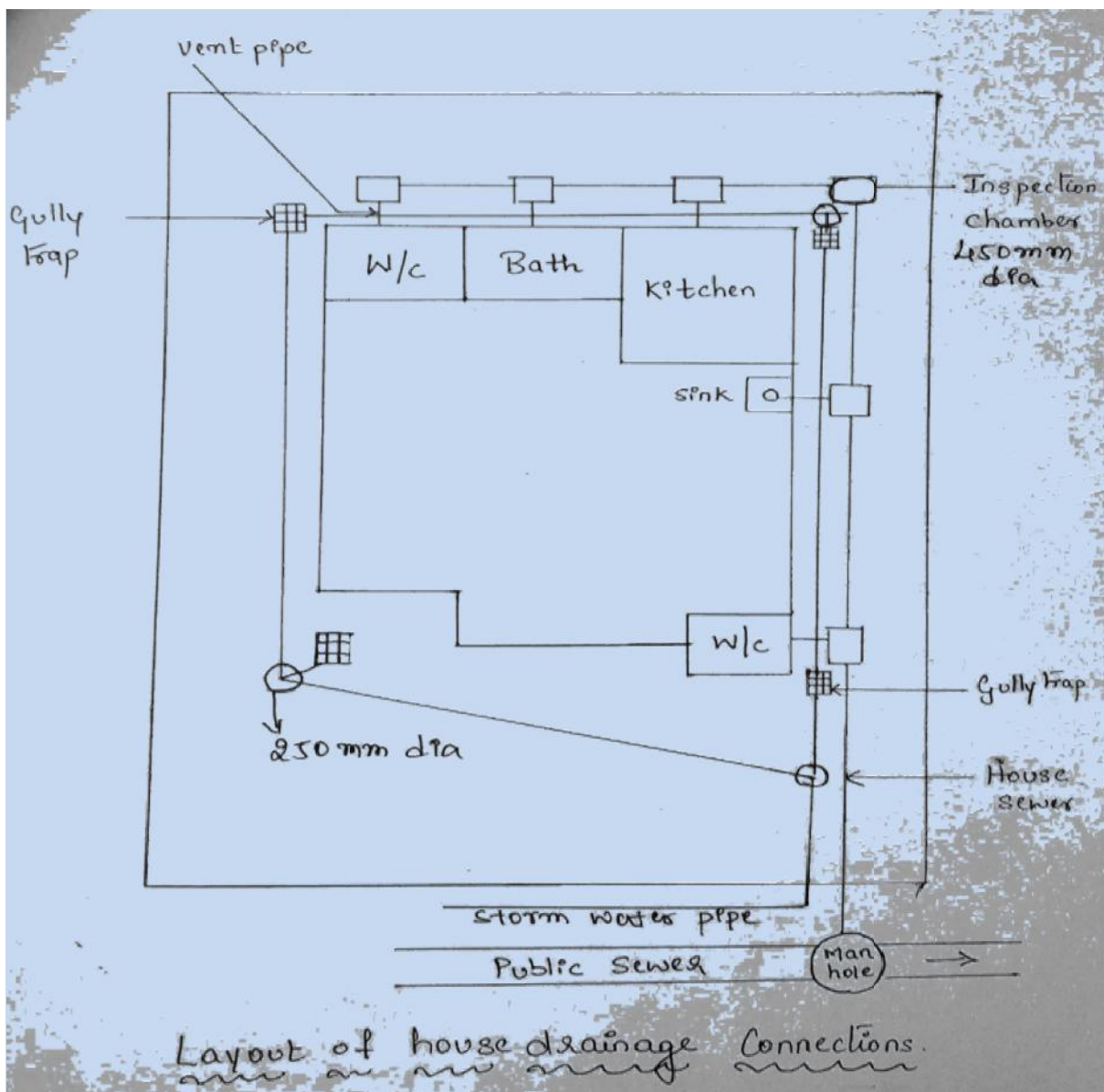


Catch Basins

Basic principles of house drainage

1. Lay sewers by the side of the building rather than below the building.
2. Drains should be laid straight between inspection chambers, avoiding sharp bends and junctions as far as possible
3. House drain should be connected to the public sewer only when public sewer is deeper than the house drain in order to avoid reverse flow.

4. Joints of sewer should be water tight and should be properly tested before putting the drainage line to use.
5. Lateral sewers should be laid at proper gradient so that they can develop self cleansing velocity.
6. Size of the drain should be sufficient so that they do not over flow at the time of maximum discharge.
7. Layout of the house drainage system should permit easy cleaning and removal of obstructions.
8. Entire system should be properly ventilated from the starting point to the final point of discharge
9. All the materials and fittings of the drainage system should be hard, strong and resistant to corrosion. They should be non-absorbent type.
10. The entire system should be so designed that the possibilities of formation of air locks,
11. Rain water pipes should drain water directly into the street gutters from where it is carried to the storm water drain.



1.10 Recommended Questions

1. Explain the methods of sewage disposal.
2. Explain the types of sewerage system.
3. Explain the factors effecting DWF and WWF.
4. Write a note on
 - a) Oxidation pond
 - b) Septic tank
 - c) Manholes
 - d) Catch basins

1.11 Outcomes

1. Acquires capability to design sewer and Sewerage treatment plant.
2. Evaluate degree of treatment and type of treatment for disposal, reuse and recycle

1.12 Further Reading

1. <https://nptel.ac.in/courses/105106119/32>
2. <https://nptel.ac.in/courses/105105048/>
3. <https://nptel.ac.in/courses/105105048/M6L6.pdf>
4. <https://nptel.ac.in/courses/105105048/M13L17.pdf>