to allow small flows to pass without trickling over the steps. The cascade steps may be made of heavy duty bricks of Class I quality (IS:2180-1985), cement concrete with granolithic finish or dressed granite

b) ***A Ramp*** - A ramp may be formed by increasing the grade of the last length of the upper sewer to about 45 degrees or by constructing a steeply graded channel or culvert leading from the high level to the low level sewer. In order to break up the flow down the ramp and minimize the turbulence in the main sewer, the floor of a culvert ramp should be obstructed by raised transverse ribs of either brick or concrete at 1.15m intervals and a stilling pool provided at the bottom of the ramp and

c) ***By Drops in Previous Successive Manholes*** - Instead of providing the total drop required at the junction manhole, the same may be achieved by giving smaller drops in successive manholes preceding the junction manhole. Thus, for example, if a total drop of 2.4m is required to be given, 0.6m drop may be given in each of the previous three manholes and the last 0.6m drop may be given at the junction manhole.

4.2.2.5 Scraper (Service) Type Manhole

All sewers above 450mm in diameter should have one manhole at intervals of 110 to 120m of scraper type. This manhole should have clear opening of 1200 x 900mm at the top to facilitate lowering of buckets.

4.2.2.6 Flushing Manholes

Where it is not possible to obtain self cleansing velocities due to flatness of the gradient especially at the top ends of branch sewers which receive very little flow, it is essential that some form of flushing device be incorporated in the system. This can be done by making grooves at intervals of 45 to 50m in the main drains in which wooden planks are inserted and water allowed to head up and which will rush on with great velocity when the planks are removed. Alternatively, an overhead water tank is built, from which connections are made through pipes and flushing hydrants to rush water to the sewers. The relevant Indian Standard is IS:4111 (part-2).

Flushing can be very conveniently accomplished by the use of a fire hydrant or tanker and hose.

Where flushing manholes are provided, they are located generally at the head of a sewer. Sufficient velocity shall be imparted in the sewer to wash away the deposited solids. The flush is usually effective upto a certain distance after which the imparted velocity gets dissipated.

The automatic systems which are operated by mechanical units get often corroded by the sewer gases and do not generally function satisfactorily and hence are not recommended.

In case of hard chokages in sewers, care should be exercised to ensure that there is no possibility of backflow of sewage into the water supply mains.

Approximate quantities of water needed for flushing are as follows:

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

4.3 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, the profile being depressed below the hydraulic grade line. Since the inverted siphon is in no sense a true siphon, an attempt has been made, but with indifferent success, to popularise the term depressed sewer for this device. In sewerage practice the word siphon has come to mean an inverted siphon unless otherwise qualified. Siphons, both true and inverted are used in sewers to pass over or under obstacles such as buried pipes, subways and stream beds. As the siphon is an appurtenance requiring considerable attention for maintenance, it should be used only where other means of passing an obstacle in line of the sewer are impracticable. The relevant Indian Standard is IS:4111 (part-3). More details of inverted siphons are discussed in 3.4.5.

4.4 HOUSE SEWER CONNECTIONS

For large diameter of sewers, house connections may be given through rider sewers. Sewers should be connected through manhole or drop manhole. Where there is no Y or T left for new connections, insertion of new Y or T is not prescribed.

House sewer connections should preferably be 150mm or more in dia with a minimum slope of 1:60 laid as far as possible, to a straight line and grade. Connections to the main street sewer should normally be made with Y branches. For sewers deeper than 5m. tees are preferable to facilitate connections at higher elevations, particularly where simultaneous discharge of house sewers into the street sewer is not expected and also prevent damage while rodding.

The Y or tee may be installed with the branch turned about 45 degrees from the horizontal so that back-flooding of the house connection will not occur when the collecting sewers flow full. Connections to large sewers are for the same reason made above the spring line of the main sewer. The house connection for deep sewers, where made by means of a vertical pipe riser, shall be encased in concrete at least 75mm thick and upto the full length of the pipe to prevent damage during backfilling.

All possible practical provision should be made for future connections in the original construction. Where possible, property connection chambers shall be constructed close to the property line to facilitate easier future connections. If possible more refined methods of cutting the sewers may be used to make the house connections without disturbing sewage flow. Connections to existing sewers, particularly those of small diameter, should wherever possible be made with these tees or Ys. The free end of the service lines or branches should be closed with a carefully fitted stopper, when service lines are not yet connected to buildings or where intermediate connections are not yet made with the tee or Y branches.

The recent practice is to make the house connection directly without providing intercepting traps. The deletion of the intercepting traps at the sewer connection provides effective ventilation of the sewer system without the use of ventilators. Intercepting traps may be useful for multistoried houses.

4.5 STORM WATER INLETS

These are devices meant to admit the surface runoff to the sewers and form a very important part of the system. Their location and design should therefore be given careful consideration.

Storm water inlets may be categorised under three major groups viz. curb inlets, gutter inlets and combination inlets, each being either depressed or flush depending upon their elevation with reference to the pavement surface.

The actual structure of an inlet is usually made of brickwork. Normally, cast iron gratings conforming to I.S.5961 shall be used. In case there is no vehicular traffic, fabricated steel gratings may be used. The clear opening shall not be more than 25mm. The connecting pipe from the street inlet to the main street sewer should not be less than 200mm in dia. and should have sufficient slope.

Maximum spacing of inlets would depend upon various conditions of road surface, size and type of inlet and rainfall. A maximum spacing of 30m is recommended.

4.5.1 Curb Inlets

Curb inlets are vertical openings in the road curbs through which the storm water flows and are preferred where heavy traffic is anticipated.

They are termed as deflector inlets when equipped with diagonal notches cast into the gutter along the curb opening to form a series of ridges or deflectors. This type of inlet does not interfere with the flow or traffic as the top level of the deflectors lie in the plane of the pavement.

4.5.2 Gutter Inlets

These consist of horizontal openings in the gutter which is covered by one or more gratings through which the flow passes.

4.5.3 Combination Inlets

These are composed of a curb and gutter inlet acting as a single unit. Normally, the gutter inlet is placed right in front of the curb inlets but it may be displaced in an overlapping or end-to-end position. Figure 4.7 shows different types of inlets.

4.6 CATCH BASINS

Catch basins are structures meant for the retention of heavy debris in storm water which otherwise would be carried into the sewer system. Their use is not recommended since they are more of a nuisance and a source of mosquito breeding apart from posing substantial maintenance problems.

Where a main sewer is laid and the sewer network is not yet laid, the dry weather flow from the open drains may be connected to the sewers by making a provision for a catch basin and overflow weir.

4.7 REGULATOR OR OVERFLOW DEVICE

These are used for preventing overloading of sewers, pumping stations, treatment plants, or of disposal arrangements, by diverting the excess flows to relief sewers etc.

The overflow devices may be sideflow or leaping weirs according to the position of the weir, siphon spillways or float actuated gates and valves.

4.7.1 Side Flow Weir

A side flow weir constructed along one or both sides of a combined sewer delivers excess flows during storm periods to relief sewers or natural drainage courses. 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 sufficiently long for effective regulation.

The length of the side-flow weir is given by the formula devised by Babbitt.

$$L = 7.6\times10^{-4} \; V \; D \log \frac{h_1}{h_2}$$

Where L = the required length in m
V = the velocity of approach in mps
D = the dia of the sewer in mm and
h_1 and h_2 = the heads in m above the crest of the weir upstream and downstream.

The formula is limited to conditions in which the weir is placed in the side of a circular pipe at a distance above the bottom, greater than d/4 and less than d/2 where 'd' is the diameter of the pipe and the edge of the weir is sharp and parallel to the invert of the channel. Its usefulness is limited in that it was devised for pipes between 450 and 600mm in dia and where the depth of flow above the weir should not exceed 3d/4.

4.7.2 Leaping Weir

A 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 all of the storm leaps. Leaping weirs have the advantage of operating as regulators without moving parts, but they offer the disadvantage of concentrating grit in the low flow channel. Some formulae based in empirical findings are available for design of leaping weirs. However, from practical considerations, it is desirable to design the weirs with moving crests to make the opening adjustable as indicated in Figure 4.8.

4.7.3 Float Actuated Gates and Valves

Control of the flow in sewers can also be regulated by means of automatic mechanical regulators. These are actuated by the water level in the sump interconnected to the sewers. These regulators involve moving parts which are actuated by the varying depths of flow in the sewers. They require periodic inspection and maintenance.

4.8 FLAP GATES AND FLOOD GATES

Flap gates or backwater gates are installed at or near sewer outlets to prevent backflow of water during high tide or at high stages in the receiving stream. Such gates should be designed so that the flap should open at a very small head differential. With a properly operated flap gate it is possible to continue to pump a quantity equivalent to the sanitary sewage flow from the combined sewer to the treatment plant even though flood conditions prevail in the stream at the sewer outlet.

In case of a sea and estuary outfall, the outfall sewer should be able to discharge at full rate when the water level in the estuary or sea is 3/4th the mean annual tide level. Adequate storage to prevent backflow into the system due to the closure of these gates at the time of high tides is also necessary if pumping is to be avoided. To control the flow from the storage tank, flood gate or penstocks are provided which can be opened and closed quickly at the predetermined states of tide. The gates are generally electrically operated and are controlled by a lunar clock.

Many flap or back water gates are rectangular and may consist of wooden planks. Circular or rectangular metallic gates are commercially available. Flap gates may be of various metals or alloys as required by the design conditions.

Flap gates are usually hinged by a link-type arrangement that makes it possible for the gate shutter to get seated more firmly. Hinge pins, linkages and links should be of corrosion resistant material.

There should be a screen chamber to arrest floating undesirables on the upstream side of the flap gate.

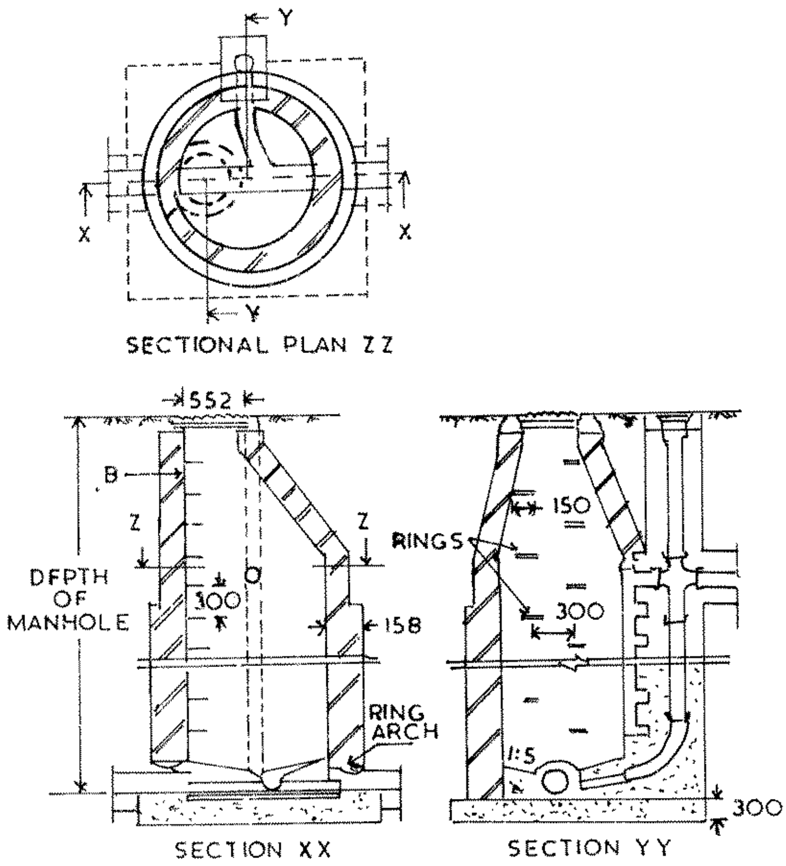
The maintenance of flap gates requires regular inspection and removal of debris from the pipe and outlet chamber, lubrication of hinge pins and cleaning of seating surfaces.

4.9 MEASURING DEVICES

This along with measurement of flow has been discussed in detail in Chapter 25.

4.10 SEWER VENTILATORS

In a modern, well designed sewerage system, there is no need to provide ventilation on such elaborate scale considered necessary in the past, specially with the present day policy to omit intercepting traps in house connections. The ventilating columns are not necessary where intercepting traps are not provided. It is necessary however, to make provision for the escape of air to take care of the exigencies of full flow and also to keep the sewage as fresh as possible specially in outfall sewers. In case of storm sewers this can be done by providing ventilating manhole covers.



TYPICAL ILLUSTRATION OF DROP MANHOLE
(ALL DIMENSIONS IN MILLIMETRES)

FIG. 4·6

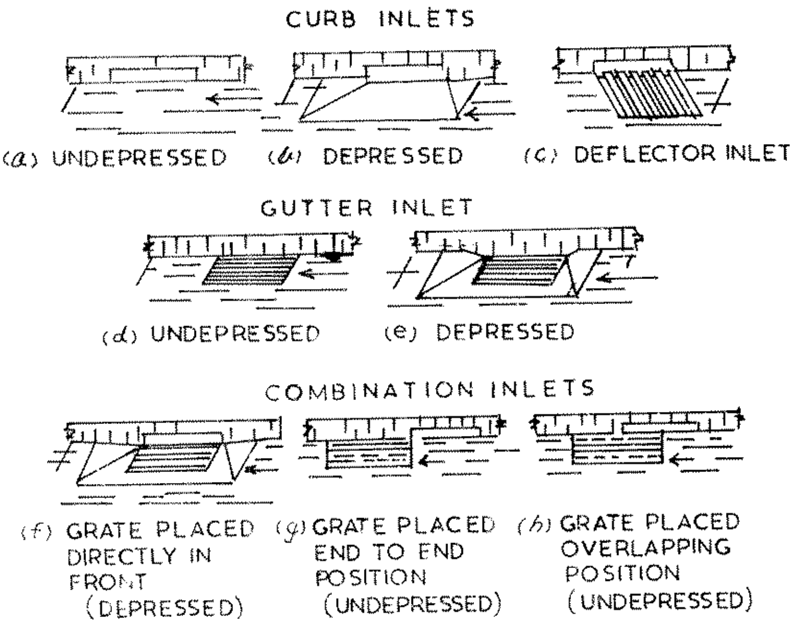
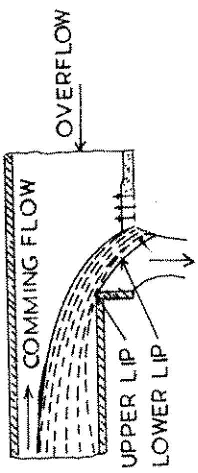


FIG. 4·7



LEAPING WEIR

FIG. 4·8

CHAPTER 5

MATERIALS FOR SEWER CONSTRUCTION

5.1 INTRODUCTION

Factors influencing the selection of materials for sewer construction are flow characteristics, availability in the sizes required including fittings and ease of handling and installation, water tightness and simplicity of assembly, physical strength, resistance to acids, alkalies, gases, solvents etc., resistance to scour, durability and cost including handling and installation.

No single material will meet all the conditions that may be encountered in sewer design. Selection should be made for the particular application and different materials may be selected for parts of a single project.

5.2 TYPES OF MATERIAL

5.2.1 Brick

Brickwork is used for construction of sewers, particularly for larger diameters. Many old brick sewers are still in use, the failures are mainly due to the disintegration of the bricks or the mortar joints. Because of the comparatively higher cost, larger space requirement, slower progress of work and other factors, brick is now used for sewer construction only in special cases. The advantage of brick sewers is that these could be constructed to any required shape and size.

Brick sewers shall have cement concrete or stone for invert and 12.5mm thick cement plaster with neat finish for the remaining surface. To prevent ground water infiltration, it is desirable to plaster the outside surface. Under special conditions protections against corrosion may be necessary.

5.2.2 Concrete

Concrete pipes may be manufactured to any reasonable strength required by varying the wall thickness and the percentage of reinforcement and shape of the reinforcing cage. A number of jointing methods are available depending on the tightness required and the operating pressure within the sewer line.

The advantages of concrete pipes are the relative ease with which the required strength may be provided, feasibility of adopting a wide range of pipe sizes and the rapidity with which the trench may be opened and backfilled.

However, these pipes are subject to corrosion where acid discharges are carried in the sewer or where velocities are not sufficient to prevent septic conditions or where the soil is highly acidic or contains excessive sulphates. Protective linings or coatings as discussed in 22.2.5.2 should be used inside and outside where excessive corrosion is likely to occur. Only high alumina cement concrete should be used when it is exposed to corrosive sewage or industrial wastes. When specifying concrete pipe, the pipe diameter, class or strength, the method of jointing and the type of protective coating and lining, if any, should be stipulated. Structural requirements of RCC and other pipes are discussed in 6.1.

5.2.2.1 Precast Concrete

Precast concrete pipes can be either plain or reinforced. Plain cement concrete pipes are used in sewerage systems on a limited scale only and generally reinforced concrete pipes are used. Non pressure pipes are used for gravity flow and pressure pipes are used for force mains, submerged outfalls, inverted siphons and for gravity sewers where absolute watertight joints are required. Non-pressure pipes used for the construction of sewers and culverts shall conform to IS:458-1988. Certain heavy duty pipes which are not specified in IS:458 should conform to other approved standards.

5.2.2.2 Cast-In-Situ Reinforced Concrete

Cast-in-situ reinforced concrete sewers are constructed where they are more economical, or when non-standard sections are required, or when a special shape is required or when the headroom and working space are limited. The sewer shape should be of an economic design, easy to construct and maintain and should have good hydraulic characteristics. Wide flat culvert bottoms should be provided with "Vee", of atleast 15cm depth in the centre. All formwork for concrete sewers should be unyielding and tight and should produce a smooth sewer interior. Collapsible steel forms will produce the desirable sewer surface and may be used when the sewer size and length justify the expense.

Reinforcement steel, concrete aggregates, cement and sand should conform to Indian Standard Specifications. It is desirable to specify a minimum clear cover of 50mm over reinforcement steel and a minimum slump consistent with workability should be used for obtaining a dense concrete structure free of voids. The distance for chuting concrete should be kept to a minimum to avoid segregation and the vibrating of concrete done by approved mechanical vibrators. Air entraining cement or plasticizing agents may be used to improve workability and ensure a denser concrete. Concrete should conforms to IS: 456-1978.

5.2.3 Stoneware or Vitrified Clay

Salt glazed stoneware pipes are manufactured in sizes 80mm to 1000mm in dia but sizes greater than 380mm dia are not generally used because of economic considerations. Specifications for the AA and A classes are identical except that in the case of Class AA pipes, 100% hydraulic testing has to be carried out at the manufacturing stage while in the case of Class A only 5% of the pipes are tested hydraulically (IS:651-1971). The lengths of vitrified clay pipes are 60cm, 75cm and 90cm, the preference being for the longer pipes for obvious reasons. Standard pipe fittings of vitrified clay are available to meet most requirements. When specifying vitrified clay pipes, the pipe diameter, class or strength, the method of jointing and the type of protective coating or lining if any, should be stipulated.

The resistance of vitrified clay pipes to corrosion from most acids and to erosion due to grit and high velocities gives it an advantage over other pipe materials in handling those wastes which contain high acid concentrations. Though a minimum crushing strength of 1600Kg/m is usually adopted for all sizes manufactured presently, vitrified clay pipes of crushing strength 2800Kg/m and over are manufactured in sizes upto 750mm dia in other countries. The strength of vitrified clay pipes often necessitates special bedding or concrete cradling to improve field supporting strength.

5.2.4 Asbestos Cement

For sewerage works, Asbestos cement pipes are usually used in sizes ranging from 80mm to 1000mm in dia (IS:1592-1970).

Some of the advantages of A.C.pipes are:

Non-corrosiveness to most natural soil conditions, freedom from electrolytic corrosion, good flow characteristics, light weight, ease in cutting, drilling, threading and fitting with G.I.Specials, allowance of greater deflection upto 12 degrees with mechanical joints, ease of handling, tight joints, and quick laying and backfilling.

A.C. pipes cannot, however, stand high superimposed loads and may be broken easily. They are subject to corrosion by acids, highly septic sewage and by highly acidic or high sulphate soils. Protective measures as outlined in 22.2.5 shall be provided in such cases. While using A.C.pipes strict enforcement of approved bedding practices will reduce possibility of flexure failure. Where grit is present, high velocities such as those encountered on steep grades may cause erosion.

5.2.5 Iron and Steel

5.2.5.1 Cast Iron

Cast iron pipes with a variety of jointing methods are used for pressure sewers, sewers above ground surface, submerged outfalls, piping in sewage treatment plants and occasionally on gravity sewers where absolutely water tight joints are essential or where special considerations require their use. I.S:1536-1989 and I.S:1537-1976 give the specifications for spun and vertically cast pipes respectively.

The advantage of cast iron pipes are long laying lengths with tight joints, ability when properly designed to withstand relatively high internal pressure and external loads and corrosion resistance in most natural soils. They are however subject to corrosion by acids or highly septic sewage and acidic soils.

Whenever it is necessary to deflect pipes from a straight line either in the horizontal or in the vertical plane, the amount of deflection allowed should not normally exceed 2.5 degrees for lead caulked joints and for mechanical joints, the deflection should be limited to 5 degrees for 80 to 300mm dia, 4 degrees for 350 to 400mm dia and 3 degrees upto 750mm dia pipes.

When specifying cast iron pipe, it is necessary to give the pipe class, the type of joint, the type of lining and the type of exterior coating. Necessary care should be taken during transport and handling of the pipes against breakage and cracks.

5.2.5.2 STEEL

Pressure sewer mains, under water river crossings, bridge crossings, necessary connections for pumping stations, self supporting spans, railway crossing and penstocks are some of the situations where steel pipes are preferred.

Steel pipes can withstand internal pressure, impact load and vibrations much better than C.I.pipe. They are more ductile and withstand water hammer better.

The disadvantage of steel pipe is that it cannot withstand high external load. Further, the main is likely to collapse when it is subjected to negative pressure.

Steel pipes are susceptible to various types of corrosion. Therefore steel pipes should not be used for partially full sewers. A thorough soil survey is necessary all along the alignment where steel pipes are proposed. Steel pipes should be protected against both internal and external corrosion.

Steel pipes should conform to IS:3589. Electrically welded Steel pipes (200mm to 2000mm) for gas, water and sewage and laying should conform to IS:5822.

5.2.5.3 Ductile Iron Pipes

Ductile Iron Pipes recently developed are also finding application in sewage conveyance systems. For further details reference may be made to IS:12288-1987.

5.2.6 Plastic Pipes

5.2.6.1 General

Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal dia with smooth internal bores. These pipes generally come in lengths of 6 metres. A wide range of injection moulded fittings, including tees, elbows, reducers, caps, pipe saddles, inserts and threaded adopters for pipe sizes upto 150mm are available.

5.2.6.2 PVC PIPES

The Chief advantages of PVC are:

- Resistance to corrosion
- Light Weight
- Toughness
- Rigidity
- Economical in laying, jointing and maintenance
- Ease of fabrication

Rigid PVC pipes weigh only 1/5 of conventional steel pipes of comparable sizes. PVC pipes are available for drainage works in sizes of outer dia.. 75,90,110,140,160,250,290,315mm at working pressures of 2.5, 4, 6 and 10 kg/cm^2. PVC pipes are not very suitable for sewerage works. Pipes stored should not exceed three layers and should be so stacked as to prevent movement. It is also recommended not to store one pipe inside another.

5.2.6.3 High Density Polyethylene (HDPE) Pipes

Among the recent developments, is the use of High Density Polyethylene pipes in special situations. These pipes are not brittle like AC and other pipes and hence a hard fall at the time of loading, unloading, handling etc. cannot do any harm to it. HDPE pipes upto 630mm dia can be joined with detachable joints and can be detached at the time of shifting the pipe line from one place to another. HDPE pipes can be joined also by welding.

For further details of PVC and HDPE pipes, reference may be made to:

IS : 7834 - 1975, Parts 1 - 8
IS : 8008 - 1976, Parts 1 - 7
IS : 7634 - 1975, Parts 1 - 3
IS : 3076 - 1985
IS : 4984 - 1987

5.2.7 Glass Fibre Reinforced Plastic Pipes

G.R.P. Pipes are widely used in other countries where corrosion resistant pipes are required at reasonable costs.

GRP can be used as a lining material for conventional pipes which are subject to corrosion. Fibre glass coating can resist external and internal corrosion whether the corrosion mechanism is galvanic or chemical in nature.

5.2.7.1 Fibre Glass Reinforced Plastic Pipes (FRP)

Fibre glass reinforced plastic pipe is a matrix or composite of glass fibre, polyester resin and fillers. These pipes possess better strength, durability, high tensile strength, low density and are highly corrosion resistant.

Fibre glass pressure pipes are manufactured in diameters upto 2400mm and length upto 18m. These pipes are now being taken up for manufacture in India.

Standard specifications have been framed by the BIS and for further details of F.R.P.pipes reference may be made to IS: 12709-1989.

5.2.8 Pitch Fibre Pipes

The pitch impregnated fibre pipes are of light weight and have shown their durability in service. The pipes can be easily jointed in any weather condition as internally tapered couplings join the pipes without the use of jointing compound. They are flexible, resistant to heat, freezing and thawing and earth currents which set up electrolytic action. They are also unaffected by acids and other chemicals, water softeners, sewer gases, oils and greases and laundry detergents. They can be cut to required length on the site. Because of the larger lengths, cost of jointing, handling and laying is reduced. These are generally recommended for all drainage uses such as house connection to sewers and septic tanks, farm drainage, down pipes, storm drains, industrial waste drainage etc. These have recently been manufactured in India. These are manufactured in 50, 75, 100, 125, 150, 200 and 225mm nominal diameter and length varies from 1.5m to 3.5m. These pipes are jointed by taper coupling joints or rubber ring joints. The details of the pipes and fittings such as dimensions etc. have been covered in IS:11925-1985.

5.3 JOINTING IN SEWER PIPES

From the consideration of structural requirements, joints may be classified as rigid and flexible joints. Joints such as cement mortar, lead, flanged and welded joints are under the category of rigid joints as they do not withstand any angular rotation. All types of mechanical joints such as rubber gasket joints are flexible as they take rotation to the extent of a few degrees and thus reduce the undue settlement stress. Flexible joints are preferable to rigid joints, particularly with granular bedding.

Chapter 6 of the CPHEEO Manual on Water Supply and Treatment gives the types of joints used for C.I., Steel, AC, concrete and plastic pipes. The socket and spigot type of joint is the most widely used joint for vitrified clay pipes. Internal flush joints have also been occasionally used.

CHAPTER 6

STRUCTURAL DESIGN OF BURIED SEWERS

6.1 INTRODUCTION

The structural design of a sewer is based on the relationship: the supporting strength of the sewer as installed divided by a suitable factor of safety must equal or exceed the load imposed on it by the weight of earth and any superimposed loads.

The essential steps in the design and construction of buried sewers or conduits to provide safe installations are therefore.

i) determination of the maximum load that will be applied to the pipe based on the trench and backfill conditions and the live loads to be encountered

ii) computation of the safe load carrying capacity of the pipe when installed and bedded in the manner to be specified using a suitable factor of safety and making certain the design supporting strength thus obtained is greater than the maximum load to be applied

iii) Specifying the maximum trench widths to be permitted, the type of pipe bedding to be obtained and the manner in which the backfill is to be made in accordance with the conditions used for the design

iv) checking each pipe for structural defects before installation and making sure that only sound pipes are installed and

v) ensuring by adequate inspection and engineering supervision that all trench widths, subgrade work, bedding, pipe laying and backfilling are in accordance with design assumptions as set forth in the project specifications.

Proper design and adequate specifications alone are not enough to ensure protection from dangerous or destructive overloading of pipe. Effective value of these depends on the degree to which the design assumptions are realised in actual construction. For this reason thorough and competent inspection is necessary to ensure that the installation conforms to the design requirements.

6.2 TYPE OF LOADS

In a buried sewer, stresses are induced by external loads and also by internal pressure in case of a pressure main. The stress due to external loads is of utmost importance and may be the only one considered in the design. Besides, if the sewer is exposed to sunlight, temperature stresses induced may be considerable and these will have to be taken into consideration particularly in case of metallic pipes. The external loads are of two categories viz. load due to backfill material known as backfill load and superimposed load which again is of two types viz. concentrated load and distributed load. Moving loads may be considered as equivalent to uniformly distributed load. Sewer lines are mostly constructed of stoneware, concrete or cast iron which are considered as rigid pipes (while steel pipes, if used, are not considered as rigid pipes).The flexibility of the pipe affects the load imposed on the pipe and the stresses induced in it.

6.3 LOADS ON CONDUITS DUE TO BACKFILL

Methods for determining the vertical load on buried conduits due to gravity earth forces in all commonly encountered conditions as developed by A. Marston are generally accepted as the most suitable and reliable for computation. Theoretically stated, the load on a buried conduit is equal to the weight of the prism of earth directly over the conduit, called the interior prism of earth plus or minus the frictional shearing forces transferred to the prism by the adjacent prism of earth.

The considerations are:

a) the calculated load due to the backfill is the load which will develop when ultimate settlement has taken place

b) the magnitude of the lateral pressure causing the shearing force is computed by Rankine's theory and

c) there is negligible cohesion except for tunnel conditions.

The general form of Marston's formula is

$$W = C.w.B^2 \qquad (6.1)$$

Where W = vertical load in kgs per meter length acting on the conduit due to gravity earth loads

w = unit weight of earth, kg/m^3

B = width of trench or conduit in meters depending upon the type of installation conditions

C = dimensionless co-efficient that measures the effect of :

- a) ratio of height of fill to width of trench or conduit
- b) shearing forces between interior and adjacent earth prisms and
- c) direction and amount of relative settlement between interior and adjacent earth prisms for embankment conditions.

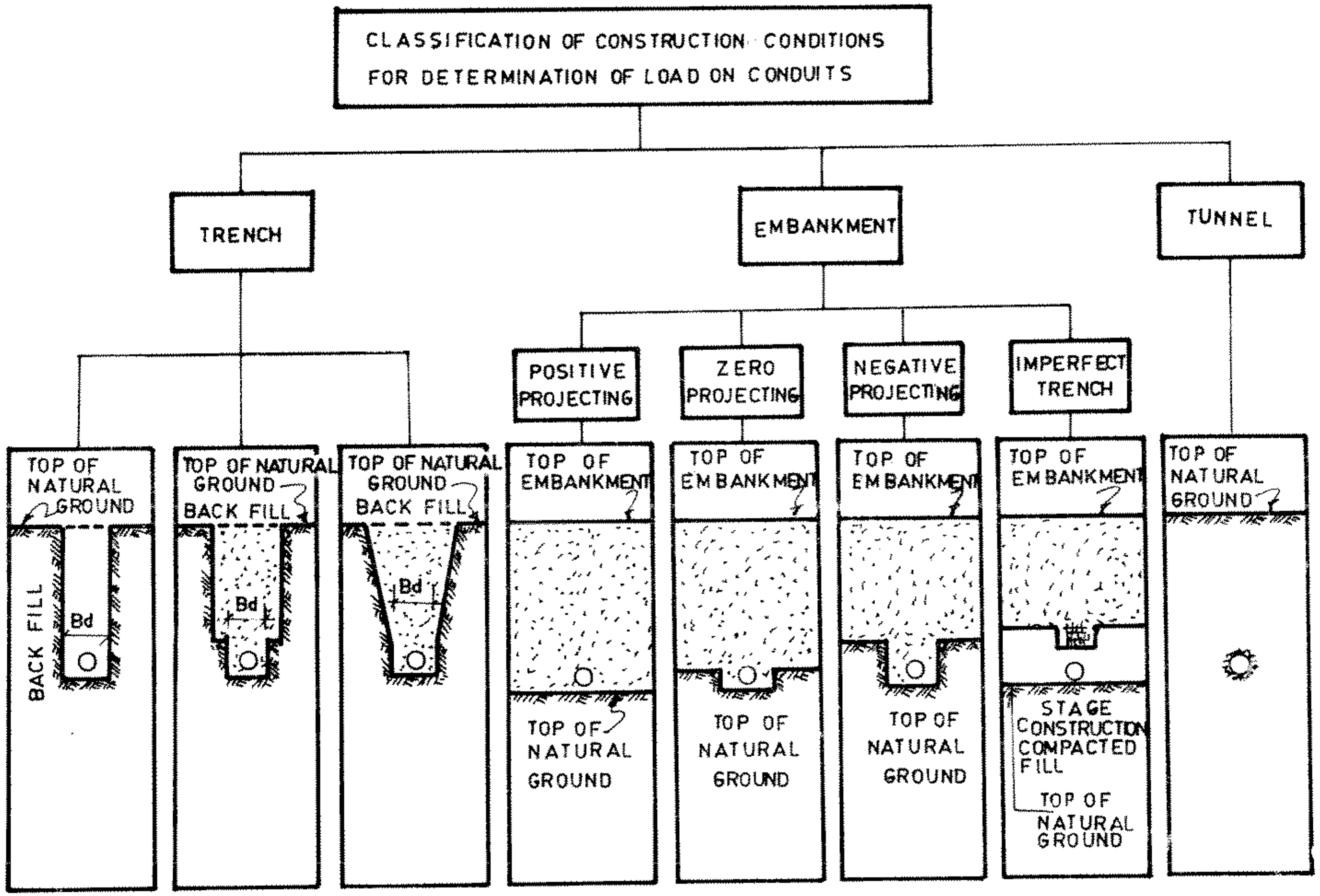
6.3.1 Types of Installation or Construction Conditions

The accepted types of installation or construction conditions are shown in Fig.6.1. There are three classifications for the construction conditions viz.

1) embankment condition 2) trench condition and
3) tunnel condition.

Embankment condition prevails when the conduit is covered with fill above the original ground surface or when a trench in undisturbed ground is so wide that trench wall friction does not affect the load on the pipe. The embankment condition is further classified, depending upon the position of the top of conduit in relation to the original ground.surface, as

i) positive projecting condition
ii) zero projecting condition
iii) negative projecting condition and
iv) imperfect trench condition.



NOTE : NORMAL GROUND WATER LEVEL WITH REFERENCE TO THE INVERT LEVEL IS TO BE TAKEN NOTE OF IN THE DESIGN.

FIG. 6.1: CLASSIFICATION OF CONSTRUCTION CONDITIONS

Trench condition exists when the pipe or conduit is installed in a relatively narrow trench (not wider than twice the external diameter of the pipe) cut in undisturbed soil and then covered with earth backfill upto the original ground surface.

Tunnel condition exists when the sewer is placed by means of jacking or tunneling.

6.3.2 Loads for Different Conditions

6.3.2.1 EMBANKMENT OR PROJECTING CONDUIT CONDITION

a) *Positive Projecting Conduit*

A conduit is said to be laid as a positive projecting conduit when the top of the conduit is projecting above the natural ground into the overlying embankment (figure 6.2).

i) Load Producing Forces

The load on the positive projecting conduit is equal to the weight of the prism of soil directly above the structure plus or minus vertical shearing forces which act in a vertical plane extending upward into the embankment from the sides of the conduit. These vertical shearing forces ordinarily do not extend to the top of the embankment but terminate in a horizontal plane at some elevation above the top of the conduit known as the plane of equal settlement as shown in Fig.6.2 which also shows the elements of settlement ratios.

$$\text{Settlement ratio } r_{sd} = \frac{\text{Settlement of critical plane-settlement of top of conduit}}{\text{Compression of height of column H of embankment}}$$

$$= \frac{(S_m + S_g) - (S_f + d_c)}{S_m} \qquad (6.2)$$

where H = height of top of conduit above adjacent natural ground surface (initial) or the bottom of a wide trench

= p. B_c where p is the projection ratios and B_c is outside width of conduit

S_m = compression column of height H of embankment

S_g = Settlement of natrual ground adjacent to the conduit

S_f = settlement of the bottom of conduit and

d_c = deflection of conduit or shortening of its vertical height under load.

When $(S_m + S_g)$ is greater than (S_f+d_c), r_{sd} is positive i.e. the shearing forces act downwards. Therefore the load on conduit is equal to weight of critical prism plus shear force.

When (S_m+S_g) is less than (S_f+d_c), r_{sd} is negative and the shear force acts in the upward direction.

The settlement ratio r_{sd} therefore, indicates the direction and magnitude of the relative settlement of the prism of earth directly above and adjoining the conduit.

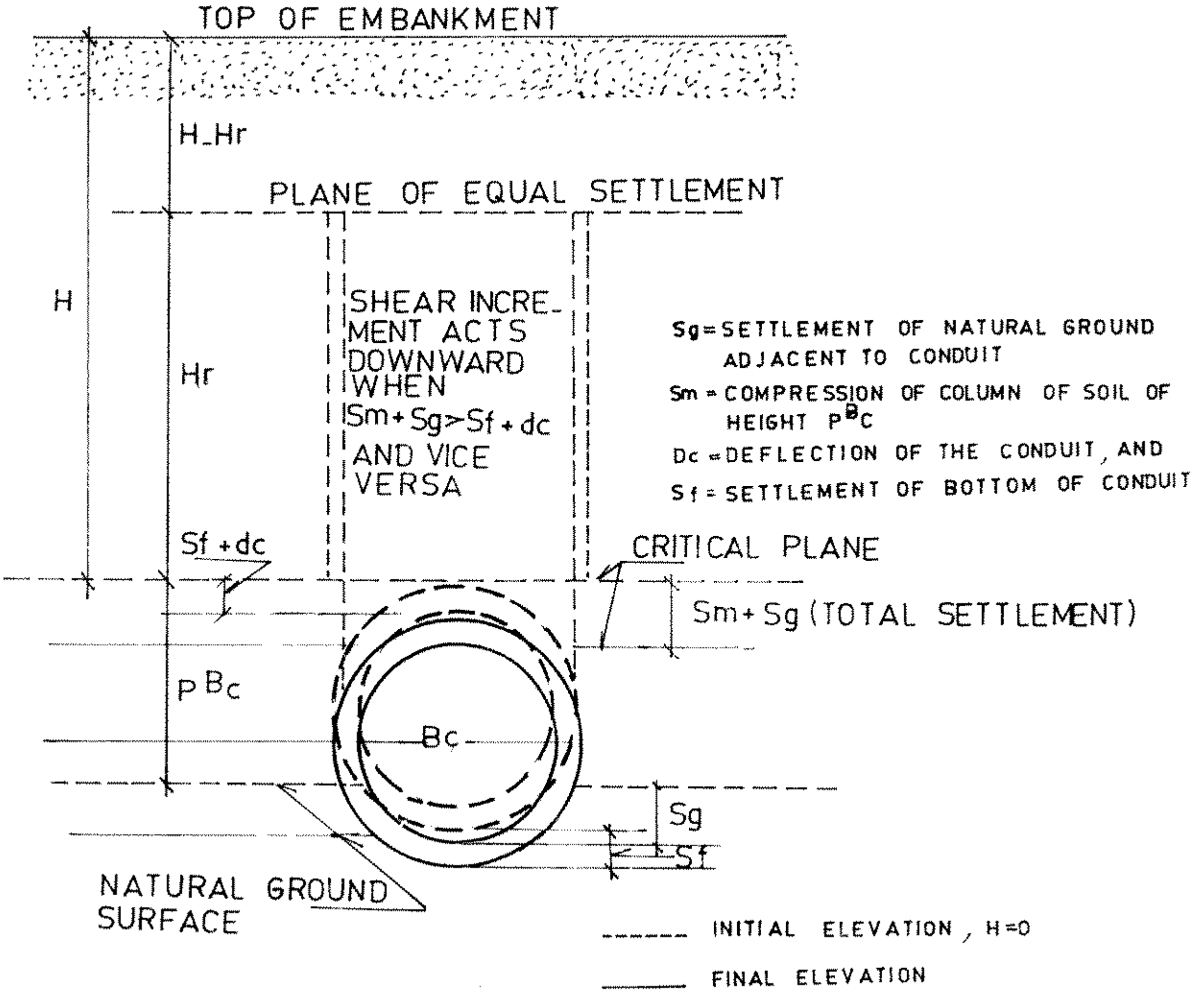


FIG.6.2: SETTLEMENTS THAT INFLUENCE LOADS ON POSITIVE PROJECTING CONDUITS.

The product r_{sd} multiplied by p gives the relative height of plane of equal settlement and hence of the magnitude of the shear component of the load.

When $r_{sd} \times p = 0$, the plane of equal settlement coincides with the critical plane and there are no shearing forces and the load is equal to the weight of the central prism. It is not practicable to predetermine this r_{sd} value. However, recommended design values based on actual experience are given in Table 6.1

TABLE 6.1
RECOMMENDED DESIGN VALUES OF SETTLEMENT RATIOS

	Type of Conduit	Type of Soil	Settlement Ratio (r_{sd})
1.	Rigid	Rock or unyielding foundation	+ 1.0
2.	Rigid	Ordinary foundation	+ 0.5 to + 0.8
3.	Rigid	Yielding foundation	0 to + 0.5
4.	Rigid	Negative projecting installation	- 0.3 to - 0.5
5.	Flexible	Poorly compacted sidefill	- 0.4 to 0
6.	Flexible	Well compacated sidefill	0

ii) Computation of Loads

Marston's formula for positive projecting conduits (both rigid and flexible) is as follows:

$$W_c = C_c \, w \, B_c^2 \qquad (6.2)$$

Where

W_c = load on conduit in kg/m

w = unit weight of backfill material in kg/m^3

B_c = outside width of conduit in m, and

C_c = load coefficient, which is a function of the product of the projection ratio and the settlement ratio and ratio of the height of fill above the top of the conduit to the outside width of the conduit (H/B). It is also influenced by the coefficient of internal friction of the backfill material and the Rankine's ratio of lateral pressure to vertical pressure K_u. Suggested values for K_u for positive and negative settlement ratios are 0.19 and 0.13 respectively.

The value of C_c can be obtained from Fig. 6.3

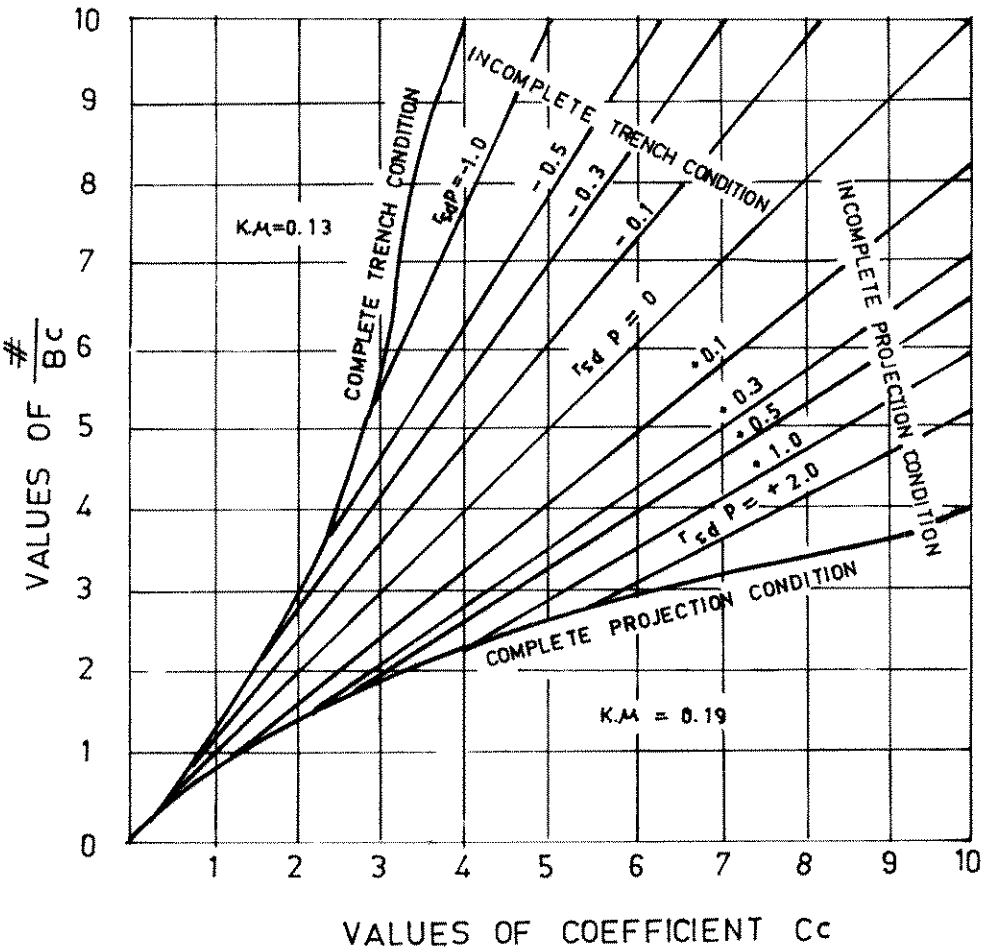


FIG. 6.3 : DIAGRAM FOR COEFFICIENT Cc FOR POSITIVE PROJECTING CONDUITS

b) ***Negative Projecting Conduit***

A conduit is said to be laid in a negative projecting condition when it is laid in a trench which is narrow with respect to the size of pipe and shallow with respect to depth of cover and the native material of the trench is of sufficient strength that the trench shape can be maintained dependably during the placing of the embankment, the top of the conduit being below the natural ground surface and the trench refilled with loose material and the embankment constructed above (Fig.6.4). The prism of soil above the conduit, being loose and greater in depth compared to the adjoining embankment, will settle more than the prism over the adjoining areas thus generating upward shear forces which relieve or reduce the load on the conduit.

i) Computation of Loads

Marston's formula for negative projecting conduits is given by

$$W_c = C_n \; w \; B^2_d \qquad (6.3)$$

Where

W_c = load on the conduit in Kg/m

B_d = width of trench in m

w = the unit weight of soil in kg/m^3 and

C_n = load coefficient, which is a function of the ratio (H/B_d) of the height of fill and the width of trench equal to the projection ratio p (Vertical distance from the firm ground surface down to the top of the conduit/width of the trench) and the settlement ratio r_{sd} given by the expression.

$$r_{sd} = \frac{\text{settlement of natural ground-settlement of critical plane}}{\text{compression of the backfill within the height } p\,B_d}$$

$$= \frac{S_g - (S_d + S_f + d_c)}{S_d} \qquad (6.4)$$

Values of C_n, for various values of H/B_d, r_{sd}, and p' are given in Fig.6.5

Exact determination of the settlement ratio is very difficult.

Recommended value of r_{sd} is -0.3 for design purposes. Elements of settlement ratios are shown in Fig.6.6.

(c) ***Imperfect Trench Conduits***

An imperfect trench conduit is employed to minimise the load on a conduit under embankments of unusual heights. The conduit is first installed as a positive projecting conduit. The embankment is then built up to some height above the top and thoroughly compacted as it is placed. A trench of the same width as the conduit is excavated directly over it down to or near its top. This trench is refilled with loose compressible material and the balance of the embankment completed in a normal manner (figure 6.7).

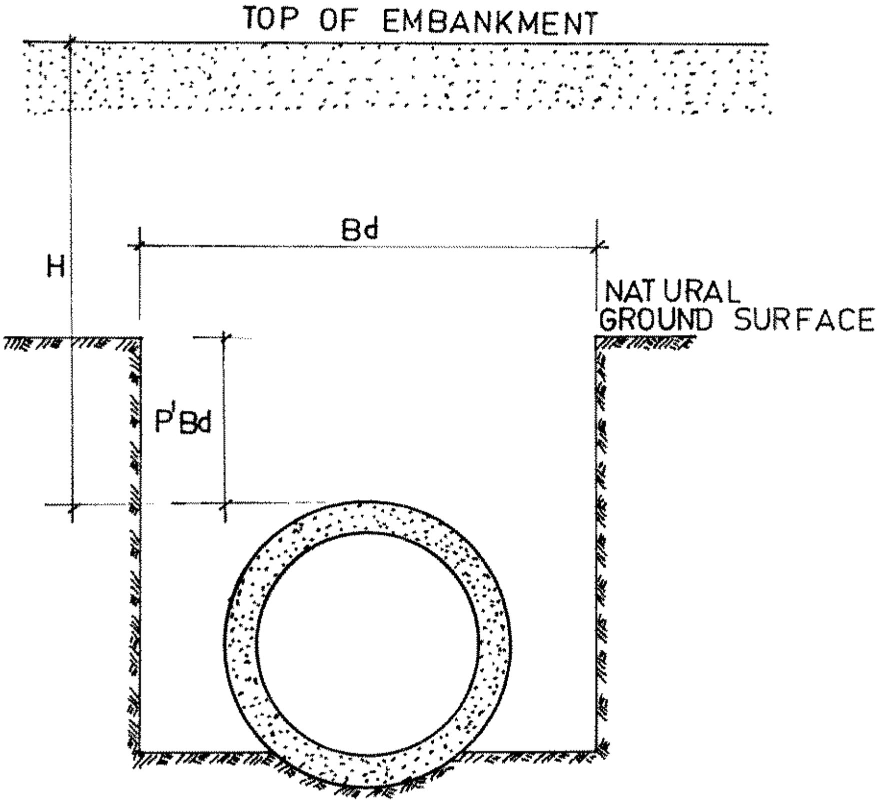


FIG.6.4: NEGATIVE PROJECTING CONDUIT