upto the average flows, the pipe is used and when the flow exceeds the average, the balance flow is taken by the second and subsequent pipes. Siphons may need cleaning oftener than gravity sewers and hence should not have any sharp bends either horizontal or vertical. Only smooth curves of adequate radius should be used. The design criteria for inverted siphons are given in IS:411 Part-III. Some of the important criteria are given below.

3.4.5.1 HYDRAULIC CALCULATIONS

As the inverted siphon is a pipe under pressure, a difference in the water levels at the inlet and outlet is the head under which the siphon operates. This head should be sufficient to cover the entry, exit and friction losses in pipes. The friction loss through the barrel will be determined by the design velocity. The Hazen-Williams formula, or the Modified Hazen-Williams Formula can be used for calculation of head loss.

3.4.5.2 VELOCITY

It is necessary to have a self-cleansing velocity of 1.0 mps for the minimum flow to avoid deposition in the line.

3.4.5.3 SIZE AND ARRANGEMENT OF PIPES

In the multiple pipe siphon, the inlet should be such that the pipes come into action successively as the flow increases. This may be achieved by providing lateral weirs with heights kept in accordance with the depth of flow at which one or more siphon pipes function. Fig. 3.7 gives the general arrangement for a three-way siphon. In the two-pipe siphon, the first pipe should take 1.25 to 1.5 times the average flow and second should take the balance of the flow.

3.4.5.4 INLET AND OUTLET CHAMBERS

The design of inlet and outlet chambers should allow sufficient room for entry for cleaning and maintenance of siphons. The outlet chambers should be so designed as to prevent the backflow of sewage into pipes which are not being used at the time of minimum flow.

3.4.5.5 GENERAL REQUIREMENTS

Provision should be made for isolating the individual pipes as well as the siphon to facilitate cleaning. This can be done by providing suitable penstocks or stop boards at the inlet and outlet of each pipe and by providing stop valve at its lower point if it is accessible. A manhole at each end of the siphon should be provided with clearance for rodding. The rise, out of the siphon for small pipes should be on a moderate slope so that sand and other deposits may be removed out of the siphon. The rising leg should not be so steep as to make it difficult to remove heavy solids by cleaning tools that operate on hydraulic principle. Further there should be no change of diameter in the barrel since this would hamper cleaning operation. It is desirable to provide a coarse screen to prevent the entry of rags etc., into the siphon.

Proper bypass arrangements should be provided from the inlet chamber and if required special arrangements should be made for pumping the sewage to the lower reach of sewer line. Alternatively a vacuum pump may be provided at the outlet to overcome maintenance problems arising out of clogging and silting of siphons. If it is possible a blow off may be installed at the low point to facilitate emergency maintenance operations.
M_1 - BACKWATER FROM RESERVOIR OR FROM CHANNEL OF MILD SLOPE (d > d_1)

M_2 - DRAWDOWN, AS FROM CHANGE OF CHANNEL OF MILD SLOPE TO STEEP SLOPE (d > d > d_c)

M_3 - FLOW UNDER GATE ON MILD SLOPE OR UPSTREAM PROFILE BEFORE HYDRAULIC JUMP ON MILD SLOPE (d < d_c)

(a) MILD SLOPE (d_1 > d_c)

S_1 - DOWNSTREAM PROFILE AFTER HYDRAULIC JUMP ON STEEP SLOPE (d < d_c)

S_2 - DRAWDOWN, AS FROM MILD TO STEEP SLOPE OR STEEP SLOPE TO STEEPER SLOPE (d > d > d_n)

S_3 - FLOW UNDER GATE ON STEEP SLOPE OR CHANGE FROM STEEP SLOPE TO LESS STEEP SLOPE (d < d_n)

(b) STEEP SLOPE (d_n < d_c)

FIG. 3.6: OPEN-CHANNEL FLOW CLASSIFICATIONS.
Positive pressure develops in the atmosphere upstream of a siphon because of the downstream movement of air induced by the sewage flow. This air tends to exhaust from the manhole at the siphon inlet. The exiting air can cause serious odour problems. Conversely air is drawn in at the siphon outlet. Attempts can be made to close the inlet structure tightly so that the air gets out at manholes or vents upstream. However this causes depletion of oxygen in the sewer and leads to sulphide generation. To avoid this, sufficient ventilation arrangements have to be provided.

3.4.6 Relief Sewers

An overloaded existing sewer may require relief, with the relief sewer constructed parallel to the existing line. Relief sewers are also called supplementary sewers. In the design it must be decided whether (a) the proposed sewer is to share all the rates of flow with the existing sewer or (b) it is to take all flows in excess of predetermined quantity or (c) it is to divert a predetermined flow from the upper end of the system.

The topography and available head may dictate which alternative is selected. If flows are to be divided according to a ratio, the inlet structure to the relief sewer must be designed to divide the flow. If the relief sewer is to take all flows in excess of a predetermined quantity, the excess flow may be discharged through a weir to the relief sewer. If the flow is to be diverted in the upper reaches of a system, the entire flow at the point of diversion may be sent to the relief sewer or the flow may be divided in a diversion structure.

A decision as to the method of relief to be chosen depends on available velocities. Self cleansing velocities have to be maintained in either or both sewers even after diversion of flows. Otherwise nuisance conditions may result. If the relief sewer is designed to take flows in excess of a fixed quantity the relief sewer itself will stand idle much of the time and deposits may occur. In some cases it might be better to make the new sewer large enough to carry the total flow and to abandon the old one.

3.4.7 Force Mains

Sewage may have to be carried to higher elevations through force mains. The size of the main should be determined by taking into account the initial cost of pipeline and cost of operation of pumping for different sizes. Velocities may be up to 3m/s. Hazen - Williams formula is generally used for computing the frictional losses (Eq.3.9). The size of force main can also be determined by using Modified Hazen - Williams formula mentioned in 3.4.2.5.

Losses in valves, fittings, etc., are dependent upon the velocity head \(v^2/2g\). Loss in bends and elbows depend upon the ratio of absolute friction factor to dia of pipe, besides velocity head. Loss due to sudden enlargement depends upon the the ratio of diameters. The losses in bends, enlargements and tapers are given in Manual on Water Supply and Treatment. In the actual design of the force mains, it may not be necessary to compute the losses individually but the same may be assumed arbitrarily as 10% of the total frictional losses depending upon the number of bends, tapers and other fittings. However, for shorter mains with a large number of bends etc., the actual loss may be computed and expressed as equivalent length. For economic design of force main a reference may be made to Chapter 6 of Manual of Water Supply and Treatment. Each individual case needs to be studied from various aspects such as operation of pumps within the specified limits, availability of land required for duplicating the main in future etc.

3.4.8 Sulphide Generation

Sewage when out of contact with air results in sulphide production. At pH 5 it is nearly all of \(H_2S\) and at pH 9 it is \(HS^-\) (Hydrogen Sulphide ion). Sulphide buildup in force mains can be prevented by
injection of compressed air into pump discharge, at the rate of 10 L/min for each cm of pipe diameter. Sulphide generation usually occurs in force mains. It can also occur in partfull sewers if the rate of oxygen transfer at the surface is insufficient to keep with the demand. Deep flow is more conducive to sulphide generation, and hence sulphide generation may be minimised by designing sewers with shallow depth of flow if economical. Velocities of about 1m/s may be required to prevent sulphide build up.

3.5 DESIGN OF SEWER SYSTEMS

3.5.1 Introduction

Sewers are meant to transport storm water or waste water from one location to another location by gravity and therefore have to be laid deep enough to receive all the flows. Sewers must resist erosion and corrosion and its structural strength must be sufficient to carry backfill, impact, and live loads satisfactorily. The size and slope of sewer must be adequate for the flow to be carried and sufficient to prevent deposition of solids. Ease and economy of maintenance, safety to the personnel and the public during its life as well as during construction also must be considered.

In the design of a sewer system the decisions are location, size, slope, and depth of sewer and sewer material and other appurtenances to be added such as manholes, junctions and other structures to minimize turbulence and save head loss and prevent deposits. The aim of design is not only to make the sewer system functional, but also build the system at lowest cost ensuring durability over the life of the system.

3.5.2 Available Head

Generally the total available energy is utilized to maintain proper flow velocities in the sewers with minimum head loss. However in hilly terrain excess energy may have to be dissipated using special devices. Hence the sewer system design is limited on onehand by hydraulic losses which must be within the available Head and on the other to maintain self cleansing velocities. It becomes difficult to meet both conditions with increasing variation in rate of flow. Where differences in elevations are insufficient to permit gravity flow, pumping may be required. The cost of construction, operation, and maintenance of pumping stations are compared with the cost of construction and maintenance of gravity sewers. Apart from the cost considerations the consequences of mechanical and electrical failures at pumping stations may also be considered, which may necessitate a gravity system even at a higher cost.

3.5.3 Layout of Systems

The sewerage system layout involves the following steps

i) Selection of an outlet or disposal point
ii) Prescribing limits to the drainage valley or Zonal Boundaries
iii) Location of Trunk and Main Sewers
iv) Location of Pumping Stations if found necessary

In general the sewers will slope in the same direction as the street or ground surface and will be connected by Trunk Sewers. The discharge point may be a treatment plant or a pumping station or a water course, a trunk or intercepting sewer. It is desirable to have discharge boundaries following the property limits. The boundaries of sub zones are on the basis of topography, economy or other practical consideration. Trunk and main sewers are located in the valleys.

The most common location of sanitary sewer is in the centre of the street. A single sewer serves both sides of the street with approximately same length for each house connection. In very wide streets
it may be economical to lay a sewer on each side, in such case the sewer may be adjacent to curb or under the footpath. Interference with other utilities has to be avoided. Sometimes sewers may be located in the back of property lines to serve parallel rows of houses in residential area. However access to such locations becomes difficult and hence sewer locations in streets are often preferred. Sewers as a rule are not located in proximity to water supplies. When such situations are unavoidable the sewers may be encased in sleeve pipes or encased in concrete. Tees or Wyes should be provided for all house connections both for present and future locations so as to avoid breaking a hole into the side of a sewer.

3.5.3.1 Plans

The following procedure is recommended for the nomenclature of sewers:

The trunk sewer should be selected first and drawn and other sewers should be considered as branches. The trunk sewer should be the one with the largest dia that would extend furthest from the outfall works. Whenever two sewers meet at a point, the main sewer is the larger of the incoming sewers. The manholes of the trunk sewer are designated as 0, 1, 2, 3 etc. commencing at the lower end (outfall end) of the line and finishing at the top end. Manholes on the mains or sub mains are again numbered 1, 2, 3, etc., prefixing the number of the manhole on trunk/main sewer where they join (e.g. 3.2 represents the second manhole on the main sewer from the manhole no. 3 on the trunk sewer). When all the sewer lines connected to the main line have thus been covered by giving distinctive numbers to the manholes, the manholes on the further branches to the branch mains are similarly given distinctive numbers, again commencing with the lower end. If there are two branches, one on each side meeting the main sewer or the branch sewer, letter 'L' (to represent left) or letter 'R' (to represent right) is again prefixed to the numbering system, reckoning against the direction of flow. If there is more than one sewer either from the left or right they are suitably designated as L1, L2, R1, R2, the subscript referring to the line near to the sewer taking away the discharge from the manhole.

Thus L1 R4.2.3 (Figure 3.8) will pinpoint a particular manhole on the submain from which the flow reaches manhole number 4 on the trunk sewer through a submain and a main. The first numeral (from the left) is the number of the manhole on the trunk sewer. The numerals on the right of this numeral, in order, represent the manhole numbers in the main, submain etc., respectively. The first letter immediately preceding the numeral denotes the main and that it is to the right of the trunk sewer. Letters to the left in their order represent submain, branch respectively. The same nomenclature is used for representing the sections e.g. Section L1 R4.2.3 identifies the section between the manhole L1 R4.2.3 and the adjoining downstream manhole. All longitudinal sections should be indicated with reference to the same datum line. The vertical scale of the longitudinal sections should be magnified ten times the horizontal scale.

Once the rough sections have been prepared the designer should go over the work for improving the spacing of manholes, the sizes and gradients of the sewers and so forth, economising on materials and excavation to the extent possible but at the same time making sure that the sewer will serve all users and that they can be actually laid according to the alignments shown in the drawing and have sufficient gradients. The sewers should have a minimum cover of 1 m at the starting point or otherwise adequately protected with cement concrete encasing.

The following scales may be adopted for the various plans and drawings:

(a) Index Plan - 1:100,000 or 1:200,000
(b) Keyplan & general layout - 1:10,000 or 1:20,000
(c) Zonal Plans - 1:2,500 or 1:5,000
(d) Longitudinal sections of sewers - 1:500 or 1:1,250 or 1:2,500
(e) Structural drawings - 1:20 or 1:50 or 1:100 or 1:200
The sewers should be shown as thick lines and manholes as small circles in plan. In section the sewer may be indicated by a line or two lines depending upon the diameters and scales adopted. Grade, size and material of pipe, ground and invert levels and extent of concrete protection should be indicated as shown in Figure 3.10.

Standard vertical plan filing systems are now available and are very convenient for storing of plans and taking them out quickly for reference. Normally, size A0 and A1 (trimmed size 841 x 1189 mm and 594 x 841 mm respectively) should be used while submitting the project drawings for approval.

All documents including drawings, design calculations, measurement sheets of estimates, etc., should be in metric system. In drawings, length should be indicated either entirely in metres correct up to two decimals or entirely in millimetres (for thickness etc.). If this practice is followed, units would be obvious and in certain cases writing of m or mm with the figure can be omitted. The flow should normally be indicated in litres per second (lps) or cubic metres per hour (m³/hr) except for very large flows which may be indicated in cubic metres per second (cumec). For uniformity, lps for sewage flows and cumec for storm flows is recommended. Similarly, areas in sewer plans and design calculations may be indicated in hectares (ha). While writing figures they should be grouped into groups of three with a single space between each group and without comma. In case of a decimal number, this grouping may be on either side of the decimal (e.g. 47 342.294 31).

In case of design of sewer network using computer programme, there is no restriction in the nomenclature of the sewers and manholes as required for the manual design. It is sufficient to give node numbers as well as pipe (link) numbers in any manner in the sewer network for design of the network for using computer software. The numbering of the network may be adopted as shown in the diagram enclosed (Fig. 3.9).

3.5.4 Design Approach

3.5.4.1 Design Steps

The first step in the hydraulic design of a sewer network is to prepare a map showing locations of all sewers and measure the contributory area to each point. Profiles along each sewerline are also to be marked. Critical levels such as basements of low lying houses and other buildings, levels of existing sewers to be intercepted high water levels in trunk sewers or disposal points have to be noted. Sewer network design computations are repetitive and hence can be easily done by Tabular form or by using suitable computer soft ware programmes.

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

1) A self cleansing velocity is maintained at present peak flow
2) A sewer runs at 0.80 full at ultimate peak flow

Appendix 3.5 gives a worked example of designing a sewer system. Appendix 3.6 gives a design of sewer network using a computer programme in BASIC.

3.6 SMALL BORE SEWER SYSTEM

3.6.1 System Description

Small bore sewer system is designed to collect and transport only the liquid portion of the domestic wastewater for off-site treatment and disposal. The solids are separated from the wastewater in septic
FIG. 3.7: INVERTED SIPHON OR SUPPRESSED SEWER FOR COMBINED SEWAGE.
FIG. 3.8: NOMENCLATURE OF SEWERS
FIG. 3.9: EXAMPLE SEWER NETWORK
tanks or aqua privies installed upstream of every connection to the small bore sewers. Where conventional sewers would be inappropriate or infeasible, this system provides an alternative. This system also provides an economical way to upgrade the existing on-site sanitation facilities to a level of service comparable to conventional sewers. Since the small bore sewer collects only settled wastewater, it needs reduced water requirements and reduced velocities of flow. This in turn reduces the cost of excavation, material and treatment.

3.6.2 Components of the System

The small bore sewer system consists of house connections, interceptor tanks, sewers, cleanouts and manholes, vents and in some cases lift stations.

3.6.3 Suitability of the System

This system is suitable under the following conditions: Where

1. effluent from pour-flush toilets and household sullage cannot be disposed off on-site
2. installation of new schemes is taken up, especially for fringe areas
3. a planned sequence of incremental sanitation improvements with small bore sewers as a first stage is contemplated
4. existing septic tank systems have failed or where there are a number of septic tanks requiring the effluent to be discharged but soil and ground water conditions do not permit such a discharge.

3.6.4 Design Criteria

Each house sewer is usually connected to an interceptor tank which is designed as a septic tank. The optimum number of house sewers to be connected to an interceptor tank can be worked out for each case. The effluent from the tank is discharged into the small bore sewer system, where flow occurs by gravity utilising the head resulting from the difference in elevation of its upstream and downstream ends. The sewer should be set deep enough to carry these flows.

A design peak flow factor of 2.0 is adopted. At peak flow, the sewer is to flow full. Where pumping is to be done, the peak flow rate will be equal to the pump discharge rate, unless the pumping cycle is less than five minutes. Unlike conventional gravity sewers which are designed for open channel flow, small bore sewers may be installed with sections depressed below the hydraulic grade line. Design decisions regarding the location, depth, size and gradient of the sewer must be carefully made to hold hydraulic losses within the limits of available head. Minimum pipe diameter of 100 mm is recommended. Maintenance of strict sewer gradients to ensure minimum self-cleansing velocities is not necessary. Minimum velocities in the range of 0.3 - 0.6 m/s may be used. The sewer may be constructed with any profile as long as the hydraulic gradient remains below all interceptor tank outlet inverts.

Ventilation is not necessary for small bore sewers, if they are laid on a falling gradient. A vent cleanout to release air may be provided at every hump.

3.6.5 Appurtenances

Cleanouts are used in place of manholes, except at major junctions and should be located at all upstream ends, intersections of sewer lines, major changes in direction, at high points and at intervals of 60-100 m in straight reaches to long flat sections. Pumping may be provided to overcome elevation conditions or to raise collected wastewater from one drainage zone to another. Long pumping intervals should be avoided to prevent excessively surcharged conditions in the small bore sewers.
3.6.6 Disposal of Effluent

The effluent from small bore sewers can be discharged into conventional sewerage systems if possible; otherwise the effluent from small bore sewers can be treated through waste stabilisation ponds, any other low cost treatment followed by fish ponds, or land treatment with the usual precautions.

3.6.7 Limitations

1. The interceptor tanks need periodical cleaning and disposal of solids. This requires an organisation for maintenance of these interceptors to ensure satisfactory performance of the system.

2. Special precautions should be taken to prevent illegal direct connections into sewers without interceptor and dumping of solid waste into interceptors, cleanouts and manholes.

One or more houses may be connected to an interceptor tank through house connections.

3.7 SHALLOW SEWERS

3.7.1 System Description

Shallow sewers are designed to receive domestic sewage for off-site treatment and disposal. They are a modification of the surface drain with covers and consist of a network of pipes laid at flat gradients in locations away from heavy imposed loads (usually in backyards, sidewalks and lanes of planned and unplanned settlements). They are usually laid at a minimum depth of 0.4 m. Where vehicular loading is present and the invert depth of sewer is less than 0.8 m, a concrete encasement is provided for the sewer.

3.7.2 Components of the System

The shallow sewer system, like the conventional sewer system consists of house connections, inspection chambers, laterals, street collector sewers, pumping stations where necessary and treatment plants. Low volume pour-flush or cistern-flush waterseal toilets are connected to the inspection chamber by means of a 75 mm diameter sewer. A vertical ventilation column of the same diameter is provided on the house connection. The sullage water generated in the house is also connected to the inspection chamber directly when water consumption is more than 75 lpcd. Where the water consumption is lesser and where grit is used for cleaning purpose, it is connected through a grit/grease trap. Inspection chambers are provided along the street collector sewers and along the length of the laterals at intervals not exceeding 40 m. Usually one chamber is provided for each house. However two or more houses may share a single inspection chamber. The chamber is provided with a lift-lifting RCC cover.

The laterals are of small diameters (min. 100 mm) and of stoneware or concrete which are buried in a shallow trench. The minimum depth of pipe invert is 0.4 m. In general, they have straight alignment between inspection chambers and are suitably aligned around existing buildings. They may even pass under property boundary walls and also under future building areas. The inspection chamber however is located in an open area.

The street collector sewer has a usual minimum diameter of 150 mm; however 100 mm sewers may also be used if hydraulic capacities permit. Where community septic tanks are provided at the exit of lateral sewers, the street sewers should be designed as small-bore sewers.

Pumping stations should, as far as possible, be eliminated.
3.7.3 Applicability

Shallow sewers are suitable where

1. high density slums and squatter settlements (usually 100 to 160 persons per hectare) exist
2. adverse ground conditions exist and on-site disposal is not possible
3. sullage also has to be disposed off and where the minimum water consumption rate is 25 lpcd.

3.7.4 Limitations

Shallow sewerage system is suitable where adequate ground slopes are available. Since these sewers are laid at flat gradients the solids are likely to get deposited unless flushed at peakflow conditions. Otherwise these sewers may get clogged and require frequent cleaning.

3.8 NON CIRCULAR SEWERS

The Mannings Formula along with appropriate coefficients of roughness (Table 3.4) can be used for design of box type ducts for conveying sewage and open drains for carrying storm water.
FIG. 3.10: A TYPICAL SEWER SECTION
CHAPTER 4

SEWER APPURtenances

4.1 INTRODUCTION

Sewer appurtenances are devices necessary, in addition to pipes and conduits, for the proper functioning of any complete system of sanitary, storm or combined sewers. They include structures and devices such as various types of manholes, lampholes, gully traps, intercepting chambers, flushing tanks, ventilation shafts, catch-basins, street inlets, regulators, siphons, grease traps, side flow weirs, leaping weirs, venturi-flumes and outfall structures.

4.2 MANHOLES

4.2.1 Ordinary Manholes

A manhole is an opening constructed on the alignment of a sewer for facilitating a person access to the sewer for the purpose of inspection, testing, cleaning and removal of obstructions from the sewer line.

4.2.1.1 SPACING

Manholes should be built at every change of alignment, gradient or diameter, at the head of all sewers and branches and at every junction of two or more sewers. On sewers which are to be cleaned manually, which cannot be entered for cleaning or inspection, the maximum distance between manholes should be 30 m.

The spacing of manholes on large sewers above 900mm diameter is governed by the following for the sewers to be cleaned manually:

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

b) The distance up to which materials for repairs may be conveyed through the sewer and

c) Ventilation requirements for men working in the sewer.

For sewers which are to be cleaned with mechanical devices, the spacing of manholes will depend upon the type of equipment to be used for cleaning sewers.

The spacing of manholes above 90 to 150 m may be allowed on straight runs for sewers of diameter 900 to 1500 mm. Spacing of manholes at 150 to 200 m may be allowed on straight runs for sewers of 1.5 to 2.0 m dia., which may further be increased up to 300 m for sewers of over 2m diameter. A spacing allowance of 100m per 1m dia of sewer is a general rule in case of very large sewers.

4.2.1.2 CONSTRUCTIONAL DETAILS

Manholes are usually constructed directly over the centre line of the sewer. They are circular, rectangular or square in shape. Manholes should be of such size as will allow necessary cleaning and inspection of manholes.
**Fig. 4.1:** Typical Illustration of Rectangular Manhole for Depth Less Than 0.90m  
(Size 900 x 800 mm)

**Fig. 4.2:** Typical Illustration of Rectangular Manhole for Depth from 0.90m Upto 2.5m  
(Size 1200 x 900 mm)
FIG 4.3: TYPICAL ILLUSTRATION OF ARCHED TYPE MANHOLE

FIG 4.4: TYPICAL ILLUSTRATION OF CIRCULAR MANHOLES
(ALL DIMENSIONS ARE IN mm)
a) **Rectangular Manholes**  The minimum internal sizes of rectangular manholes (Fig. 4.1 & Fig. 4.2) between brick faces should be as follows:

i) For depths of manholes less than 0.90m, 900 x 800mm and

ii) For depths of manholes from 0.9m and upto 2.5m, 1200 x 900mm

b) **Arch Type Manholes**  For depths of 2.5m and above, arch type manholes (Fig. 4.3) can be provided and the internal sizes of chambers between brick faces shall be 1400 x 900mm. The width of manhole chamber on bends and junctions of pipes with diameter greater than 450mm, should be suitably increased to 900mm or more so that benching width on either side of channel is at least 200mm.

c) **Circular Manholes**  The circular manholes may be constructed as alternative to rectangular and arch type manholes.

Circular manholes are stronger than rectangular and arch type manholes and thus these are preferred over rectangular as well as arch type manholes.

The circular manholes can be provided for all depths starting from 0.9m. Circular manholes are straight down in lower portion and slanting in top portion so as to narrow down the top opening equal to internal dia of manhole cover. Depending upon the depth of manhole, the diameter of manhole changes. The internal diameter of circular manholes may be kept as following for varying depths:

i) For depths above 0.90m and upto 1.65m, 900mm diameter

ii) For depths above 1.65m and upto 2.30m, 1200mm diameter

iii) For depths above 2.30m and upto 9.0m, 1500mm diameter

iv) For depths above 9.0m and upto 14.0m, 1800mm diameter.

Some types of circular manholes have been shown in Fig. 4.4.

If the sewer is constructed in a tunnel, the manhole should be located at the access or working shafts and the manhole chamber may be constructed of a size to suit the working shaft or vice-versa.

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

The opening for entry into the manhole (without cover) should be of such minimum dimensions as to allow a workman with the cleaning equipments to get access into the interior of the manhole without difficulty. A circular opening is generally preferred. A minimum clear opening of 60cm is recommended. Suitable steps usually of malleable cast iron shall be provided for entry.

Access Shafts for large Sewers - Access shaft shall be circular in shape and shall have a minimum internal dia of 750mm, where the depth of the shaft exceeds 3m suitable dimensions shall be provided to facilitate cleaning and maintenance.

Access shaft where built of brickwork should be corbeled on three sides to reduce it to the size of the opening in the cover frame, and to provide easy access on the fourth side to step irons or ladder. In determining sizes, the dimensions of the maintenance equipment likely to be used in the sewers, shall be kept in view.
Where the diameter of the sewer is increased, the crown of the entering and leaving pipes shall be fixed at the same level and necessary slope is given in the invert of the manhole chamber. In exceptional cases and where unavoidable, the crown of entering sewer may be fixed at lower level but in such cases too the peak flow level of the two sewers shall be kept the same.

A slab, generally of plain cement concrete at least 150mm thick should be provided at the base to support the walls of the manhole and to prevent the entry of ground water. The thickness of the base also shall be suitably increased up to 300mm, for manholes on large dia. sewers, with adequate reinforcement provided to withstand excessive uplift pressures. In the case of larger manholes, the flow in the sewer should be carried in U-shaped smooth channel constructed integrally with the concrete base of the manhole. The side of the channel should be equal to the dia. of the largest sewer pipe. The adjacent floor should have a slope of 1 in 10 draining to the channel. Where more than one sewer enters the manhole the flow through channel should be curved smoothly and should have sufficient capacity to carry the maximum flow.

It is desirable to place the first pipe joint outside the manhole as close as practicable. The pipe shall be built inside the wall of the manhole flush with the internal periphery protected with an arch of masonry or cement concrete to prevent it from being crushed.

The sidewalls of the manhole are usually constructed of cement brick work 250mm thick and corbelled suitably to accommodate the frame of the manhole cover.

The inside and outside of the brickwork should be plastered with cement mortar 1:3 (1 cement: 3 coarse sand) and inside finished smooth with a coat of neat cement.

Where subsoil water condition exists, a richer mix may be used and it shall further be waterproofed with addition of approved water proofing compound in a quantity as per manufacturer’s specifications.

4.2.1.3 COVERS AND FRAMES

The size of manhole covers should be such that there should be clear opening of not less than 560mm diameter for manholes exceeding 0.9m depth.

When cast iron manhole covers and frames are used they shall conform to IS 1726 (parts 1 to 7). The frames of manhole shall be firmly embedded to correct alignment and level in plain concrete on the top of masonry. After completion of the work, manhole covers shall be sealed by means of thick grease.

Where sewers are to be laid in high subsoil water conditions, manholes may be constructed in reinforced cement concrete of grade M 20 or 1:1 1/2:3. The manholes in this type of construction shall be preferably circular type (Fig.4.5).

Heavy reinforced concrete covers with suitable lifting arrangements could also be used instead of C.I. manhole covers. Reinforcing materials other than Mild Steel are being tried. However Precast Cement Concrete covers reinforced by materials other than Mild Steel should be used provided that these are properly tested & certified for use by competent authority. Fibre Reinforced Plastic covers (FRP) conforming to relevant I.S. may be used wherever such covers are available.

4.2.2 Types of Manholes

4.2.2.1 STRAIGHT THROUGH MANHOLES

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

4.2.2.2 JUNCTION MANHOLES

A manhole should be built at every junction of two or more sewers, and the curved portions of the inverts of tributary sewers should be formed within the manhole. To achieve this with the best economy of space, the chamber may be built of a shape other than rectangular. The soffit of the smaller sewer at a junction should be not lower than that of the larger sewer, in order to avoid the surcharging of the former when the latter is running full, and the hydraulic design usually assumes such a condition.

The gradient of the smaller sewer may be steepened from the previous manhole sufficiently to reduce the difference of invert level at the point of junction to a convenient amount.

4.2.2.3 SIDE ENTRANCE MANHOLES

In large sewers or where it is difficult to obtain direct vertical access to the sewer from ground level, owing to existing services, gas, water, 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.

In the tunnelled sewers the shaft and lateral access heading may be used as a working shaft, the tunnel being broken out from the end of the heading, or alternatively the shaft and heading may be used as a working shaft, the tunnel being broken out from the end of the heading, or alternatively the shaft and heading may be constructed after the main tunnel is complete, provision having been made for breaking in from the access heading to build the chamber.

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 sewer where the floor of the side-entrance passage is above the soffit either steps or a ladder (which should be protected either by a removable handrail or by safety chains) should be provided to reach the benching.

4.2.2.4 DROP MANHOLES

When a sewer connects with another sewer, where the difference in level between water lines (peak flow levels) of main line and the invert level of branch line is more than 600mm or a drop of more than 600mm is required to be given in the same sewer line and it is uneconomical or impractical to arrange the connection within 600mm, a drop connection shall be provided for which a manhole may be built incorporating a vertical or nearly vertical drop pipe from the higher sewer to the lower one. This pipe may be either outside the shaft and encased in concrete or supported on brackets inside the shaft, which should be suitably enlarged. 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, which should be provided with a half blank flange. If the drop pipe is inside the shaft, it should be in cast iron and it would be advantageous to provide adequate means for rodding and water cushion of 150mm depth should also be provided. The diameter of the back drop should be at least as large as that of the incoming pipe. A typical illustration of a drop manhole is shown in Fig.4.6.

The drop pipe should terminate at its lower end with a plain or duck-foot bend turned so as to discharge its flow at 45 degrees or less to the direction of the flow in the main sewer and the pipe, unless of cast iron, should be surrounded with 150mm of concrete.

In the case of sewers over 450mm in diameter the drop in level may be accomplished by one of the following methods:

a) A Cascade - This is a steep ramp composed of steps over which the flow is broken up and retarded. A pipe connecting the two levels is often concreted under the steps.
FIG. 4.5: TYPICAL ILLUSTRATION OF R.C.C. MANHOLE
(CONCRETE NOT SHOWN)