COMMON SANITARY FIXTURES

Selection of sanitary fixtures is very important. They shall be durable and long lasting. Care should be taken in fixing sanitary fixtures either in floor or in wall. Water filled trap is to be provided for each fixture or a group of fixtures to prevent foul smelling. The diameters of water trap pipe and discharge pipe are fixed according to the type of fixture usage. The following table 1-A gives diameter of trap pipe and discharge pipe

Note: Discharge pipe is a pipe that conveys discharge from sanitary fixtures.

Table 1-A

Sanitary fixture	*Diameter of trap pipe and discharge pipe in mm*	*Maximum length of unvented pipe in m*
Water closet	*100*	*6*
Wash basin	*40*	*2.5*
Sink		
Domestic	*40*	*2.5*
Commercial	*50*	*2.5*
Shower (Single)	*40 or 50*	*2.5*
Shower (Multiple)	*50*	*2.5*
Urinal (Bowel Type)	*50 or 65*	*2.5*
Urinal (Stall, Trough)	*65 or 80*	*2.5*
Floor Waste Gully		
(Without fixture connection)	*50*	*2.5*
(With fixture connection)	*Up to 100*	*2.5*
Washing Machine	*50*	*2.5*
Bath tub	*40*	*2.5*
Bidet	*40*	*2.5*

The following slopes are to be provided for discharge pipes:

Table 1-B

Diameter of discharge pipe in mm	*Minimum slope to be provided*
40	*1/40*
50	*1/40*
65	*1/40*
80	*1/60*
100	*1/60*
125	*1/80*
150	*1/80*

Common sanitary fixtures are given below:

a) Washbasins
b) Water closets
c) Showers
d) Sinks
e) Bathtubs
f) Bidets
g) Urinals
h) Floor drains (floor Gullies)

a) Washbasins (Fig. 1.1)

Washbasins are usually made of vitreous china clay, fire clay, stainless steel, or porcelain channeled sheet steel. They are fitted either to wall or to floor or to tabletop. Comer fitting type washbasins are also available in the market. The fixing height of washbasin above finished floor level is between 76 cm to 80 cm. Different sizes of washbasins are available. 500mm x 500mm washbasin made of glazed vitreous china clay, with two tap holes is commonly used. Hot and cold chrome plated pillar taps are fitted to wash basins.

In the case of tabletop washbasin, the gaps between the washbasin and the surroundings are to be sealed perfectly, to prevent seepage of wastewater.

Fig. 1.1 Washbasin

For each washbasin, one floor drain is to be provided for cleaning the floor water. As far as possible, washbasin is to be placed near the entrance of toilet. Minimum space required for proper useage of washbasin is 90 cm x 90 cm.

b) Water closets (Fig.1.2)

Water closets are used to collect and convey human waste in a very hygienic manner. The selection of water closet pan is such that, it will produce less noise while flushing. Wash down type is widely used, and in this type, the force of water flush removes the content of the pan. Single trap or two trap syphonic water closet pans are also available. In this type syphonic action generated in the trap is used for the removal of the content.

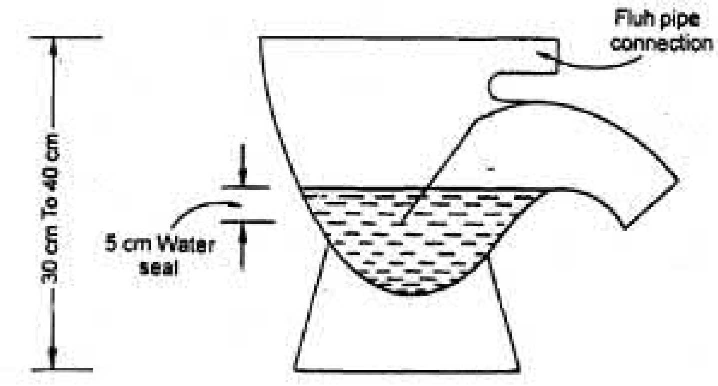


Fig. 1.2 Pedestal type water closet (European type)

According to the type of use, water closets are divided into two:

1. Squatting type (Indian or Turkish type)
2. Pedestal type (European type)

Squatting type water closets are not having any seat. It consists of a floor level bowel, with a squatting plate. The steps are slightly raised from the finished floor level. In the case of squatting type water closet, the floor of the room is to be sloped by 2% towards the pan for the proper drainage, and no separate floor drain needs to be provided. If it is fixed on raised platform, separate floor drain is to be provided on the floor of closet room. For pedestal type water closet, it is advisable to provide a floor drain in the closet room for the proper cleaning of the floor.

Pedestal type water closet pan is fixed firmly on the floor and provided with a seat. Wall hanging type water closet is fixed direct to load bearing wall with bolts and nuts.

Open front seat is recommended in public toilets, as it is less fouled than ring type seat. Capacity of flushing cistern is such that, it is sufficient to flush properly the water closet bowel. Capacity usually ranges from 5 liters to 15 liters. The re-filling time of cistern is not more than 2 minutes. 32 mm bore pipe is used as flush water pipe from cistern. 100mm diameter waste pipe is used as discharge pipe from water closet pan.

As far as possible water closet is to be fixed away from the entrance of toilet. In any case water closet should not be placed near the head side of bathtub. Minimum space required for a water closet is 90 cm x 120 cm. Handrail is to be provided near the water closet of hospitals, for assisting sick people.

c) Showers

Body washing with running water is more hygienic and economical in usage of water. The shower room is to be well ventilated to reduce condensation. A minimum space of 90 cm x 120 cm is to provide for shower room. Shower room is to be provided with a shower tray of size 75 cm x 75 cm, with slip resistant base. Shower tray is made of either by glazed fire clay, or by glass reinforced polyester. Chrome plated shower mixer with cold and hot taps are to be provided. The riser tube is concealed in the wall. Chrome plated shower arm tube with swivel spray head, having a diameter of 38 mm is fixed. Chest level umbrella spray type showerheads are also used. The floor of shower room is to be sloped (2%) towards the tray and the waste outlet of tray is connected to the water trap. 40 mm or 50 mm diameter discharge pipe is provided for conveying wastewater. Wastewater from one shower room should not be allowed to enter in to another shower room. A minimum residual head of lm is to be provided in the shower spray head. It is advisable to provide a foot-tap in all shower rooms. Showers usually take 30 to 40 liters of water per head for bathing. Hot water storage for shower is 20 to 30 liters per head.

d) Sinks (Fig.1.3)

Stainless steel sinks are more commonly used. Fire clay sinks are also in use. Sink is either fitted in a cantilever or inserted in a table top. Sinks may be of single or double drains and single or double bowels. Common sizes of sinks are 1000 mm x 6(X) mm, 12(X) nun x 600 mm 1600 mmx 600 mm, 1800 mm x 600 mm, 2400 mmx 600mm, and 2800 mm x 600 mm. Depth of sink varies from 200 mm to 300 mm.

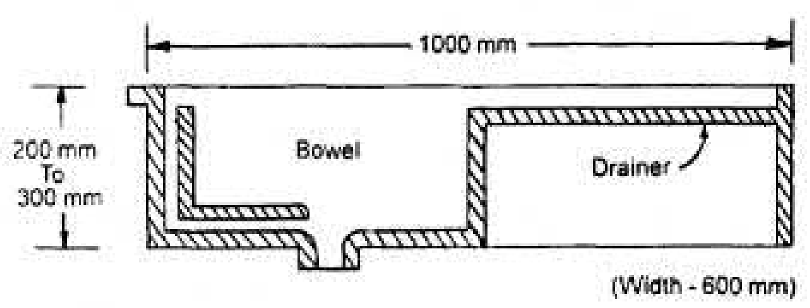


Fig. 1.3 Kitchen sink

e) Bath tubs (Fig. 1.4)

Different varieties of bathtubs are available. Length of bathtub varies from 1450 mm to l850 mm and width is from 700 mm to 725 mm. The height of bathtub is usually between 480 mm to 540 mm from the floor. Bathtub is having a flat bottom, with sloping towards the out let. Water trap pipe and discharge pipe are of 40mm, diameter. The gap between bathtub and surrounding wall is to be well sealed to prevent seepage of wastewater. 2 nos, chrome plated pillar type taps are to be provided, one for cold water and other for hot water. Spray type showerhead connected to flexible pipe is also sometimes provided.

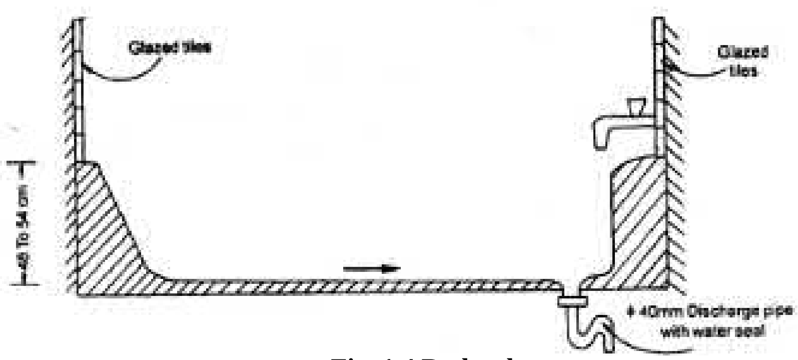


Fig. 1.4 Bath tub

f) Bidets (Fig. 1.5)

Two types of bidets are used:

1. Over rim water feed
2. Submersible water feed.

Both types are either pedestal or wall mounted. They are used for washing perineal and foot. Water is supplied through an ascending spray. In the case of submersible water feed, care should be taken to prevent siphoning of wastewater in to the water supply system or any other fittings.

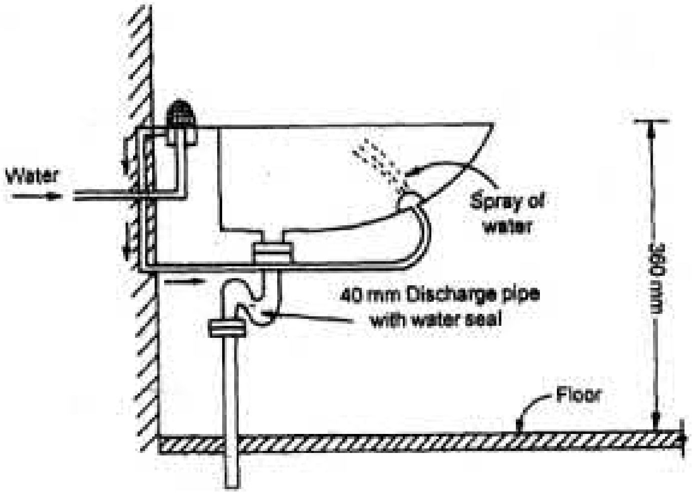


Fig. 1.5 Submersible Feed type bidet

g) Urinals (Fig. 1.6- 1.8)

4 types of urinals are commonly used. They are :

1. Slab type (Fig. 1.6).
2. Stall types (Fig. 1.7).
3. Bowel types (Fig. 1.8).
4. Trough types.

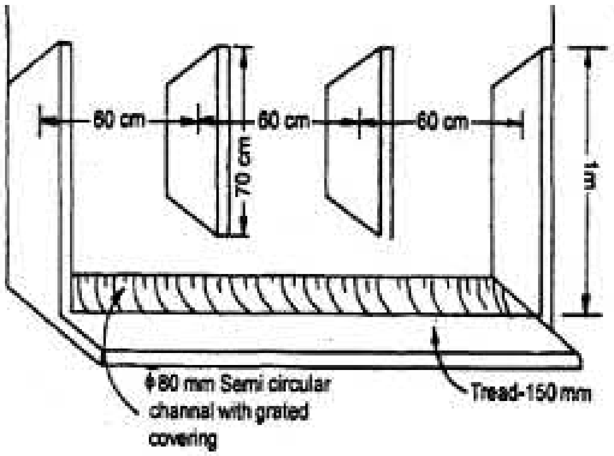


Fig. 1.6 Slab type urinals

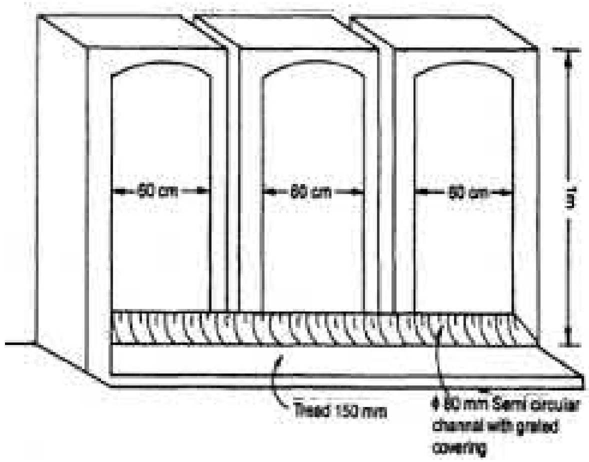
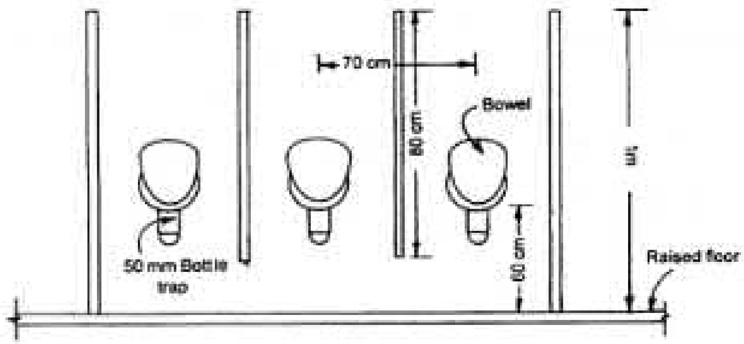


Fig. 1.7 stall urinals

Urinals require privacy. Slab type and stall type urinals are more or less same. The difference is that the way in which individual urinal is separated for privacy. Channel is required for slab type and stall type urinals. Trough is required for trough type urinals. Channel and trough are to be smooth and laid in a slope towards the trap. Maximum run of channel is up to a length of 2.40 m (4 stalls only). Width of individual urinal is not less than 60 cm.

For bowel type urinal, the height from floor to the mouth of bowel is 60



cm, and horizontal distance from center to center of bowel is 70 cm. A bottle trap or a ’U’ trap is provided for each bowel.

Urinals are to be flushed every 20 minutes, by an automatic flushing unit at the rate of 3.5 liter/stall or bowel. A minimum diameter of 65 mm to 80mm is provided for the discharge pipe of combined urinals.

Fig. 1.8 Bowel type urinals

h) Floor drains

Floor drains are to be rust resistant and provided with gratings. The diameter of floor drain varies from 50 mm to 100 mm. Discharge pipes of other fixtures can also be connected to the floor drain. Three to four fixtures can be connected to the discharge pipe of floor drain. In this case the diameter of discharge pipe of floor drain is to be increased to 80mm and a common water trap in the discharge pipe of floor drain is provided. Discharge pipe of water closet should not be connected to the floor drains.

Floor drain shall be provided near washbasin, kitchen sink, and pedestal water closet. If squatting type water closet is fixed on raised platform, a floor drain shall be provided in the water closet room. Floor drain shall not be provided in operation theaters, and consulting rooms of hospitals.

LAY OUT OF SANITARY FIXTURES IN TOILETS

Toilets are to be arranged in such a way that they will give privacy, comfort and satisfaction, while using them.

The floor of the toilet is to be 2 cm lower than other finished floors, so as to prevent entry of wastewater to other rooms. The floor of the toilet should be non-skid and sloped 2% towards the floor drain.

Walls of toilet are fixed with glazed tiles or painted with waterproof paints. Proper ventilation is to be provided in all toilets to reduce odor and humidity. A minimum space of l/20th of floor area of toilet is to be provided for ventilation. If sufficient natural ventilation is not available, forced ventilation with exhaust fan is to be adopted. The capacity of exhaust fan is such that it can change room air at the rate of 3 to 6 air changes per hour or a minimum of 4 m^3 per hour. Illuminations of the toilet should be sufficient to illuminate face from all angles. If natural lighting is not sufficient, additional electric lighting may be arranged. Sufficient storage place shall be provided for current and reserve supplies. Counter top surface provides excellent facilities. It is better to provide full-length mirror. Standard practice is to provide a crystal glass mirror of size 500 mm x 400 mm above washbasin at a height of 120 cm from the finished floor. Grab bar shall be provided vertically above bathtub. It shall be adequate in size and fixed firmly on the wall. Rack shall also be provided.

Shower curtain, soap tray, towel rail, towel rack, bath mat, wastebasket, sanitary bin, tissue paper holder, electric shaver socket, etc. .. .are to be invariably provided. Space shall be provided between fixtures for cleaning purpose, assisting other people and for using them conveniently without obstruction.

Water closet is fixed away from bathtub. In any case, it should not be fixed near the head side of the tub. As far as possible, it should not be provided near the entrance of toilet.

In hospitals, handrail is provided near water closet and fixed shower, for the use of sick and elderly persons. Glazed tiles are to be fixed, if space is left over between bathtub and sidewall and they shall be sloped towards the tub. Fixed shower is fixed at a height of 190 cm from the floor level. Some time adjustable hand shower with flexible hose is also provided. Shower is provided with or without shower tray. Shower tray is of enameled cast iron, glazed fire clay, or plastic. Pre-fabricated shower tray in enameled sheet steel, in aluminum or in plastic is also available.

Only one door is provided for toilet. Generally door swings into toilet. Door should not strike any person, while using sanitary fittings. As far as possible, door should conceal water closet, when opened.

False ceiling is provided for multistoried buildings to conceal, water and waste water pipe coming out from toilet below roof. Some time floor of the toilet is raised or lowered than other floors to accommodate water and waste water pipes, instead of false ceiling. Duct shall be provided for *taking* vertical pipes of water and wastewater from one floor to another, in case of multistoried buildings. Proper access is also being provided in the duct for maintenance of pipes.

In toilet, towel rail should not obstruct space for movement. Handrail and soap holder are fixed at a height of 105 cm, and towel rail is fixed at a height of 130 cm from the floor.

Minimum space required for each sanitary fixture, if fixed independently are given in Fig. 2.1 (a) to 2.1 (d)

Inside dimensions of some residential toilets are shown in Fig. 2.2 to 2.8.

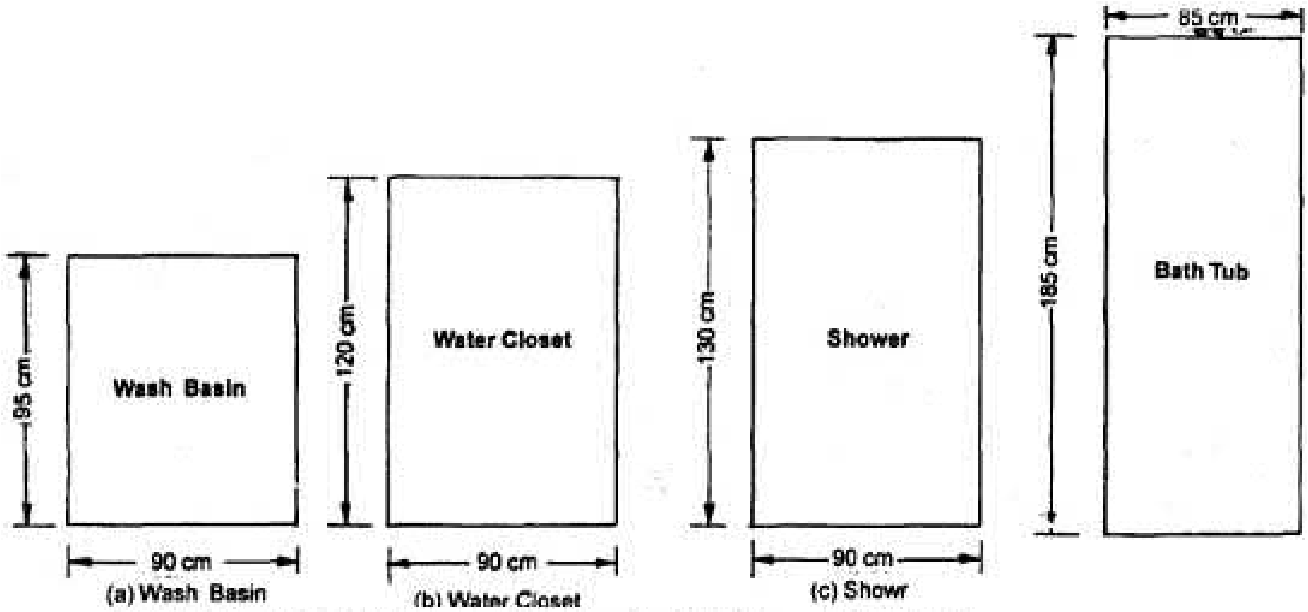


Fig. 2.1. (*a*) Wash basin, (*b*) Water closet, (*c*) Shower, (*d*) Bath tub (NOT TO SCALE)

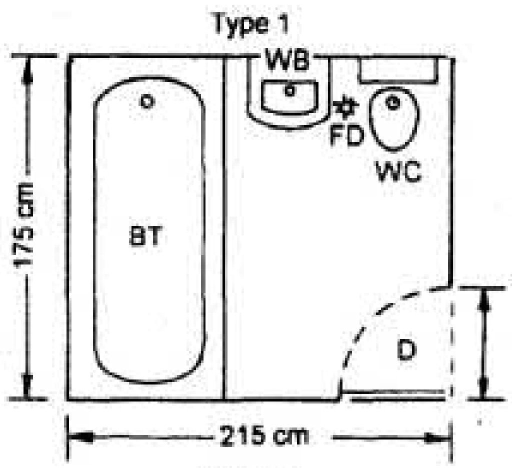


Fig. 2.2.

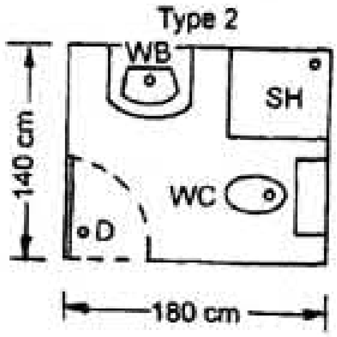
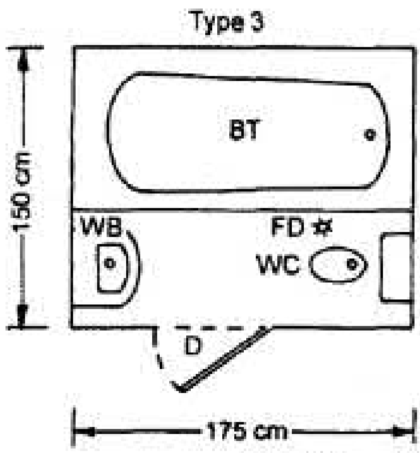


Fig. 2.3.

LEGEND

D — Door
BT — Bath tub
WB — Wash Basin
WC — Water closet
BD — Bidet
SH — Shower



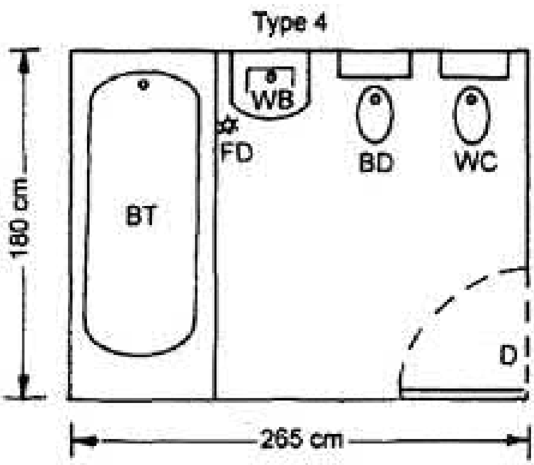


Fig. 2.4. (NOT TO SCALE) Fig. 2.5.

LEGEND

D — Door
BT — Bath tub
WB — Wash Basin
WC — Water closet
BD — Bidet
SH — Shower
FD — Floor Drain

Arrangements of sanitary fixtures and their pipes connection, in toilet of multistoried buildings (Hospitals), are shown in Fig. 2.9.

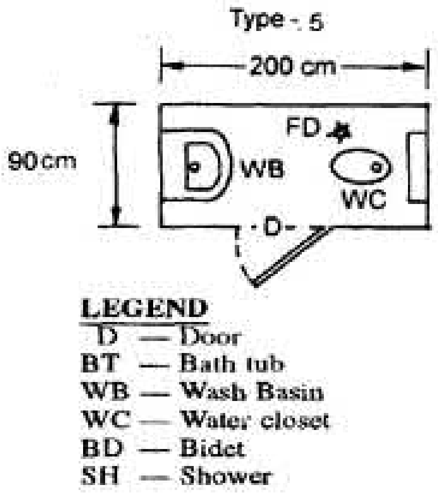


Fig. 2.6.

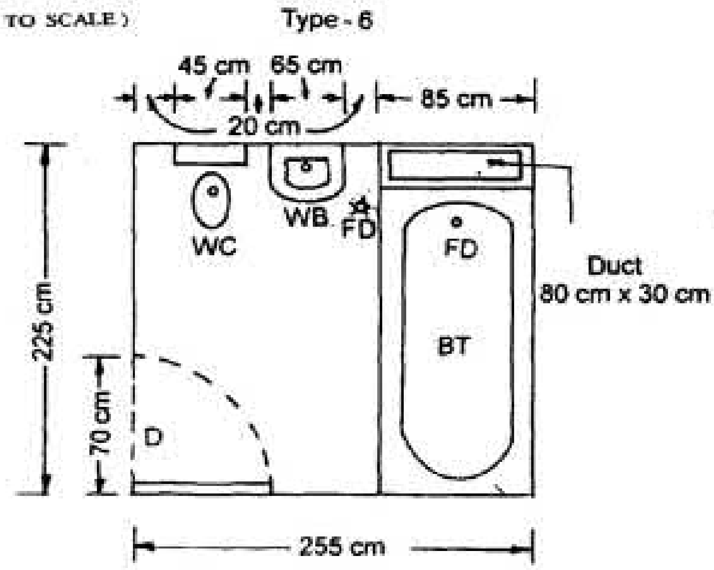


Fig. 2.7.

NOTE

1- A minimum space of 10 cm to 25 cm is t o be left between each sanitary fixture for convenient use.

2- A minimum open space of 60 cm is to be provided in front of any sanitary fixture for movement.

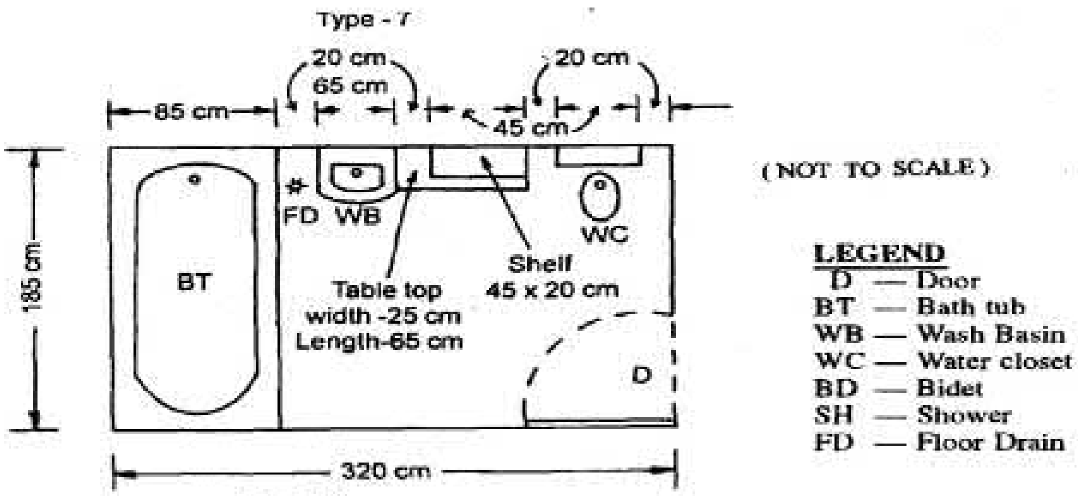


Fig. 2.8.

NOTE

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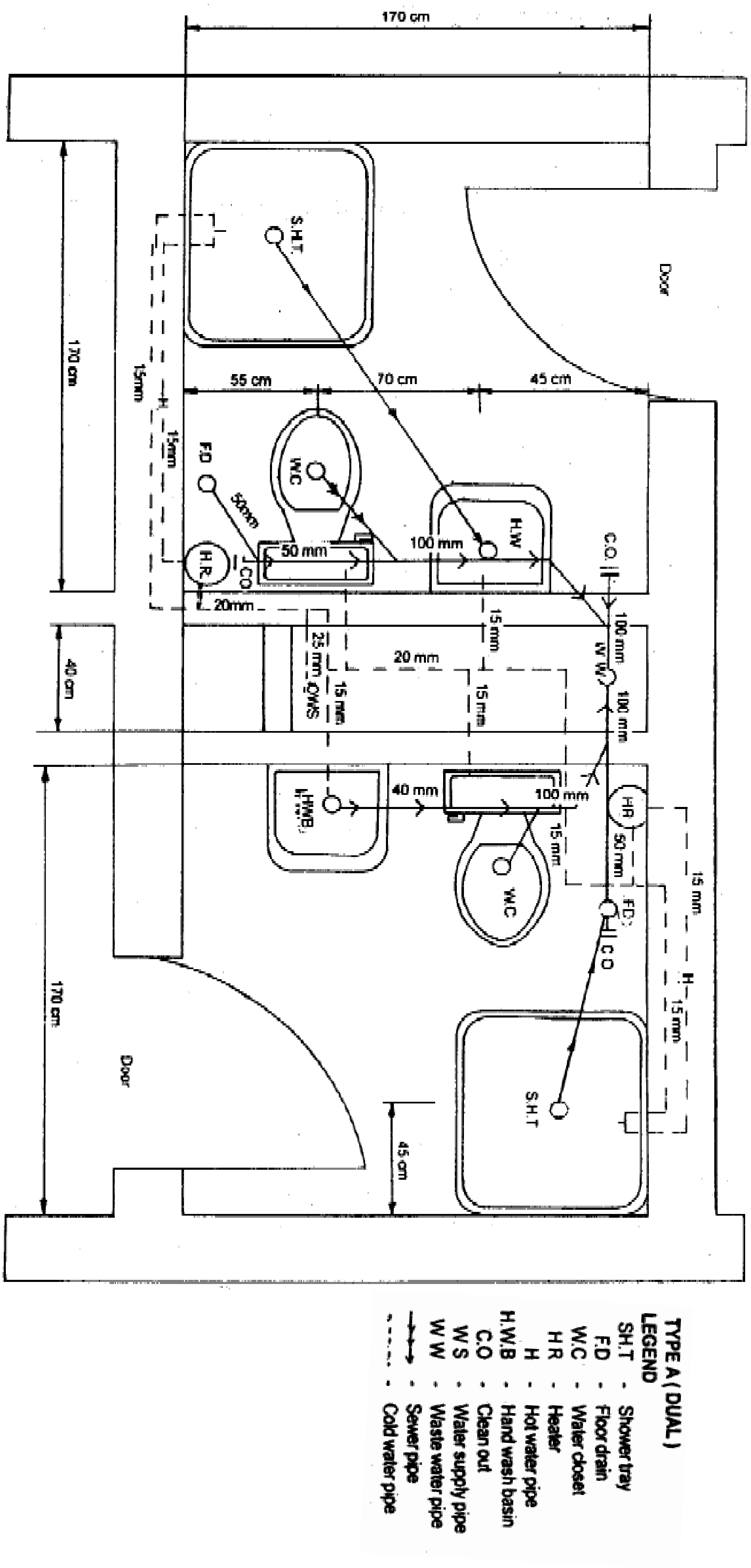


(NOT TO SCALE)

Fig. 2.9

FORMULAE FOR FLOW THROUGH PIPES

When a fluid flows through a pipe, the flow may be either streamline or turbulent. When all particles of the fluid are moving in a straight line, in the same direction, as the axis of the pipe, it is called streamline flow. When all particles are moving in a disorderly way, it is called turbulent flow. The flow through pipes will be turbulent in most water supply systems.

The type of flow depends upon

1. Diameter of the pipe
2. Velocity of flow
3. Density of the fluid
4. Viscosity of the fluid.

There are different -formulae used to find out the head loss in pipes due to friction.

1- Darcy's formula:

$$Hf = (4 f v^2)/(2 g d)$$

where,

H_f = loss of head due to friction in meters
f = coefficient of friction (0.007)
l = length of pipe in meter
v = velocity of flow in m/sec
g = acceleration due to gravity = 9.81 m/sec^2
d = diameter of pipe in meter

2- Chezy's formula:

Chezy's formula is also derived in the same way as Darcy's formula.

$$V = C (mi)^{1/2}$$

where,

C = a constant usually taken as 55
V = velocity of flow in m/sec
m = hydraulic mean depth
= Cross sectional area of flow/length of wetted perimeter
i = slope or fall Chezy's constant can be found from the relation

$$C= (2 g / f)^{1/2}$$

which is the relation between Darcy's coefficient 'f' and Chezy's constant 'C' is:

When $f = 0.007$, $C = (2 \times 9.81/0.007)^{1/2} = 55.33$, Usually 'C' taken as 55.

It is assumed in both Darcy's and Chezy's formulae that the frictional resistance is varied as the square of the mean velocity for turbulent flow.

Darcy's equation $H_f = \dfrac{4f\, lv^2}{2gd}$

Chezy's equation $H_f = \dfrac{v^2 l}{C^2 m}$

In practice, it is seen that the head loss in turbulent flow does not vary as the square of the mean velocity, but as some power between 1.7 and 2, or more. Also 'f' is depended upon the roughness of pipe surface, and may vary according to slope. So Manning's formula came after modifying Chezy's formula.

3- Manning's formula:

$V = 0.003968\, D^{/32}\quad S^{1/2} / N$ for circular sections running full.

where,

V= velocity of flow in m/sec

D = diameter of pipe in millimeter

S = Hydraulic gradient or slope of pipe in meter/meter

N = roughness coefficient of pipe varying from 0.015 to 0.013

This formula is usually used to design circular drains, sewers etc. Tables and graphs are available as per Manning's equation. (Appendix).

4- Hazen William's formula:

For designing, water supply pipelines, flowing full, under hydraulic pressure, Hazen Williams's formula is usually used.

$$V = 1.0955 \times 10^{-4} \times C \times D^{0.63} \times H_f^{\ 0.54}$$

where,

V = velocity of flow in m/sec

D = diameter of pipe in mm

H_f = hydraulic gradient or friction loss of head in meter/1000m

C = coefficient, depending upon roughness of pipe (Varying from 80 to 140)

Hazen William's formula is used for designing water supply pipelines. Tables and graphs are also available as per Hazen William's equation. (Appendix).

Example 1. *Calculate the head loss dm to friction in a pipe of 80mm diameter, 400m lengths, when the velocity of flow of water through pipe is 0.8m/sec. (Use Darcy's formula, f= 0.007)*

Ans.

As per Darcy's formula

Head loss $H_f = \dfrac{(4\, f\ l\ v^2)}{2\, g\, d}$

where,

f= 0.007, l=400 m, v = 0.8 m/sec, g = 9.81 m/sec^2 , d = 80 mm = 0.08 m,

$$H_f = \frac{(4\, f\ l\ v^2)}{2\, g\, d} = \frac{(4 \times 0.007 \times 400 \times 0.8 \times 0.8)}{2 \times 9.81 \times 0.08} = 4.56\, m$$

Example 2. *Calculate the discharge through a pipe of 50mm diameter laid for a length of 80 meter when the head available is 3 meter? (Use Darcy's formula, f = 0.007)*

Ans.

For finding discharge through a pipe, velocity is to be calculated initially.

As per Darcy's formula

$$H_f = \frac{(4 f l v^2)}{2 gd} \Rightarrow V^2 = \frac{(H_f \times 2 gd)}{4 fl}$$

$$V = \left(\frac{H_f 2gd}{4 fl}\right)^{1/2} = \frac{(3 \times 2 \times 9.81 \times 0.050)^{1/2}}{(4 \times 0.007 \times 80)^{1/2}} = 1.15 \text{ m/sec.}$$

$$Q = A \times V = \left(\frac{\pi d^2}{4}\right) \times 1.15 = \left(\frac{3.142}{4}\right) \times 0.05 \times 0.05 \times 1.15 = 2.26 \text{ liters/sec}$$

Example 3. *A circular sewer of 250 mm ∅ flowing full, laid in a slope of 1 in 300. Calculate the flow through the sewer?* (Use both Chezy's and Manning's formulas. *C = 55*, and *N = 0.013*)

Ans.

(a) As per Chezy's formula

$$V = C (mi)^{1/2}$$

$$C = 55$$

'*m*' when flowing full $= \frac{(\pi d^2/4)}{(\pi d)} = \frac{d}{4}$

$$i = \text{slope} = \frac{1}{300}$$

$$d = 0.25 \text{ m}$$

$$V = 55 \sqrt{(d/4)\, i} = 55 \sqrt{(0.25/4) \times (1/300)}$$

$$= 55 \times 0.0144 = 0.79 \text{ m/sec.}$$

But $Q = AV = (\pi d^2/4)\ V = \frac{3.142 \times 0.25 \times 0.25 \times 0.79}{4}$

$$= 0.0388 \text{ m}^3\text{/sec} = 38.8 \text{ lit/sec.}$$

(b) As per Manning's formula

$$V = (0.003968/N)\, D^{2/3}\, S^{1/2}$$

$N = 0.013$, $D = 250$ mm and $S = 1/300$

$\therefore$ $V = \left(\frac{0.003968}{0.013}\right) 250^{2/3}\ (1/300)^{1/2} = 0.693 \text{ m/sec}$

But $Q = A\ V = \left(\frac{\pi d^2}{4}\right) 0.693 = 34.02 \text{ lit/sec.}$

<u>**Note**</u>: There is a small difference in discharge, as per Chezy's and Manning's formulae. Since Manning's formula is a modified formula, the discharge as per Manning's formula is more reasonable.

Example 4. *Calculate the slope required for a foul sewer, having a diameter of 200 mm to run half full, with a self cleansing velocity 0.75 m/sec? (Use both Chezy's and Manning's formula) C = 55 and N = 0.013*

Ans.

Note: In practice, foul water sewers are usually designed for half depth or up to a maximum of 3/4 depth flow, while surface drains (Storm sewers) are designed for running full depth.

(a) As per Chezy's formula

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

where $C = 55$, i = slope = $1/L$

When 1/2 full, $m = \pi D^2/(4 \times 2)/\pi D/2 = D/4$

Note: For circular pipes, either running full bore or half bore, m will be equal to *D/4*.

$$V = 55\sqrt{(D/4) \times (1/L)}$$

$$\frac{1}{L} = \left(\frac{V}{55}\right)^2 \times \frac{4}{D} = \left(\frac{(0.75 \times 0.75 \times 4)}{(55 \times 55 \times 0.2)}\right) = 0.00371$$

$$L = \frac{1}{0.00371} = 269.5 \text{ m}$$

Slope to be provided to the Sewer is 1 in 270.

(b) As per Manning's formula:

$$V = 0.00396 \times D^{2/3} \times S^{1/2}/N$$

where $N = 0.013$; $D = 200$ mm; $V = 0.75$ m/sec.

$$0.75 = 0.003968 \times 200^{0.666} \times S^{1/2}$$

$$S^{1/2} = 0.721$$

$$S = 0.00519 = \frac{1}{L}$$

$$L = 192.3 \text{ m}$$

Slope to be provided to the sewer is 1 in 193.

Note: For circular pipe, relation between depth of flow and hydraulic mean depth is given below in table 3-A.

Table 3-A

Depth of flow	*Hydraulic mean depth*
Full or 1/2 full	0.25 × diameter
3/4 depth	0.30 × diameter
2/3 depth	0.29 × diameter
1/3 depth	0.19 × diameter
1/4 depth	0.15 × diameter

Example 5. *Cast iron pumping main of a town water supply system is 250 mm diameter, and 4200 meter length. Calculate the head loss due to friction, if it discharges 5.7 million liters per day of treated water? C =100 (Use Hazen William's formula, since pipe line is under pressure flow).*

Ans.

$$Q = 5.7\ \text{mld} = \frac{5.7 \times 10^6}{(1000 \times 60 \times 60 \times 24)} = 0.06597\ \text{m}^3/\text{sec.}$$

But $Q = A \times V$

$$V = \frac{Q}{A}$$

$$V = \frac{0.06597}{(\pi D^2/4)} = \frac{(0.06597 \times 4)}{(3.14 \times 0.25 \times 0.25)}$$

$$= 1.34\ \text{m/sec.} \qquad (D = 0.25\ \text{m})$$

As per Hazen William's Formula,

$$V = 1.0955 \times 10^{-4} \times C \times D^{0.63} \times H_f^{0.54}$$

$C = 100,\ D = 250\ \text{mm},\ V = 1.34\ \text{m/sec.}$

$$1.34 = 1.0955 \times 10^{-4} \times 100 \times 250^{0.63} \times H_f^{0.54}$$

$$H_f = 3.77^{1.851}$$

$$H_f = 11.64\ \text{m}/1000\ \text{m}$$

For a length of 4200m of Pumping main.

Total head loss due to friction = 11.64 x 4200/1000 = 48.8 m

WATER SUPPLY IN BUILDINGS

Drinking water is supplied to buildings either from Municipal water supply system or from any other reliable source. The head required to supply water directly to all water supply fittings of a single storied building is 7 meters, and that of a double storied building (ground + one) is 12 meters. Generally Municipal water supply system is designed to take care of either single story or double stories buildings only. For getting water to multistoried buildings, separate ground level reservoir is constructed and water is collected in it and then pumped into the roof tanks for distribution through various water supply fixtures.

Direct System

If water from Municipal water supply system is having sufficient pressure to feed the water supply fittings in a building or to the roof tank of the building, the system is called direct system.

Pumped system

If sufficient terminal pressure is not available in the Municipal water supply system to feed the water supply fittings, water is stored in a ground level or underground reservoir and then pumped into the roof tank or to the sanitary fittings

For pumped system, a ground level or underground water reservoir, with pump house, pump sets (duplicate of which one is standby) pumping main, roof tank etc. are required.

Ground level or Underground reservoir

Usually the capacity of ground level or underground reservoir is for 2 to 3 days storage. But storage capacity may vary from place to place, according to the reliability of source. If regular and uninterrupted supply is expected, the storage capacity of reservoir can be reduced. But a minimum of one-day storage is provided in any case.

Underground reservoirs are preferable in most cases to save land, and minimum disturbances. In this, outlet of over flow pipe shall be placed at a minimum of 20 cm above finished ground level, or at any level satisfying the over flow of water. Reservoir is to be constructed in such a way that no surface water shall enter into it. Reservoir shall also be well ventilated with one or more ventilating pipe of diameter 50mm or more (Fig. 4.1).

Elevated roof tank (storage cistern)

Capacity of elevated roof tank for dwelling houses is usually for 1/2-day storage. If uninterrupted supply from Municipal Water Supply System is anticipated, 2 hours storage is sufficient. The capacity of roof tank is calculated either by the number of occupants using the building, or by the available number of sanitary fittings. For a single dwelling house of 5 to 8 members, it is sufficient to provide an elevated roof tank of l m^3 capacity.

For public institutions, such as Hospitals, Hotels, Hostels, etc... one day storage is preferred, if water is directly supplied from the Municipal system, without a ground level or underground reservoir. (Fig. 4.2)

The storage capacities per day required for different type of buildings are given in Table 4-A

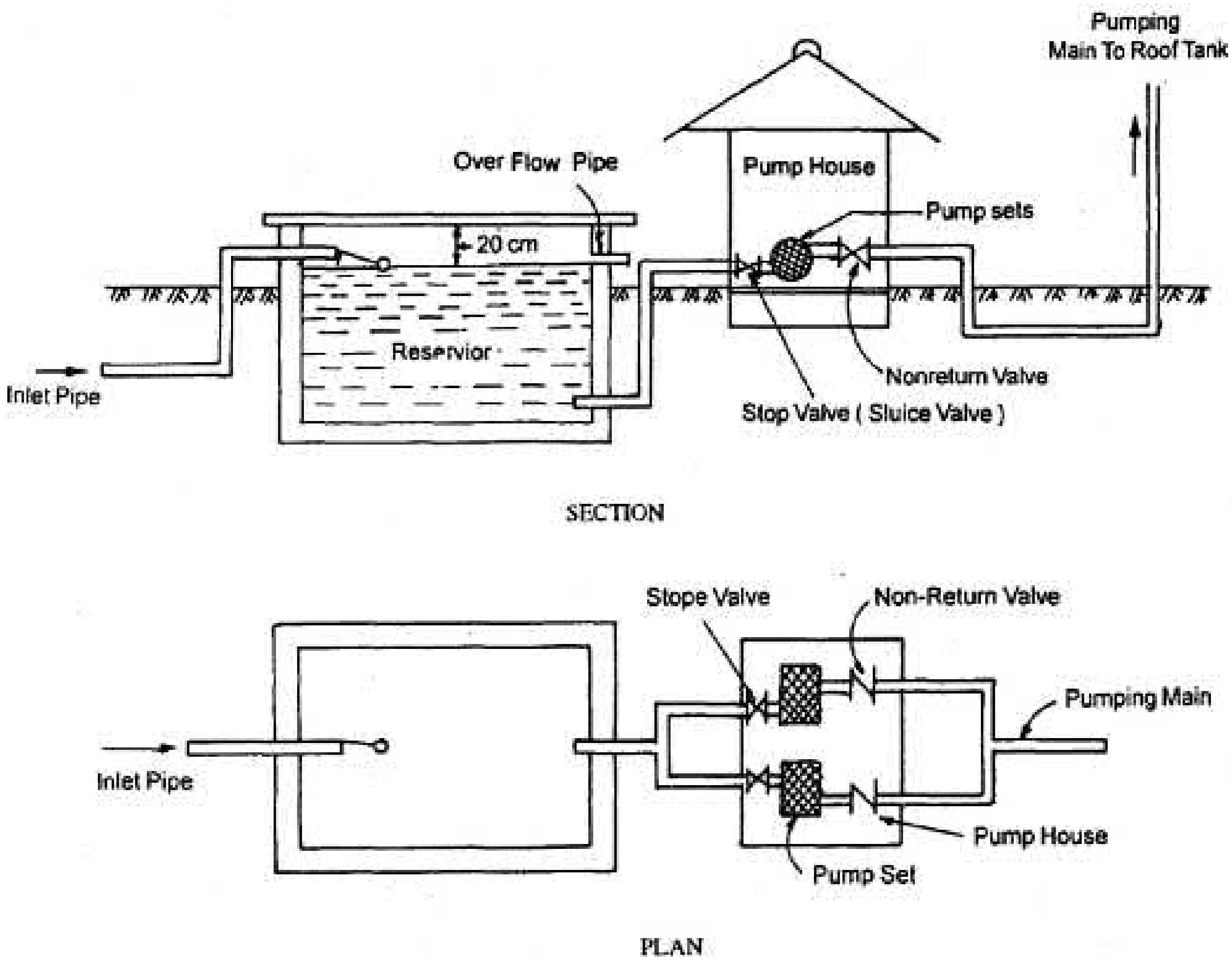


Fig. 4.1 Arrangement of Underground Reservoir and Pump house

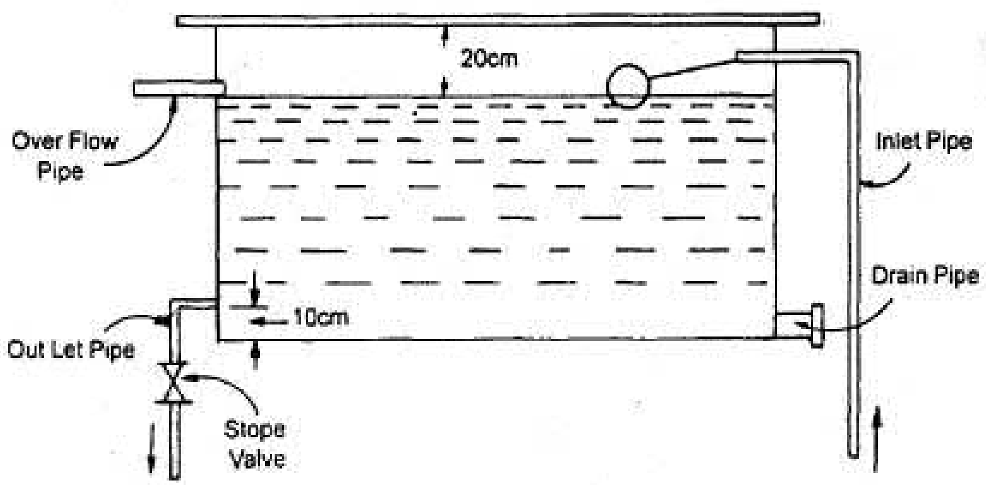


Fig. 4.2 Elevated Roof Tank

Table 4-A

	Type of Building	Cold water storage/day/head in liters
(a)	Factories with bathrooms	
	1. With Canteen	45
	2. Without Canteen	40
(b)	Factories without bathrooms	
	1. With Canteen	25
	2. Without Canteen	20
(c)	Dwelling house with House connection	100
(d)	Dwelling house with Yard connection	35
(e)	Hospitals (per bed)	150 to 200
(f)	Hostels (per bed)	60
(g)	Hotels (per bed)	100 to 150
(h)	Offices	25
(i)	Restaurants (per seat)	60
(j)	Bars (per seat)	50
(k)	Schools	
	1. Day school	15
	2. Boarding school	60

Cold water storage for one day based on sanitary appliances are given in table 4-B:

Table 4-B

S. No.	Sanitary appliances	Storage Capacity
1.	Water closet	180 lit/day
2.	Sink	200 lit/day
3.	Wash basin	180 lit/day
4.	Shower	200 lit/day
5.	Urinal	200 lit/day

Note: Storage capacity of tank above 5000 liters should preferably be divided into two or more compartments to avoid interruption of water supply, due to repair of one tank.

Example 1. *Calculate the size of an underground reservoir for a multistoried building, having* 50 *occupants?*

Ans.

No: of occupants in the building = *50*

Assume a storage capacity for dwelling house = *100 lit / capita / day*.

Therefore, Total storage required = *50 x 100 = 5000 lit /day*.

For 3 days storage = *5000 x 3 = 15000 liters = 15* m^3.

Therefore, size of underground reservoir is, = *5 m x 3 m x 1.2 m* (0.2 m of depth is for freeboard)

Example 2. *In a 200-bedded hospital, what will be the size of roof tank?*

Ans.

No of bed in hospital = *200*

Assuming, storage capacity required per bed = *200 lit / day*.

Total storage for 1/2 day = *200 x 200 x 1/2 = 20000 lit = 20 m3*.

Adopt 2 Nos : Steel tank of size 4 m x 2.5 m x 1.2 m (0.2 m is for freeboard) with inter connection or

Adopt 5 m3 capacity, 4 Nos: Syntex (plastic) tank with inter connection.

Example 3. *Calculate the size of roof tank, if the building is having 5 Nos: of water closets, 10 Nos: of wash basins, 5 Nos: of sinks, and 5 Nos: of shower?.*

Ans.

Assuming storage capacity required for each appliances

i.e. for Water closet =180 lit/day
Wash basin = 180 lit/day
Sink =200 lit/day
Shower =200 lit/day

Therefore storage capacity required for the building is

Water closets =5 x 180 =900 lit
Wash basins =10 x 180 =1800lit
Sinks =5x200=1000lit
Showers =5 x 200 =1000lit
Total =4700 liters/ day

Therefore 1/2 day storage = 4700/2 = 2350 liters = 2.35 m^3

Adopt a roof tank of 3 m^3 storage capacity. Size of tank = 2 m x 1.5 m x 1. 2m (0.2 m is freeboard)

PUMP SETS AND PUMPING MAIN

Pump sets:

Power =Work done / time
But Work done = Force x Distance
Therefore, Power = Force x distance/time
But, Force = mass x acceleration
Therefore, Power = mass x acceleration x distance/time
Power = mass (kg) x acceleration (m/sec2) x distance (m)/time(sec) Watts

Note: (1 Horse Power = 0.746 Kilowatts)

When water is pumped through a pipe, pipe friction and acceleration due to gravity are acting against the direction of flow. So a force is required to overcome these factors.

Friction of pipe is expressed in terms of meters in pipe length and added to the vertical height up to which water is to be lifted. Work done will be mass of water to be lifted, multiplied by acceleration due to gravity, and total head of water in meters inclusive of friction head expressed in meters.

Therefore, Power of pump = mass x acceleration due to gravity x total head / (l second x η)

η = Efficiency (usually 65%)

Power of pump = mass (kg) x 9.81 (m /sec^2) x total head (meters) / η Watts

Notes:

1- 1/2 to 1/4 storage time of roof tank is taken as filling time of roof tank. For 1/2-day storage, the filling time will be 1/4 of storage time.

= 1/4 x 1/2 day = 1/4 x 12 hours = 3 hours.

Generally filling time of roof tank is taken between 2 to 3 hours for small tanks and between 3 to 6 hours for big tanks.

2- Velocity in pumping main is generally taken between 1.5 m/sec to 3 m/sec.

Example 4. *Calculate size of a roof tank, diameter of pumping main, and power of pump sets, to be fixed for dwelling flats, occupying 50 persons?. Per capita rate of water supply is 100 liters/day.*

The flat is having 4 floors (Ground + 3 floors). No storage for fire fighting is to be considered.

Ans.

(*a*) *Storage capacity of roof tank*

Storage capacity required per person in dwelling house = 100 lit/day

Therefore, one day storage for 50 persons = 50 × 100 = 5000 lit

Assuming 1/2-day storage

Storage capacity of roof tank = 5000/2 lit

= 2500 liters

= 2.5 m^3

Adopt a roof tank, having a capacity of 3m^3.

Therefore, size of tank = 2 m × 1.5 m × 1.2 m (0.2 m for free board)

(*b*) *Pumping main*

Storage capacity of roof tank = 3m^3

Assuming a filling time of 2 hours

Rate of filling = 3m^3 /2 hours

= 3/(2 × 60 × 60)

= 0.0004166 m^3/sec

= 0.4166 lit/sec

(Say 0.5 lit/sec)

$Q = A \times V$

$A = Q / V$

Assume a velocity in pumping main = 1.5 m/sec

Therefore, $A = Q/1.5 = 0.5/(1.5 \times 1000)$ $\qquad Q = 0.5/1000\ m^3/sec$

Therefore, $(\pi \times d \times d) = 0.5/(1.5 \times 1000)$

$(\pi \times d \times d) = 4 \times 0.5/(1.5 \times 1000)$

Therefore, $d = \sqrt{(94 \times 0.5)/(3.142 \times 1.5 \times 1000)}$

= 0.02059 m

= 20.59 mm

Since being small diameter, adopt 32 mm minimum

Adopt a pumping main of 32 mm diameter.

(*c*) *Pump Sets*

Pump set head = $(H_1+H_2+H_3+H_4+H_5)$+10% Factor of safety

where,

H_1 = pipe friction loss in m

H_2 = loss in fittings and valves (0.5 m/each fitting)

H_3 = total height in m to where water lifted

H_4 = discharge head (2 m)

H_5 = pump loss (2 m)

Vertical length of pumping main = 4 × 4 m = 16 m +1 m (roof tank height)

= 17 m

(Ground+3 floor building, having 4 m heights for each floor)

Assume a horizontal length of 10m for connection of pump set, valves etc...

Therefore, total length of pumping mains =17 m +10 m

= 27m.

Discharge through pumping main = $3/(2 \times 60 \times 60)$

= $0.0004166\ m^3/sec$

= 0.4166 lit/sec. (Say 0.5 lit/sec)

Q = 0.5 lit/sec

∅ of pumping main = 32 mm.

As per Hazen William's equation

Hf for 1000 m = $0.029049 \times Q_k^{1.851851}$

where,

H_f = friction loss in meter

Q_k = discharge in kilo liter/day

Therefore, $Q_k = 0.5 \times 60 \times 60 \times 24 \times 24/1000$

= 43.2 kilo lit/day

Therefore, H_f for 1000 m = $0.029049 \times 43.2^{1.851851}$

= 31.03 m

Therefore, for 27 m length

Friction loss = $(31.03 \times 27)/1000$ = 0.84 m

There fore, H_1 = 0.84 m

H_2 = Loss in fittings and valves (0.5 m per each fitting)

Assuming 4 No fittings

$H_2 = 4 \times 0.5 = 2$ m

H_3 = total height to which water is to be lifted

= $4 \times 4 + 1$ (roof tank height)

= 16 +1 =17 m (Note:- 4 floors with 4m height of each floor)

H_4 = discharge head = 2 m

H_5 = Pump loss = 2 m

Therefore total pump head = 0. 84 m + 2 m +17 m + 2 m + 2 m

= 23.84 m (say 24 m)

Pump discharge = 0.5 lit/sec

Total head = 24 m

Therefore, Power of pump set = mass × acc. due to gravity × total head/η

= $0.5\ kg \times 9.81\ m/sec^2 \times 24\ m \times 100/65$

(η = 65%), (1 liter = 1 kg, acceleration due to gravity = $9.81\ m/sec^2$)

Power = 181.1 watts

= 0.1811 kilo watts

(But 1 Hp = 0.746 kilowatts)

Therefore, Horse Power of pump = 0.1811/0.746 = 0.242 Hp

Adopt two pump sets of 0.5 Hp, out of which one is standby, to pump a quantity of 0.5 lit/sec, against a head of 24 m.

WATER PIPE SIZING IN BUILDINGS

For small buildings, it is possible to size water supply pipes on the basis of practical experiences. But for big buildings, pipe size shall be calculated. The size of pipes and fittings used in a water supply system of a building shall provide, sufficient rate of delivery of water, without wasteful over sizing.

It rarely occurs that, all appliances are used simultaneously. So it is practicable to provide a simultaneous demand much lesser than the possible maximum

The simultaneous design flow rate can be found by using probability equation. This equation can be used, where an individual draw off is not greater than 0.5 lit/sec., even if it is there, such flows shall be for shorter period. Continues flows if any, shall be taken into account, by adding 100% of their flow rates.

Row Rates And Loading Units (As Per Probability Equation) are given in table 5-A

Table 5-A

S. No.	Fittings	Flow rate (lit/ sec)(q)	loading unit (z)
1.	W.C, bidet, Wash Basin	0.125	0.50
2.	Flush Valve (Urinal)	0.125	0.50
3.	Sink	0.25	1.00
4.	Shower	0.25	1.00
5.	Bath tub	0.35	1.96
6.	Flush Valve (W.C)	0.25	4.32
7.	Laundry tub	0.52	1.00
8.	Washing machine	0.25	1.00
9.	Hose tap (20 mm)	0.30	1.44
10.	Hose tap (15 mm)	0.20	0.64
11.	Cistern for Urinal	0.004	(to be calculated)
12.	Spray tap	0.04	(to be calculated)

The relation between *'q'* and *'z'* is given below

$$z = (q/0.25)^2$$

where *'q'* is the flow rate in liters/sec, equal to 0.25 lit/sec

Note: The constant is based on, by giving a flow rate of 0.25 lit/sec as a unit loading.

The probable simultaneous design flow

$$Q = q\,(Z_1 + Z_2 + \dots + Z_n)^{1/2}$$

$$= 0.25\,(Z_1 + Z_2 + \dots + Z_n)^{1/2}$$

where,

Z_1 = *Z* value x No: of same type of appliances

i.e. Loading Unit of W.C = Z_1 = *Z* value of W.C x No of W.C

Loading Unit of W.B = Z_2 = *Z* value of W.B x No of W.B

Loading Unit of Sink = Z_3 = *Z* value of Sink x No of sink etc.

Example 1. *Calculate the design flow rate of a water supply pipe line in a building, feeding 3 Nos. W.C, 3 Nos. Wash Basins, 3 Nos Showers and 2 Nos. Sinks?*

Ans.

As per probability equation,

W.C.	$Z_1 = 3 \times 0.5 = 1.5$
W.B.	$Z_2 = 3 \times 0.5 = 1.5$
Shower	$Z_3 = 3 \times 1.0 = 3.0$
Sink	$Z_4 = 2 \times 1.0 = 2.0$
Total	$= 8.0$

$$Q = 0.25\,(Z_1 + Z_2 + Z_n)^{1/2}$$
$$= 0.25\,(1.5 + 1.5 + 3 + 2)^{1/2}$$
$$= 0.25\,(8)^{1/2}$$
$$= 0.25 \times 2.82 = 0.7 \text{ litres/second}$$

The flow rates of water through pipes depend upon; the length, diameter, roughness and pressure drop along the pipe. Head loss in pipe fittings (elbow, Tee etc) and valves are calculated in equivalent length of pipe.

Head loss expressed In equivalent pipe length (B. S) are given in table 5-B

Table 5-B

Type of fittings	*approximate equivalent length in pipe diameter* (*i.e.* Diameter × this value gives in mm)
90°	30-36
Easy bend	10
Flush connection to cistern or tank	20
Globe valve	340
Tee:	
Straight	20
Reducing one side	30
Reducing two sides	36
Water entering branch	70 to 90
Gate valve	7

Example 2. *In a 15 mm pipe, having a length of 3m, there are 2 Nos 900 bend and one gate valve. Calculate the effective length?*

Ans.

Equivalent length of 2 Nos 90° bend $= 2 \times 15 \text{ mm} \times 36$
$= 1080 \text{ mm} = 1.08 \text{ m}$

Equivalent length of one gate valve $= 1 \times 15 \text{ mm} \times 7 = 105 \text{ mm} = 0.1 \text{ m}$

Effective length of 15 mm pipe $= 3 \text{ m} + 1.08 \text{ m} + 0.1 \text{ m}$
$= 4.18 \text{ m}$

Note: Head loss due to friction for 4.18m is to be found.

In any 15 mm end pipe connection to appliances, there can be expected a minimum of 2 Nos 90° bend, and one gate valve. So total equivalent pipe length for fittings = $(2 \times 15 \text{ mm} \times 36) + (1 \times 15 \text{ mm} \times 7) = 1080 + 105 = 1185 \text{ mm} = 1.185 \text{ m}$

So 1.185 m is to be added to the actual length to get the effective length, for calculating the head loss due to friction in 15 mm pipe

Note: *(a)* Loss through water meter is to be added, as assessed from the manufacturers.

(b) The residual head available at each tap should be at least equal to the loss of head through the tap, at the design flow rate. It is better to have a residual head of 0.2 kg/cm^2 in all appliances.

Typical loss of head through taps and their equivalent lengths are given in table 5-C

Table 5-C

Ø of tap in mm	*Tap flow rate in lit/sec*	*Loss of head in m*	*Equivalent length in m*
15	0.15	0.5	3.7
	0.2	0.8	3.7
20	0.3	0.8	11.8
25	0.6	1.5	22.0

Required minimum terminal pressure in appliances are given in table 5-D

Table 5-D

(*a*) Bath tub (Hand Spray)	....	0.8 m (15 mm, Q = 0.2 lit/sec)
(*b*) Wash Basin	....	0.5 m (15 mm, Q = 0.15 lit/sec)
(*c*) Water Closet	....	0.5 m (15 mm, Q = 0.10 lit/sec)
(*d*) Sink 15 mm	....	0.5 (15 mm, Q = 0.15 lit/sec)
20 mm	....	0.8 (20 mm, Q = 0.3 lit/sec)
(*e*) Float valve	....	0.3 m
(*f*) Shower	....	0.8 m to 1 m

Note: But it is better to have a terminal pressure of 2 m (0.2 kg/cm^2) in all water supply appliances; at the delivery point.

Sizing of pipes

Initial available head is normally measured from the outlet of the storage tank.

Trial and error method, starting from the 1st pipe length, from the storage tank is to be done. The residual head of each pipe length (junction point to junction point) is to be calculated, taking into account the head loss due to pipe work and head loss due to position. If the residual head available at the discharge point is negative or less than the required head, the Ø of the preceding pipe is to be adjusted and the procedure repeated.

Because of too many variables involved in designing Ø of the pipe, tables and charts are available showing, diameter of pipe, head loss, velocity, discharge etc. which will make easy the design of pipes.

Design assumptions

(a) Velocity of flow for design of gravity pipe (supply pipe) may be < 1 m/sec preferably 0.8 m/sec. In any case it should not be greater than 3 m/sec.

(b) Velocity of flow for design of pumping main shall be between 1.5 m/sec to 3 m/sec, preferably 1.5 m/sec

(c) Head loss in main pipe is preferably limited to 2 m/100 m

(d) Reduction in capacity due to ageing can be neglected.

Junction 'A' to Junction 'B'—Main Pipe(Fig.5.1)

Junction 'B' to Junction 'C'—Sub Pipe

Junction 'B' to Junction 'D'—Sub Pipe

Note: Design is to be done junction-to-junction starting from the storage tank.

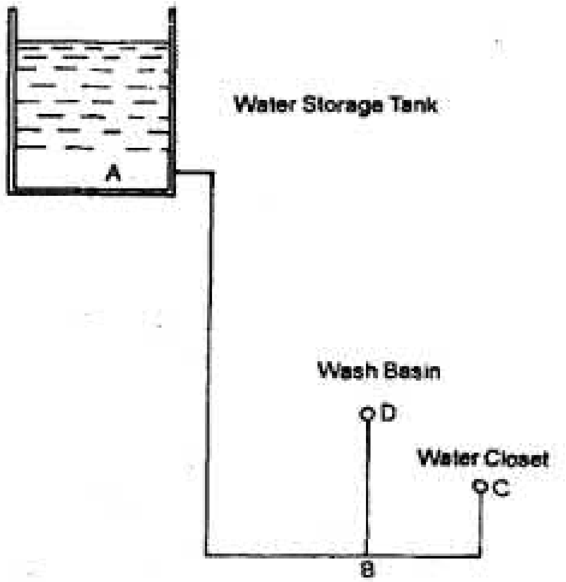


Fig. 5.1

Procedure for pipe sizing

1. Prepare the pipe work diagram, numbering from junction to junction, starting from storage tank.
2. Calculate the fixtures fed by each pipe.
3. Determine the loading units for each length of pipe.
4. Convert the loading units into design flow rates in liters/sec (use Probability equation).
5. Starting from storage tank with known flow rate and velocity less than 3 m/sec, (preferably in between 1 m/sec and 0.8 m/ sec) , select a diameter of pipe. Note that the head loss is in meter/100 meter.
6. Determine the height difference between the inlet and the outlet of pipe (positive for drop, negative for rise).
7. Measure actual length of pipe being considered.
8. Determine an equivalent length of pipe for fittings, valves, etc.
9. Determine the effective length of pipe work by adding actual length and equivalent length of pipe-fittings, valves etc.
10. Determine actual head loss of pipe work considering effective length
11. Deduct actual head loss from available head.
12. If the residual head is less than the required head, for a particular out let fitting or if the head is negative, repeat the same with a larger 0.

Note: *(a)* If the details of pipe fittings and valves are not known, add 20 to 30% of actual head loss in pipe work, as minor head loss due to fittings and valves.
(b) The average rate of flow is to be taken for single Fitting, while designing last pipe.

Average rate of flows with friction loss and velocity for single fitting are given in table 5-E.
where, hf = friction head loss in meter, V = velocity in m/sec.

Table 5-E

A. Bath tab, 20 mm.	$Q = 0.3$ lit/sec	$h_f = 11.8$ m/100 m $V = 0.954$ m/sec
B. Sink, 2 0mm.	$Q = 0.3$ lit/sec	$h_f = 11.8$ m/100 m $V = 0.954$ m/sec
C. Sink 15 mm,	$Q = 0.2$ lit/sec	$h_f = 23.79$ m/100 m $V = 1.13$ m/sec
D. Shower, 15 mm,	$Q = 0.2$ lit/sec	$h_f = 23.79$ m/100 m $V = 1.13$ m/sec
E. Wash basin, 15 mm	$Q = 0.15$ lit/sec	$h_f = 14.44$ m/100 m $V = 0.84$ m/sec
F. Water closet, 15 mm	$Q = 0.1$ lit/sec	$h_f = 6.32$ m/100 m $V = 0.56$ m/sec

The best method to proceed for finding the diameter of pipe is that

(a).Find the critical fixture, which may be farthest or highest one, having minimum available head.

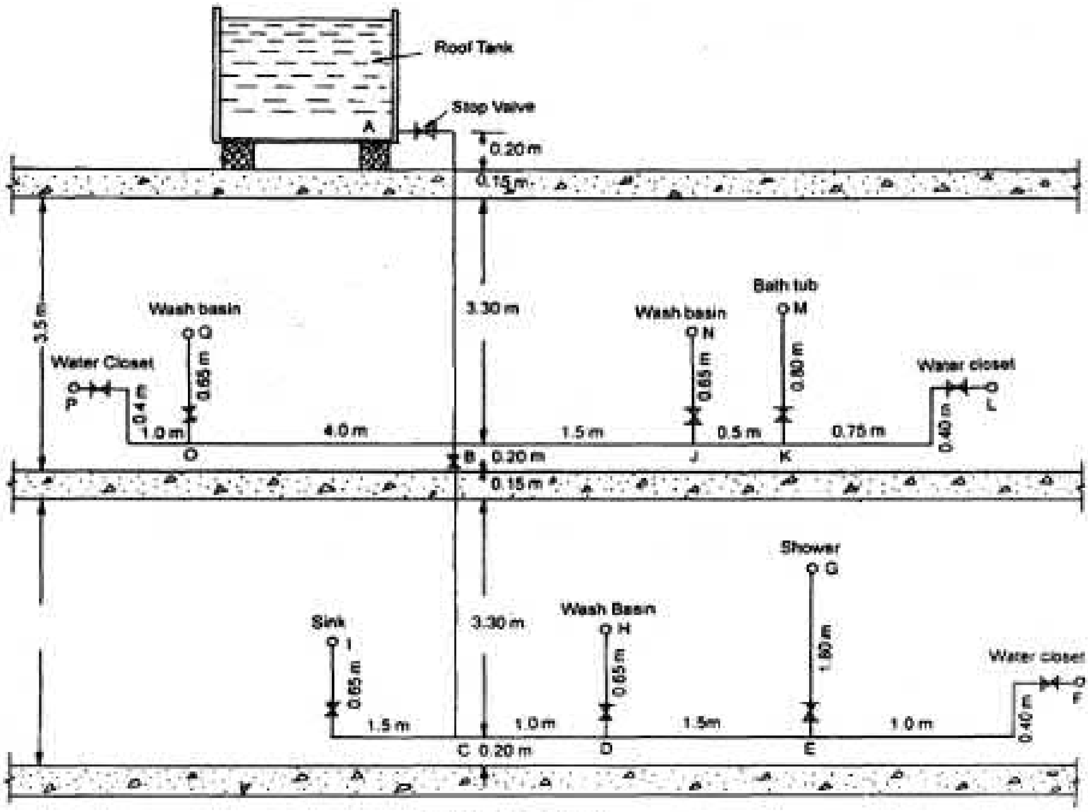
(b).Compute the available head, from out let of the storage tank to that fixture, after deducting residual head required.

(c).Compute the length from out let of storage tank to that fixture.

(d).Divide available head by length and fix the average % head loss (H/L) x 100), H&L are in meters.

(e).Follow this average head loss %, for finding the diameter of pipe.

(f).Aging is not considered for pipes.



(NOT TO SCALE)

Fig. 5.2

Example 3. *Calculate the diameter of pipes of a residential building as shown in Fig. 5.2?*

Ans.

Note: The flow rate is computed, as per probability equation.

Where $Q = 0.25 \times \sqrt{(Z_1 + Z_2 + Z_3 + \ldots + Z_n)}$

Computation of flow in each pipe:

Pipe	EF = 1WC = 1 × 0.5 = 0.5	Single WC	$Q = 0.1$ lit/sec
	EG = 1 Shower = 1 × 1 = 1.0	Single shower	$Q = 0.2$ lit/sec
	DE = EF + EG = 0.5 +1 = 1.5		$Q = 0.25 \times \sqrt{(1.5)} = 0.3$ lit/sec
	DH =1 WB =1 × 0.5 = 0.5	Single WB	$Q = 0.15$ lit/sec
	CD = DE + DH =1.5 + 0.5 = 2		$Q = 0.25 \times \sqrt{(2)} = 0.35$ lit/sec
	CI = 1 sink = 1 × 1 =1	Single sink	$Q = 0.2$ lit/sec
	BC = CI + CD = 1 + 2 = 3		$Q = 0.25 \times \sqrt{(3)} = 0.43$ lit/sec
	KL =1 WC = 1 × 0.5 = 0.5	Single WC	$Q = 0.1$ lit/sec
	KM = 1 Bath tub =1 × 2 = 2	Single bath tub	$Q = 0.3$ lit/sec
	JK = KL + KM = 0.5 + 2 = 2.5		$Q = 0.25 \times \sqrt{(2.5)} =0.39$ lit/sec
	JN = 1WB = 1 × 0.5 = 0.5	Single WB	$Q = 0.15$ lit/sec
	BJ = JK + JN = 2.5 + 0.5 = 3		$Q = 0.25 \times \sqrt{(3)} = 0.43$ lit/sec
	OP = 1WC = 1 × 0.5 = 0.5	Single WC	$Q = 0.1$ lit/sec
	OQ = 1WB = 1 × 0.5 = 0.5	Single WB	$Q = 0.15$ lit/sec
	BO = OP + OQ = 0.5 + 0.5 = 1.0		$Q = 0.25 \times \sqrt{(1)} = 0.25$ lit/sec
	AB = BO + BJ + BC = 1 + 3 + 3 = 7		$Q = 0.25 \times \sqrt{(7)} = 0.66$ lit/sec

Calculated results are given in Table 5-F

Table 5-F

Tabulated result of Example 3

S. No.	*Pipe details*	*Design flow (lit/sec)*	*Pipe size (mm)*	*Velocity (m/sec)*	*Head loss per 100m (m)*	*Head (m)*	*Drop (+ve) Rise (−ve)*	*Available head (m)*	*Actual length (m)*	*Effective length (m)*	*Head loss (m)*	*Minor loss 30% to 40% (m)*	*Total head loss (m)*	*Available head (m)*	*Required head and remarks*
1.	AB	0.66	32	0.86	5.70	–	–	3.65	3.65	–	0.21	0.06	0.27	3.38	NB:Residual head
2.	BC	0.43	25	0.94	8.55	3.38	+3.65	7.03	3.65	–	0.31	0.09	0.40	6.63	preferably 2 m
3.	CD	0.35	20	1.10	15.50	6.63	–	6.63	1.00	–	0.16	0.04	0.20	6.43	in all
4.	DE	0.30	20	0.92	11.20	6.43	–	6.43	1.50	–	0.17	0.05	0.22	6.21	appliances, But not
5.	EF	0.10	15	0.56	6.32	6.21	−0.40	5.81	1.40	–	0.09	0.02	0.11	5.70	less than
6.	EG	0.20	15	1.13	23.79	6.21	−1.80	4.41	1.80	–	0.43	0.13	0.56	3.85	a. Bath tub 0.8m
7.	DH	0.15	15	0.84	14.44	6.43	−0.65	5.78	0.65	–	0.09	0.03	0.12	5.66	b. Washbasin 0.5 m
8.	CI	0.20	15	1.13	23.79	6.63	−0.65	5.98	2.15	–	0.51	0.15	0.66	5.32	c. W.C. 0.5 m
9.	BJ	0.43	25	0.94	8.55	3.38	–	3.38	1.50	–	0.13	0.04	0.17	3.21	d. Sink 0.5 m
10.	JK	0.39	20	1.29	20.70	3.21	–	3.21	0.50	–	0.10	0.03	0.13	3.08	
11.	KL	0.10	15	0.56	6.32	3.08	−0.40	2.68	1.15	–	0.07	0.02	0.09	2.59	
12.	KM	0.30	20	0.95	11.80	3.08	−0.80	2.28	0.80	–	0.09	0.03	0.12	2.16	
13.	JN	0.15	15	0.84	14.44	3.21	−0.65	2.56	0.65	–	0.09	0.03	0.12	2.44	
14.	BO	0.25	15	1.41	34.43	3.38	–	3.38	4.00	–	1.38	0.40	1.78	1.60	OK > 0.5 m
15.	OP	0.10	15	0.56	6.32	1.60	−0.40	1.20	1.40	–	0.09	0.03	0.12	1.08	OK > 0.5 m
16.	OQ	0.15	15	0.84	14.44	1.60	−0.65	0.95	0.65	–	0.09	0.03	0.12	0.82	OK > 0.5 m

Hazen Williams's equation (simplified form) to find H_f and V, if Q is known. C=100

A. 15 mm diameter
H_f for 1000 m = $1.163522\ Qk^{1.851851}$
$V\ m/sec = 0.060335\ H_f$
Where H_f = head loss in m
V = velocity in m/sec
Qk = Kilolitre/day

B. 20 mm diameter
H_f for 1000 m = $0.286600 Qk^{1.851851}$
$V\ m/sec = 0.0732324\ H_f^{0.54}$

C. 25 mm diamter
H_f for 1000 m = $0.096669 Qk^{1.851851}$
$V\ m/sec = 0.08324 H_f^{0.54}$

D. 32 mm diameter
H_f for 1000 m = $0.029049 Qk^{1.851851}$
$V\ m/sec = 0.097247\ H_f^{0.54}$

E. 40 mm diameter
H_f for 1000 m = $9.798264 \times 10^{-3}\ Qk^{1.851851}$
$V\ m/sec = 0.111925\ H_f^{0.54}$

F. 50 mm diameter
H_f for 1000 m = $3.304924 \times 10^{-3}\ Qk^{1.851851}$
$V\ m/sec = 0.128820\ H_f^{0.54}$

G. 65 mm diameter
H_f for 1000 m = $9.209057 \times 10^{-4}\ Qk^{1.851851}$
$V\ m/sec = 0.151973\ H_f^{0.54}$

H. 80 mm diameter
H_f for 1000 m = $3.349821 \times 10^{-4}\ Qk^{1.851851}$
$V\ m/sec = 0.173212\ H_f^{0.54}$

I. 100 mm diameter
H_f for 1000 m = $1.129884 \times 10^{-4}\ Qk^{1.851851}$
$V\ m/sec = 0.199357\ H_f^{0.54}$

Note: Graphs/Tables are available for computation of H_f and V as per Hazen William's Equation (in the Appendix)

Example 4. *Calculate the head loss due to friction, and velocity for a 40mm pipe, having 85tn long, discharging water at the rate of 2 lit/sec (by simplified formula and by table of Hazen William)?*

Ans.

Q = 2 lit/sec = 2 × 60 × 60 × 24 = 172800 lit/day

For 40mm pipe, as per Hazen William's simplified equation

H_f for 1000 m = $9.798264 \times 10^{-3} \times Qk^{1.851851}$
= 136.37 m

$V = 0.111925 \times H_f^{0.54}$
$= 0.111925 \times 136.37^{0.54}$
= 1.59 m/sec

For 85 m length, H_f = (136.37/1000) × 85 = 11.59 m

As per Hazen William's table(Appendix—D), for D = 40 mm, Q =2 lit/sec

H_f = 132 m for 1000 m

and V = 1.57 m/sec

For 85 m length, H_f = (132/1000) × 85 = 11.22 m

Alternatively,

$$Q = A \times V$$

$$V = \frac{Q}{A} = \frac{2}{1000 \times \left(\frac{\pi d^2}{4}\right)}$$

$$= \frac{(2 \times 4)}{(1000 \times 3.142 \times 0.04 \times 0.04)}$$

$$= 1.59 \text{ m/sec}$$

As per Hazen William's equation,

$$V \, m/sec = 1.0955 \times 10^{-4} \times C \times D^{0.63} \times H_f^{0.54}$$

$$1.59 = 1.0955 \times 10^{-4} \times 100 \times 40^{0.63} \times H_f^{0.54}$$

$$= 0.111920637 \, H_f^{0.54}$$

D = 40 mm

H_f = m/1000 m

$$H_f = \left(\frac{1.59}{0.111920637}\right)^{1.851851} = 136.2 \text{ m/1000 m}$$

For 85 m length $= \left(\frac{136.2}{1000}\right) \times 85 = 11.58$ m

Maximum numbers of smaller diameter water pipes that can be connected to bigger diameter pipes:

Box formula is $q = \sqrt{d^5 \times (H/25) \times L \times 10^5}$

where,

q = liter/sec (discharge)
d = diameter in mm
H = head in meter
L = length in meter

$N = \sqrt{(D/d)^5}$ Which is the relative discharge power of pipes, derived from box formula. This is used for computing the discharge power of various diameters of pipes.

By using $N = \sqrt{(D/d)^5}$, relative discharge capacity of various diameter of pipes can be found out. This equation holds good for branch pipes of short length.

Number of smaller pipes that can be connected to bigger pipes, according to discharge carrying capacity (assuming only 65 % of the appliances are working at a time):

Table 5-G

S. No.	Ø in mm	15 mm Nos.	20 mm Nos.	25 mm Nos.	32 mm Nos.	40 mm Nos.	50 mm Nos.	65 mm Nos.
1.	20	3	1					
2.	25	6	3	1				
3.	32	10	5	3	1			
4.	40	18	9	5	3	1		
5.	50	31	15	9	5	3	1	
6.	65	60	29	17	9	5	3	1

Example 5. *How many umbers of short length 15 mm pipes can be connected to 32 mm?*

Ans.

Assuming only 65% of the appliances using water at a time, actual number of 15 mm pipes that can be connected to 32 mm is

$$6.64 \times \frac{100}{65} = 10.2 \text{ say } 10 \text{ numbers}$$

Note: This will give a general idea in fixing the diameter of various water pipes in a building.

Table 5-H is a ready table for fixing various component of water supply system of residential flats for varying No of users.

Capacity of under ground reservoir, roof tank, diameter of pumping main, horsepower of pump sets etc. for different number of users in residential flats:

Height of each floor = 4 m

Height of roof tank bottom above roof = 1 m to 2 m

Suction Head = 2 m

G = Ground floor

G +1 = Ground floor + 1st floor, etc.

Table 5-H

No of users (Persons)	*Floors of building*	*Vertical lift of water m*	*One day water requirement (100lit/day) Liters*	*Capacity of Underground Reservoir (3days storage) Cum*	*Capacity of roof tank (1/2 day storage) Cum*	*∅ Of pumping main mm*	*Theoretical horse power of Pump set*	*Adopted horse power of pump sets H.P.*	*Remarks*
10	G	7	1000	3.0	1.0	32	–	0.5	
10	G+1	11	1000	3.0	1.0	32	–	0.5	
15	G	7	1500	4.5	1.0	32	–	0.5	
15	G+1	11	1500	4.5	1.0	32	–	0.5	
20	G+1	11	2000	6.0	1.0	32	–	0.5	
20	G+1+2	15	2000	6.0	1.0	32	–	0.5	
30	G+1	11	3000	9.0	1.5	32	–	0.5	
30	G+1+2	15	3000	9.0	1.5	32	–	0.5	
40	G+1+2	15	4000	12.0	2.0	32	–	0.5	
40	G+1+2+3	19	4000	12.0	2.0	32	–	0.5	
50	G+1+2	15	5000	15.0	2.5	32	–	0.5	
50	G+1+2+3	19	5000	15.0	2.5	32	–	0.5	
60	G+1+2+3	19	6000	18.0	3.0	32	–	0.5	
60	G+1+2+3+4	23	6000	18.0	3.0	32	–	0.5	
70	G+1+2+3	19	7000	21.0	3.5	32	–	0.5	
70	G+1+2+3+4	23	7000	21.0	3.5	32	–	0.5	
80	G+1+2+3	19	8000	24.0	4.0	32	–	0.5	
80	G+1+2+3+4	23	8000	24.0	4.0	32	–	0.5	

No of users (Persons)	Floors of building	Vertical lift of water m	One day water requirement (100lit/day) Liters	Capacity of Under-ground Reservoir (3days storage) Cum	Capacity of roof tank (1/2 day storage) Cum	∅ Of pumping main mm	Theoretical horse power of Pump set	Adopted horse power of pump sets H.P.	Remarks
90	G+I+2+3+4	24	9000	27.0	4.5	32	0.29	0.5	Suction head 2m
90	G+1+2+3+4+5	28	9000	27.0	4.5	32	0.32	0.75	
100	G+I+2+3+4	24	10000	30.0	5.0	32	0.32	0.75	
100	G+1+2+3+4+5	28	10000	30.0	5.0	32	0.36	1.0	
150	G+1+2+3+4	24	15000	45.0	7.5	32	0.51	1.25	
150	G+1+2+3+4+5	28	15000	45.0	7.5	32	0.58	1.50	
200	G+1+2+3+4+5	28	20000	60.0	10.0	40	0.74	1.50	
200	G+1+2+3+4+5+6	32	20000	60.0	10.0	40	0.82	2.0	
300	G+1+2+3+4+5	28	30000	90.0	15.0	50	1.08	2.0	
300	G+1+2+3+4+5+6	32	30000	90.0	15.0	50	1.20	2.0	

Note: 1.Two sets of pumps are to be erected, out of which one is standby.

2. No storage for fire fighting water is considered in roof tank. If required, add 20% more.

3.Two times theoretical Horse Power is considered for arriving the actual Horse Power of Pump sets.

PLUMBER'S CHART

Plumber's chart is used to assess the approximate estimation of sizes of water supply pipes in buildings. If sufficient capacity of water is stored in roof tank, this chart can safely be used for single and double story buildings.

Table 5-I

S. No.	Sanitary fixtures	Number of fixtures						
		1	2	4	8	12	16	24
1.	Water Closets Pipe Size in mm	15	20	25	32	40	40	50
2.	Urinals Pipe Size in mm	15	20	25	32	32	32	40
3.	Wash Basins Pipe Size in mm	15	15	20	25	25	32	32
4.	Bath Tubs Pipe Size in mm	20	25	32	40	50	50	65
5.	Shower (tap) Pipe Size in mm	15	20	32	40	50	50	65
6.	Sink Pipe Size in mm	20	25	32	40	40	50	50

Table 5-J Equivalent Pipe size

Size of Pipe in mm	15	20	25	32	40	50	60
No. of equivalent 15 mm diameter pipe	1	1.8	3.7	5.9	12	23	42

Example 6*. Using plumber's chart, calculate the diameter of cold water pipes as shown in the Fig.5.3?*

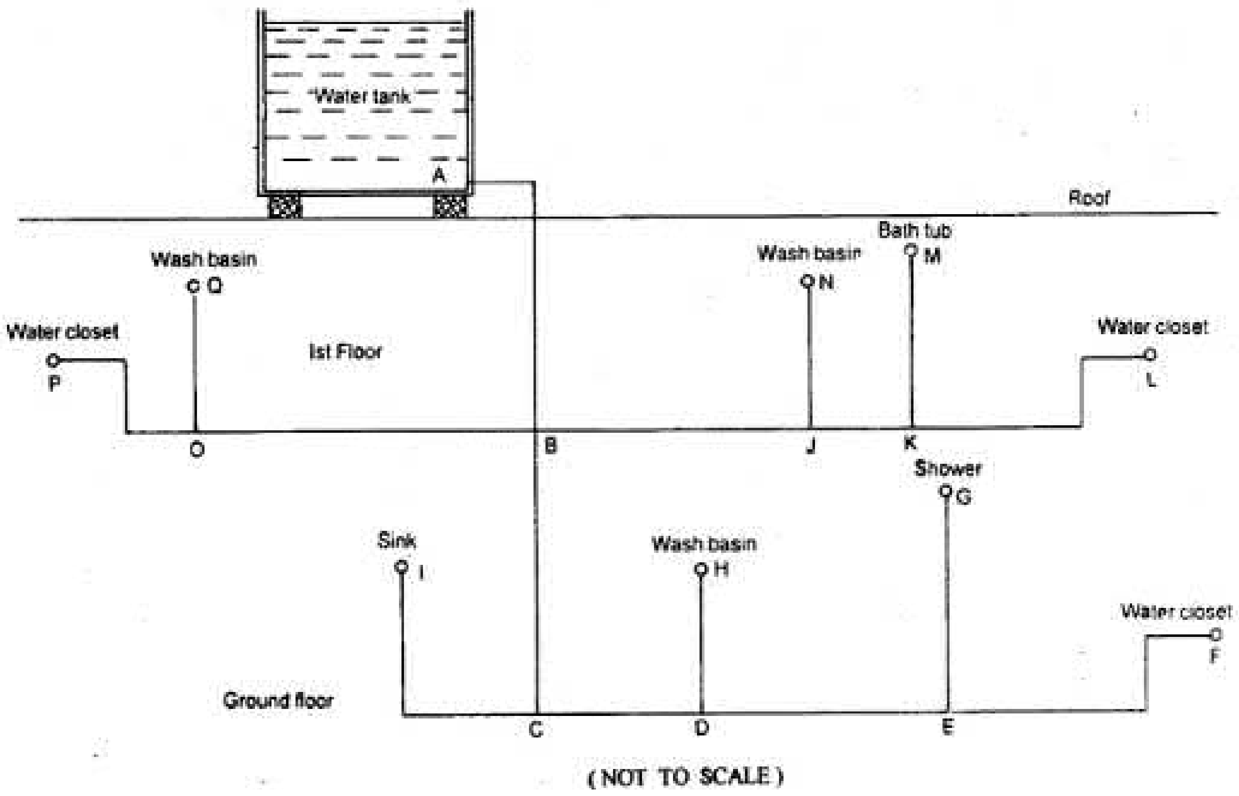


Fig. 5.3

Ans. Pipe AB is feeding all fixtures. So the diameter of that pipe shall be sufficiently big

Line AB

Washbasin	= 3 Nos.
Water closet	= 3 Nos.
Sink	= 1 No.
Shower	= 1 No.
Bathtub	= 1 No.

As per plumber's chart (Table 5-I)

Wash basin	= 3 Nos.,	Ø = 20 mm, equivalent 15 mm = 1.8
Water closet	= 3 Nos.,	Ø = 25 mm, equivalent 15mm = 3.7
Sink	= 1 No.,	Ø = 20 mm, equivalent 15mm = 1.8
Shower	= 1 No.,	Ø = 15 mm, equivalent 15mm = 1
Bath tub	= 1 No.,	Ø = 20 mm, equivalent 15mm = 1.8
		Total = 10.1

From Table 5-J, for value 10.1, 40 mm diameter required (Near value)

Line BC (As per Table 5-I)

Wash basin	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
Water closet	= 1 No.,	Ø = 15 mm, equivalent 15 mm	=1
Sink	= 1 No.,	Ø = 20 mm, equivalent 15 mm	= 1.8
Shower	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
		Total	= 4.8

From Table 5-J, for value 4.8, 32 mm diameter pipe required (Near value)

Line CD (As per Table 5-I)

Wash basin	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
Water closet	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
Shower	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
		Total	= 3

From table 5-J, for value 3, 25 mm diameter pipe required (Near value)

Line DE (As per Table 5-I)

Water closet	= 1 No.,	Ø =15 mm, equivalent 15 mm	= 1
Shower	= 1 No.,	Ø =15 mm, equivalent 15 mm	= 1
		Total	= 2

From table 5-J, for value 2, 20 mm diameter pipe required (Near value)

Line BJ (As per Table 5-I)

Wash basin	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1

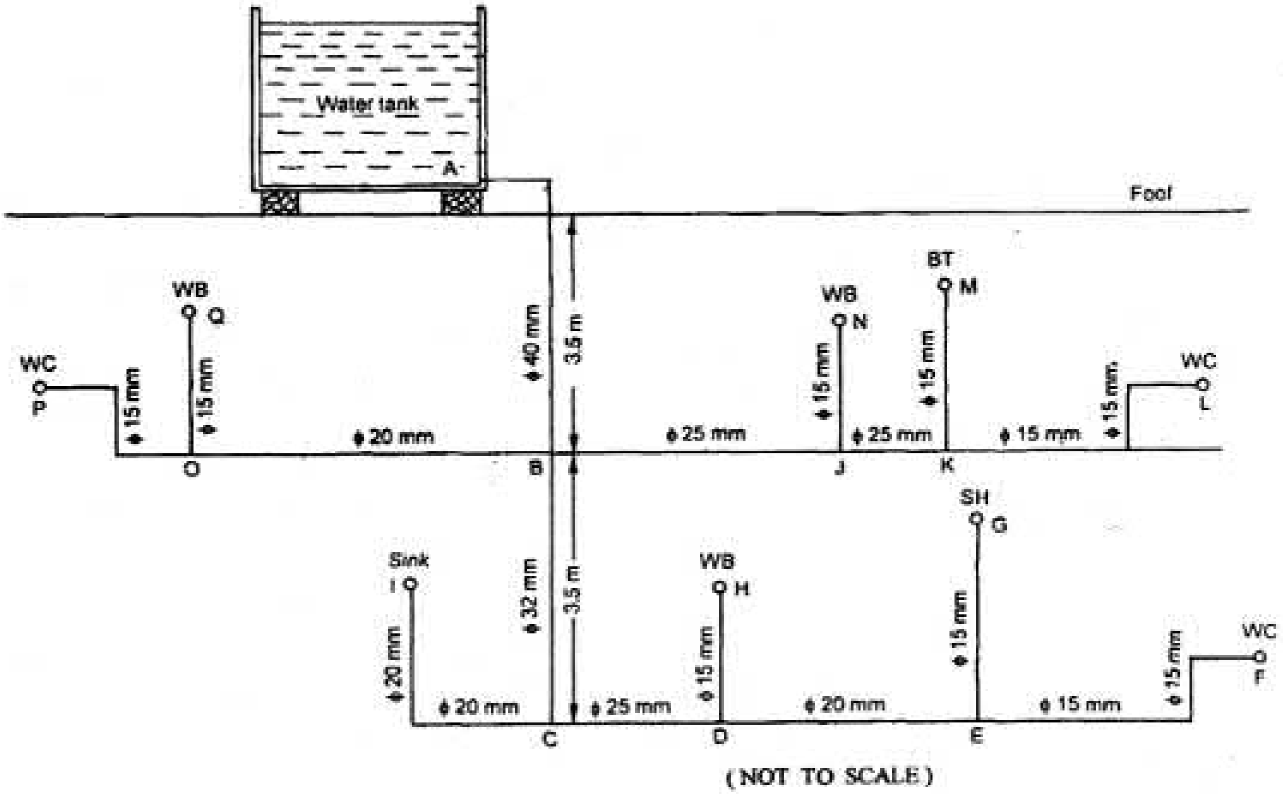


Fig. 5.4

Water closet	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
Bath tub	= 1 No.,	Ø = 20 mm, equivalent 15 mm	= 1.8
		Total	= 3.8

From table 5-J, for value 3.8, 25 mm diameter pipe required (Near value)

Line JK (As per Table 5-I)

Water closet	= 1 No.,	Ø = 15 mm, equivalent 15 mm	= 1
Bath tub	= 1 No.,	Ø = 20 mm, equivalent 15 mm	= 1.8
		Total	= 2.8

From Table 5-J, for values 2.8, 25 mm diameter pipe is required (Near value), (Fig. 5-4)

FOUL WATER DRAINAGE IN BUILDINGS

Foul water drainage system of a building consists of

♦ Stack
♦ Branch drain/discharge pipe
♦ Horizontal drain

Stack

A vertical waste-pipe passing through different floors of a building for collecting and conveying wastewater from branch drains is called stack. All branch drains are directly connected to the stack. Stack also acts as a ventilating pipe for air movement, (Fig. 6.1)

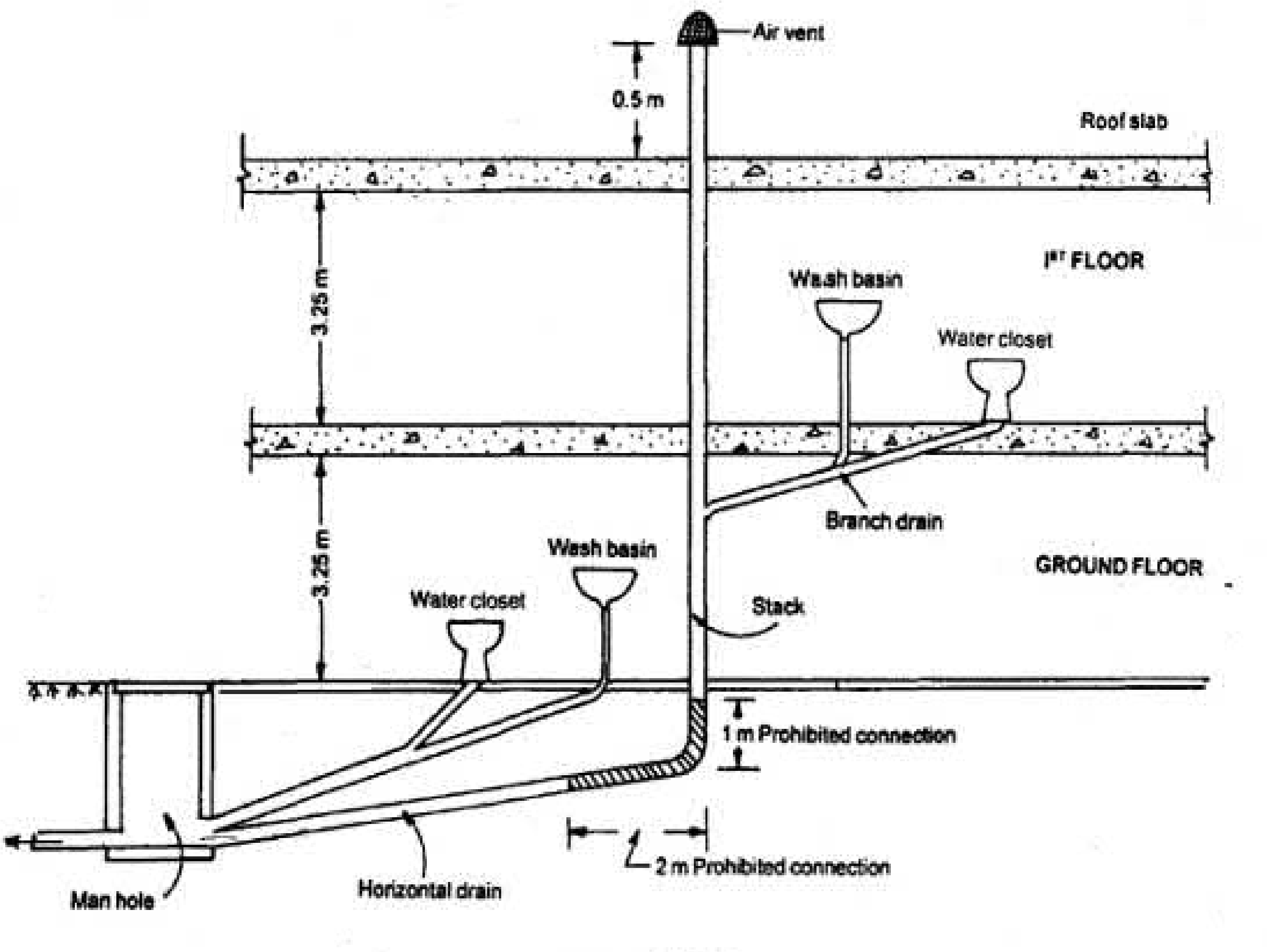


Fig. 6.1. Arrangements of stack, branch drain & Horizontal drain

When wastewater is flowing downwards, through stack, the acceleration due to gravity (9.81 m/sec^2) is acting on it downward, while the friction of the pipe acting against the direction of flow. The flow finally attains a balanced velocity of flow and with that velocity the wastewater flows further downwards. If the quantity of wastewater flowing down words, through a stack is more than 1/4, the function of stack will be disordered due to air disturbances. This will affect water seals of sanitary fittings and also stagnation of wastewater within stack foot. (Fig. 6.2)

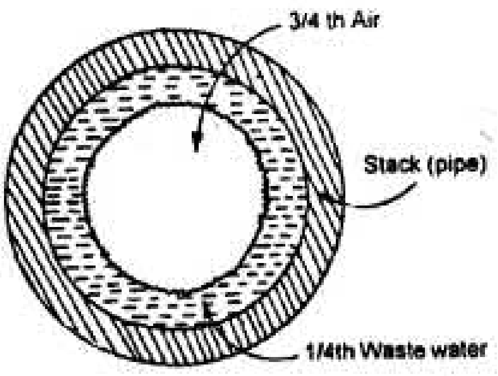


Fig. 6.2 Flow of Wastewater through stack

Due to this, there is a limit for carrying capacity of each stack. To reduce air disturbances, stack loading should only be 1/4 full of stack.

The diameter of stack is fixed by discharge unit method. Each sanitary appliance is given a discharge unit value, which represents, the discharge capacity and frequency.

Table 6-A. Fixture Unit Rating

Fixtures	*Discharge Pipe Ø in mm*	*Fixture unit rate*	*Max: length of un vented pipe*
Wash basin	DN: 40	1	2.5 m
Water closet	DN: 100	7	6.0 m
Sink	DN: 40/50	1-3	2.5 m
Bath. (Spray)	DN: 40	4	2.5 m
Shower	DN: 40/50	2	2.5 m
Floor waste gully	DN: 50/100	3	2.5 m
Sink laboratory	DN: 50	1	2.5 m
Trough:			
(*a*) Ablution	DN: 40/50	3	2.5 m
(*b*) Laundry	DN: 40/50	5	2.5 m
Urinal:			
(*a*) Wall hangs	DN: 50/65	1	2.5 m
(*b*) Stall/trough	DN: 65/80	1	6 m
Bathroom group in Single room (Washbasin, bath, shower, and water closet)	—	7	

Table 6-B. Maximum No: of discharge units allowed in stack (*Three or less floors*)

Diameter of pipe (stack) in mm	*Max: discharge units allowed/Floor*	*Max: discharge units allowed per stack*
DN 40	2	6
DN 50	5	15
DN 65	6	18
DN 80	13	40
DN 100	65	195
DN 125	150	450
DN 150	250	750
DN 200	950	3850

Table 6-C. Maximum No: of discharge units allowed in stack (*Four or more floors*)

Diameter of Stack in mm	*Max. Discharge units allowed per floor*	*Max. Discharge units allowed per stack*
DN 40	4	16
DN 50	9	36
DN 65	14	56
DN 80	20	80
DN 100	125	500
DN 125	250	1000
DN 150	600	2400
DN 200	1750	7000

Single stack system:

This is the most economical stack system, which eliminates a separate ventilating stack. This system can well be used in flats and dwelling houses, up to 5 floors .In this the sanitary appliances are grouped close to the stack and as for as possible each sanitary appliances is independently connected to the stack.

The bend of the foot of the stack shall be 200 mm radius or more. Horizontal connection of appliances is prohibited from the foot of stack for distance of '1 m' height and '2 m' horizontal, to avoid clogging of foot of stack.

The stack diameter shall not be in any circumstances less than the diameter of the branch drainpipes. The minimum diameter of W.C. connection to a stack is 100 mm. Hence a minimum of 100 mm shall be provided for stack, if there is a W.C connection.

A minimum of 200 mm vertical distance shall be left from any W .C connection to the stack, for any small branch connection, to avoid flooding of small branch drain.

As stacks are also act as ventilating pipe, the top outlet shall be covered with a durable wire mesh or cage, which does not restrict sufficient airflow.

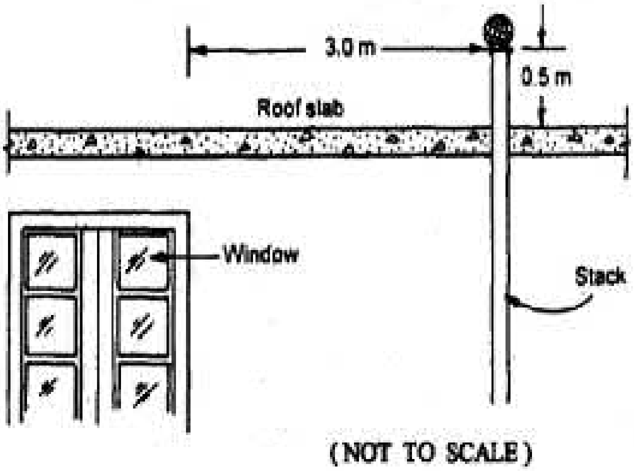


Fig. 6.3

A minimum height of 50 cm above the roof shall be given for stack top outlet to avoid smelling nuisance. Stack outlet shall also be a minimum of 3m horizontal distance away form any type of house ventilation, such as doors, windows etc. (Fig. 6.3)

Branch drain or fixture discharge pipe

Branch drains of ground floor fixtures shall be connected preferably to external manhole. For other floors, branch drain shall be connected to the stack. The size of drain shall be computed by the number of fixture units discharging in it. The minimum diameter of fixture discharge pipe is to be 40mm.

The minimum slope is to be provided for different diameter of fixture discharge pipes are given in Table 6-D.

Sufficient length of water seal trap shall be provided for each discharge pipe, to avoid bad smelling nuisance.

Table 6-D1 shows the maximum number of fixture unit loading for sloped discharge pipes from sanitary appliances.

Table 6-D.

Diameter of Discharge pipe in mm	*Minimum Grade %*	*No of fixture units that can be connected*
DN: 40	2.5 (1/40)	4
DN: 50	2.5 (1/40)	8
DN: 65	2.5 (1/40)	21
DN: 80	1.65 (1/60.6)	16
DN: 100	1.65 (1/60.6)	115
DN: 125	1.25 (1/80	254
DN: 150	1.00 (1/100)	509

Table 6-D1 Maximum fixture units loading for sloped discharge pipes from sanitary fixtures.

Dia of discharge pipe	*Slope*						
	5%	3.35%	2.5%	2	1.65%	1.25%	1%
DN 150	1959	1445	1148	953	813	627	509
DN 125	953	686	509	410	342	254	—
DN 100	376	248	182	142	115	—	—
DN 80	65	39	27	20	16	—	—
DN 65	51	27	21	—	—	—	—
DN 50	15	10	08	—	—	—	—
DN 40	06	05	04	—	—	—	—

Horizontal drain

This is the drainpipe connecting building to external manholes and manhole-to-manhole The diameter of horizontal drain depends on discharge of wastewater from different sanitary appliances, during peak demand period.

The factors, which are to be considered while designing horizontal drains, are

- No: and type of sanitary appliances.
- Possible peak frequency use of sanitary appliances
- The average duration of discharge of appliances
- The volume of wastewater discharging from the appliances.

A. Design of Horizontal drains by discharge unit method.

When the number and type of sanitary appliances are known, the diameter and gradient of horizontal drain can be found by discharge unit method. (Discharge unit values of sanitary appliances are already given in table 6-A).

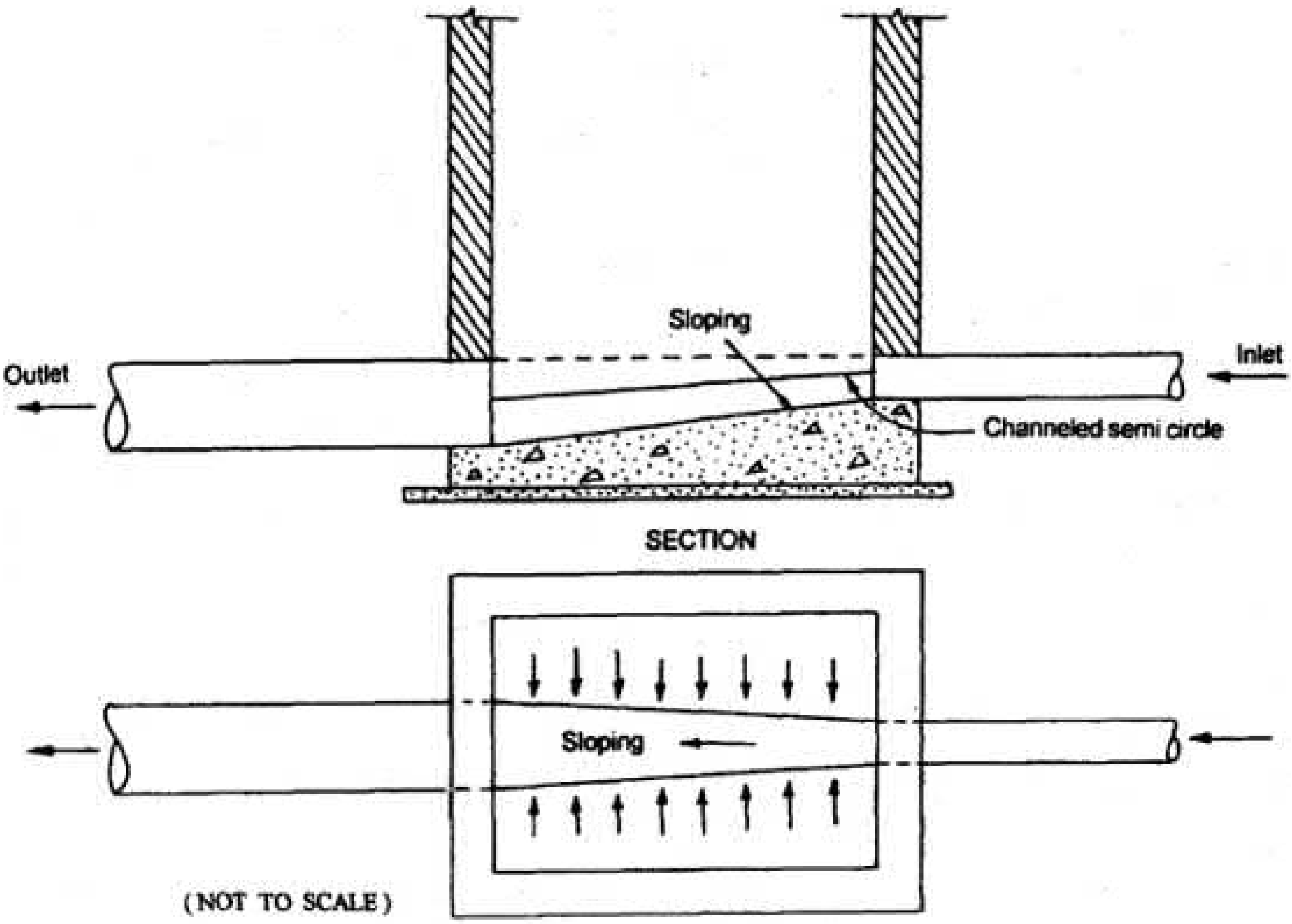
Maximum fixture units allowed in horizontal drain (for full flow) are given in Table 6-E

Table 6-E

Grade %	DN 80	DN 100	DN 125	DN 150	DN 200	DN 300
5%	215	515	1450	2920	11900	26900
3.35%	140	345	1040	2200	9490	21800
2.5%	100	255	815	1790	8060	18700
2%	76	205	665	1510	7090	16600
1.65%	61	165	560	1310	6370	15000

Grade %	DN 80	DN 100	DN 125	DN 150	DN 200	DN 300
1.45%	50	140	485	1160	5810	13900
1.25%	—	120	425	1040	5360	12900
1.10%	—	—	380	935	4970	12100
1%	—	—	—	855	4500	11400
0.85%	—	—	—	—	3850	10300
0.65%	—	—	—	—	3250	9090
0.5%	—	—	—	—	—	7720
0.4%	—	—	—	—	—	6780

Horizontal drains are connected soffit to soffit in manhole when there is a change is diameter. A slope of 1 in 40 is to be provided in the manhole channel, along direction of flow. Manhole is to be benched, up to half diameter of the drain. (Fig 6.4)



Fiq. 6-4. Section of Manhole (Soffit to Soffit connection)

Example: 1. *Find the diameter of vertical stack in a 10-story building with the following number of sanitary appliances?*

Water closet = 40 Nos., Wash basin = 60 Nos., Sink = 40 Nos., and Urinal = 20 Nos.

Ans. Fixture discharge unit loading (table 6-A)

W.C	= 40 × 7	= 280
W.B	= 60 × 1	= 60
Sink	= 40 × 3	= 120
Urinal	= 20 × 1	= 20
Total		= 480

From table 6-C, it is seen that 100mm is sufficient. (For 100 mm diameter stack, maximum discharge units loading is 500)

Example 2. *A five story building having 10 water closets, 10 washbasins, 5 sinks, and 5 showers, in each floor. Calculate the diameter of the horizontal drain (sewer)?*

Ans. Fixture discharge unit loading (table 6-A)

WC	= 5 × 10 × 7	= 350
W.B	= 5 × 10 × 1	= 50
Sink	= 5 × 5 × 3	= 75
Shower	= 5 × 5 × 2	= 50
Total Loading units		= 525

Since foul drain pipe (sewer) is to run half full, total loading unit = 2 × 525 = 1050

From the table 6-E

150 mm horizontal sewer with a slope of 1.25% (1/80) is sufficient, (since sewer is flowing 1/2 full)

B. Design of Horizontal drains using Manning's formula

Note: **1.** Manning formula is generally used for fixing the diameter and slope of horizontal drains (sewers).

$$V = \frac{0.003968\, D^{2/3} \cdot S^{1/2}}{N}$$

where,

N = 0.013

D = diameter in mm

S = slope.

2. Foul sewer (drain) is designed for flowing half full or 3/4 full. (Usually 1/2 full)

3.Usually the minimum self-cleansing velocity of a foul sewer (drain) is taken as 0.60 m/sec.

4.With the use of Manning's formula, and fixing V = 0.60 m/sec, minimum slope required for different diameter of sewer can be found out.

Example 3. *Find the minimum slope required for 150 mm and 250 mm diameter foul sewers, running 1/2 full ,to have the self cleansing velocity of 0.75 m/sec?*

Ans.

Circular sewer, when running full or running 1/2 full, the velocity of flow is the same.

Diameter = 150 mm, Self-cleansing velocity = 0.75 m/sec.

As per Manning's formula

$$V = \frac{0.003968\, D^{2/3} \cdot S^{1/2}}{N}$$

V = 0.75 m/sec

N = 0.013

D = 150 mm

$$0.75 = \frac{0.003968 \times 150^{2/3} \times S^{1/2}}{0.013}$$

$$= 8.588\, S^{1/2}$$

$$S^{1/2} = \frac{0.75}{8.588} = 0.0873$$

$$S = (0.0873)^2 = 0.00762 = \frac{762}{100000}$$

Slope $= \frac{1}{131}$

or 0.76%

A slope of 1/131 is to be provided for 150 mm diameter sewer to get a self-cleansing velocity of 0.75m/sec.

When diameter = 250 mm

$$V = \frac{0.003968 \times 250^{0.666} \times S^{1/2}}{0.013}$$

$$0.75 = 12.068\, S^{1/2}$$

$$S^{1/2} = \frac{0.75}{12.068} = 0.062$$

$$S = (0.062)^1 = 0.00384$$

$$= \frac{384}{100000} = 0.38\%$$

$$= \frac{1}{260}$$

A slope of 1/260 is to be provided for 250 mm diameter sewer to get a self-cleansing velocity of 0.75m/sec.

SEPTIC TANK, SOAK AWAY *PITS Etc.*

SEPTIC TANK

Disposing domestic sewage of a small community is by the use of septic tank. In septic tank most of the suspended particles and harmful organisms are removed. Anaerobic bacterial action is taken place in septic tank. The effluent coming out from septic tank is not free from suspended solids and harmful organisms .The effluent is allowed to percolate through soil for final purification. This is done through soak away pit or dispersion trench.

The recommended distance of soak away pit from any drinking water source shall be more than 20m. The ground water table shall also be a minimum of lm below the bottom of soak away pit to prevent direct contamination of ground water. The detention time adopted in septic tank is in between 1 day to 2.5 days. De-sludging of septic tank is usually once in a year.

Septic tank can be constructed either in R.C.C or in brick. Single chamber septic tank is usually used, if the length of tank is less than 4 m. If the length is more than 4m, double chamber is used. The Ist chamber (inlet chamber) is 2/3 length, and the II chamber is 1/3 length. The depth usually provided for septic tank is not more than 1.5 m to 2 m .In the inlet chamber a baffle wall is provided at a distance a 1/5 length to prevent entry of foam to the sedimentation zone (Fig. 7.1). A free board of 30 cm is provided. The flow is to be slopped (1/40) towards the manhole opening, so as to facilitate de-sludging. An air vent of 50 mm diameter pipe is to be provided for escape of gases, and it height shall be 2.5 m to 3 m to avoid smell nuisances. If the septic tank is deep below ground level, brickwork is to be made to take the entrance of manhole to the top of ground level (Fig. 7.2). A minimum of one manhole entrance shall be provided in any septic tank, and it shall be closed with iron manhole cover, or RCC slab. The out let of septic tank shall be 5 to 7 cm below inlet to a void flooding of inlet.

Various equations are used to find out the capacity of septic tank. The following gives two methods of designing septic tank.

- Rate of water supply method
- Fixture discharge method

Rate of Water Supply method

Total Capacity of septic tank =Volume of Sediment + Volume of sludge

Volume of Sediment $= \dfrac{t \times p \times q}{1000}$ m^3 and

Volume of Sediment $= \dfrac{s \times d \times p}{1000}$ m^3

(Total capacity of septic tank $= \dfrac{(t \times p \times q)}{1000} + \dfrac{(s \times d \times p)}{1000}$ m^3

where,

t = Hydraulic detention time, taken between one day and 2 days (Preferably 1.5 days)

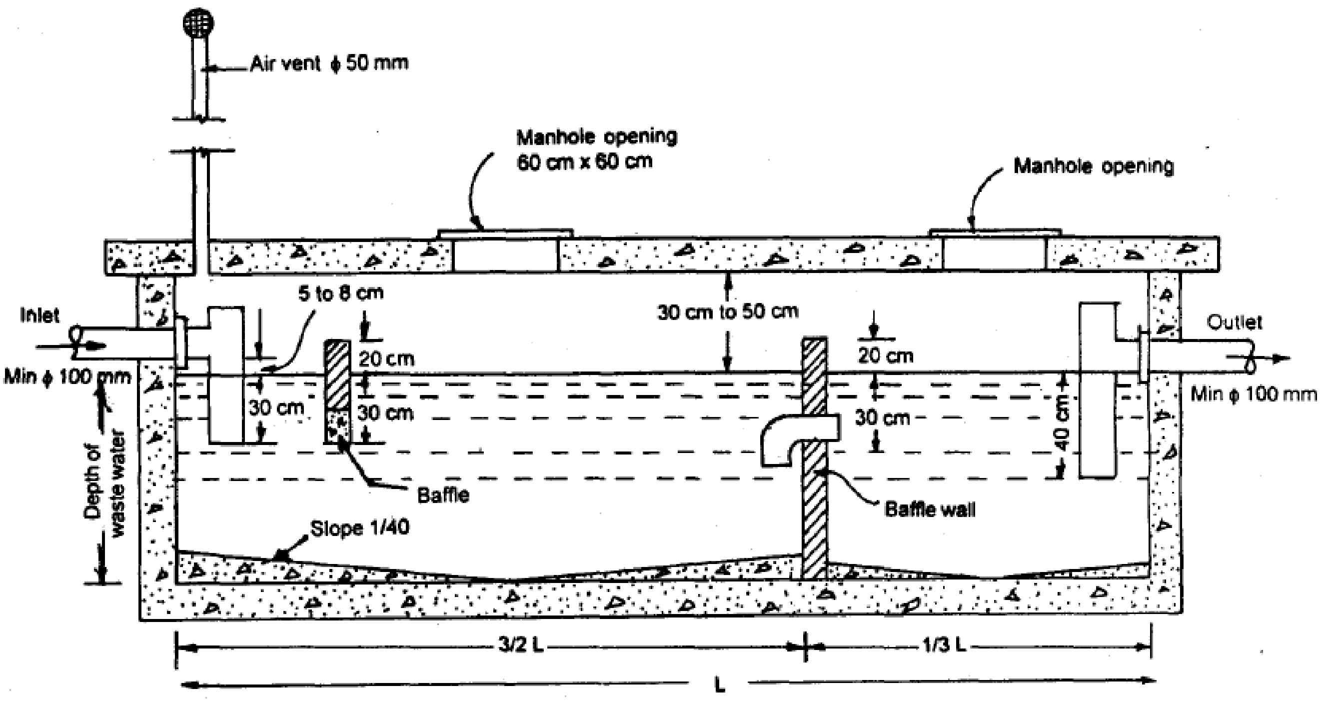
p = Population served

q = Water consumption in liter/capita/day

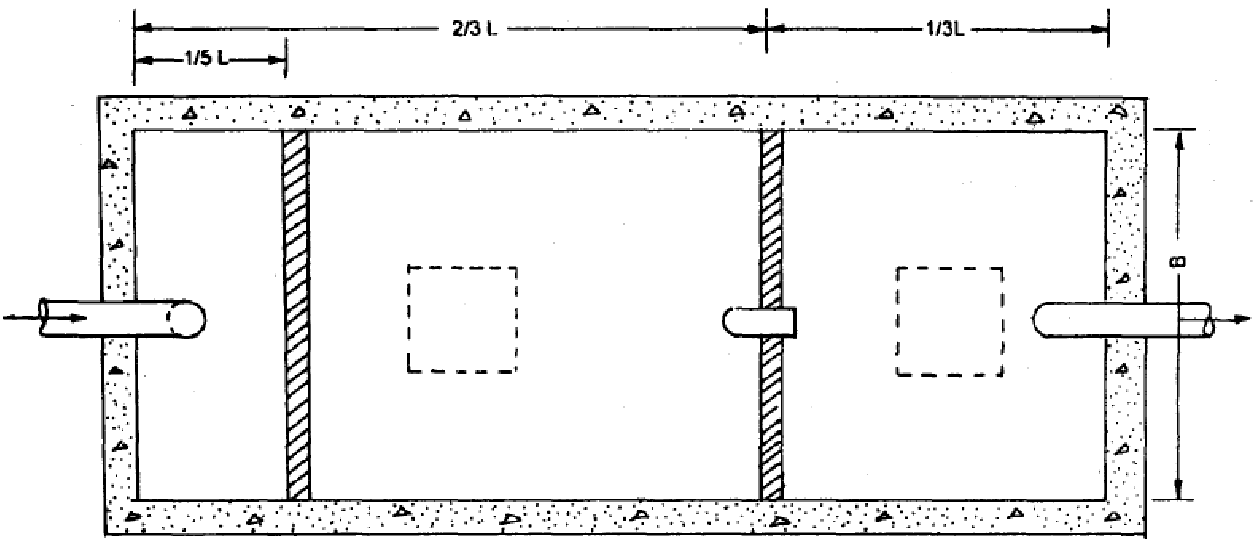
s = sludge production in liter/capita/ day

= 0.15 liter/capita/day

d = No of days between de-sludging (Minimum one year)



SECTIONAL ELEVATION



(NOT TO SCALE)

PLAN

Fig. 7.1. Septic Tank

Length breadth ratio = 2 : 1

Fixture discharge method

For good performance of a septic tank two important factors are to be considered

1. Surface loading
2. Detention time

Surface loading adopted is 0.92 m^2 per 10 lpm (As in Manual). A minimum depth of 25 cm to 30 cm is to be provided for sedimentation. Detention time adopted is 24 hours to 48 hours. De-sludging of septic tank is once in a year.

Total volume required:

For sedimentation = Surface area × 0.3m in m^3

For digestion = No. Of people × 0.032 in m^3

For sludge storage = 0.0002 × 365 days × No. of people in m^3

For free board = surface area × 0.3m in m^3

Peak flow of domestic sewage is to be assumed for calculating the surface area. Peak flow is found out from the discharge of sanitary fixtures.

Table 7-A. Approximate rate of discharge from sanitary fixtures

Wash basin	= 0.6 lit/sec
Bath tub	= 1.00 lit/sec
Sink (32mm diameter)	= 0.5 lit/sec
Sink (38mm diameter)	= 1.00 lit/sec
Urinal	= 0.15 lit/sec
Shower	= 0.15 lit/sec
Water closet (9 lit to14 lit)	= 2.3 lit /sec

Peak discharge from sanitary Fixture at a time can be calculated either by

(a) Using fixture units or by

(b) Using simultaneous discharge factor of *5%*

***Example 1**. Calculate the dimensions of a septic tank to serve 150 people?. Water is supplied at the rate of 100-liter/capita/day. De-sludging is expected once in an year. (As per rate of water supply method and fixture discharge method)*

Ans. Rate of water supply method:

$$\text{Volume of sediment} = \frac{t \times p \times q}{1000}\ m^3$$

where,

t = 1.5 days

p = population, 150

q = rate of water supply 100 lpcd

$$\text{Volume of sediment} = \frac{1.5 \times 150 \times 100}{1000}$$

$$= 22.5\ m^3$$

$$\text{Volume of sludge} = \frac{s \times d \times p}{1000}\ m^3$$

where,

s = Sludge production 0.15 lit./capita/day

d = De-sledging period in days, 365 days
p = Population, 150

Volume of sludge $= \dfrac{0.15 \times 365 \times 150}{1000}\ m^3 = 8.2\ m^3$

Total volume of septic tank = $22.5 + 8.2 = 30.7\ m^3$

Adopting a depth of 1.15 m (effective)

Surface area $= \dfrac{30.7}{1.15} = 26.69\ m^2$

Length breadth ratio of septic tank = 2:1

$$2B + B = 26.9\ m^2$$
$$2B^2 = 26.9\ m^2$$
$$B^2 = \frac{26.9}{2} = 13.34\ m^2$$
$$B = 3.65\ m \text{ say } 3.75\ m$$

Length $= 2B = 2 \times 3.75 = 7.5\ m$

Size of septic tank $= 7.5\ m \times 3.75\ m \times 1.40\ m$

Effective depth = 1.15 m
Free board = 0.25 m
(Total in side depth = 1.40 m)

Since length is more than 4 m, septic tank is to be divided into two compartments

Inlet compartment length $= \dfrac{2}{3}$ Length

$= \dfrac{2}{3} \times 7.5 = 5\ m$

IInd compartment length $= 7.5 - 5 = 2.5\ m$

Distance to Baffle wall $= \dfrac{1}{5}L = \dfrac{1}{5} \times 7.5 = 1.5\ m$

2. Fixture discharge method:

(*a*) Peak discharge as per fixture units

Assuming 5 people in a house

No: of houses = 150/5 = 30 Nos: Also assuming the following sanitary fixtures in each house.

Water closet	= 1 No.	= 7 fixture units (table 6-A)
Washbasin	= 1 No.	= 1 fixture unit
Kitchen sink	= 1 No.	= 1 fixture unit
Shower	= 1 No.	= 2 fixture unit
Total		**= 11 fixture units**
For 30 houses	= 30 × 11	= 330 fixture units

From fixture unit discharge table (Appendix-B)

Discharge for 330 fixture units = 5.4 lit/sec = 5.54 × 60 = 324 lit/minute

(*b*) Peak discharge as per simultaneous discharge factor

Assuming 5 people in a house

No of houses = 150/5 = 30

Also assuming the following sanitary fixtures in each house

Water closet	= 1
Wash basin	= 1
Kitchen sink	= 1
Shower	= 1

Discharge from each house, (From table 7-A)

Water closet	...	1 No.	= 2.30 lit/sec
Wash basin	...	1 No.	= 0.60 lit/sec
Kitchen sink	...	1 No.	= 0.50 lit/sec
Shower	...	1 No.	= 0.15 lit/sec
Total discharge			= 3.55 lit/sec

Discharge from one house = 3.55 lit/sec

Discharge from 30 houses = 30 × 3.55 = 106.5 lit/sec

Assuming a simultaneous discharge value of 5%

Total simultaneous peak discharge from 30 house = 106.5 × 5/100
= 5.33 lit/sec
= 5.33 × 60 lpm (lpm = lit/minute)
= 319.8 lpm. (Say 320 lpm)

Note: In both ways discharge from 30 houses comes approximately same. Here discharge from 3 houses is taken as 320 lpm

Surface loading of septic tank = 0.92 m^2 per 10 lpm

$$\text{Surface area required} = \frac{320 \times 0.92}{10} = 29.44\ m^2$$

Volume of septic tank;

For sedimentation = Surface area × 0.3 m in m^3
= 29.44 × 0.3 = 8.83 m^2

For digestion = No. of people × 0.032 = 152 × 0.032
= 4.8 m^3

For sludge storage= 0.0002 × 365 × No. People

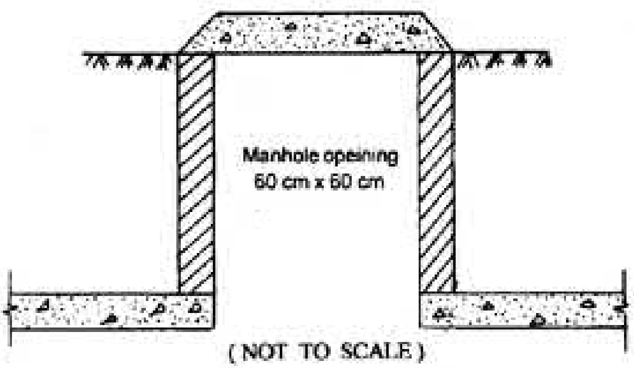


Fig. 7.2. Raised manhole opening of septic tank

$$= 0.0002 \times 365 \times 150$$

$$= 0.95 \text{ m}^3$$

For free board $= \text{Surface area} \times 0.3 \text{ m in m}^3$

$$= 29.44 \times 0.3$$

$$= 8.83 \text{ m}^3$$

Total volume of septic tank $= 8.83 + 4.8 + 10.95 + 8.83$

$$= 33.41 \text{ m}^3$$

Depth of septic tank $= \dfrac{\text{Volume}}{\text{Surface area}}$

$$= \frac{33.41}{29.44} = 1.13 \text{ m}$$

Adopt a depth of 1.20 m.

Length breadth ratio of septic tank = 2:1

$$2B \times B = 29.44$$

$$B^2 = \frac{29.44}{2} = 14.72 \text{ m}^2$$

$$B = 3.83 \text{ m. Say } 4 \text{ m}$$

Size of septic tank

Length $L = 2B = 2 \times 4 = 8$ m

Breadth $= B = 4$ m

Depth $= 1.2$ m

i.e. 8 m × 4 m × 1.2 m (free board 0.3 m) (Fig 7.3)

Since length is more than 4m, septic tank is to be divided into two compartments

Inlet compartment $= \dfrac{2L}{3} = \dfrac{8 \times 2}{3} = 5.30$ m

IInd compartment $= 8 - 5.30 = 2.7$ m

Distance of Baffle wall from

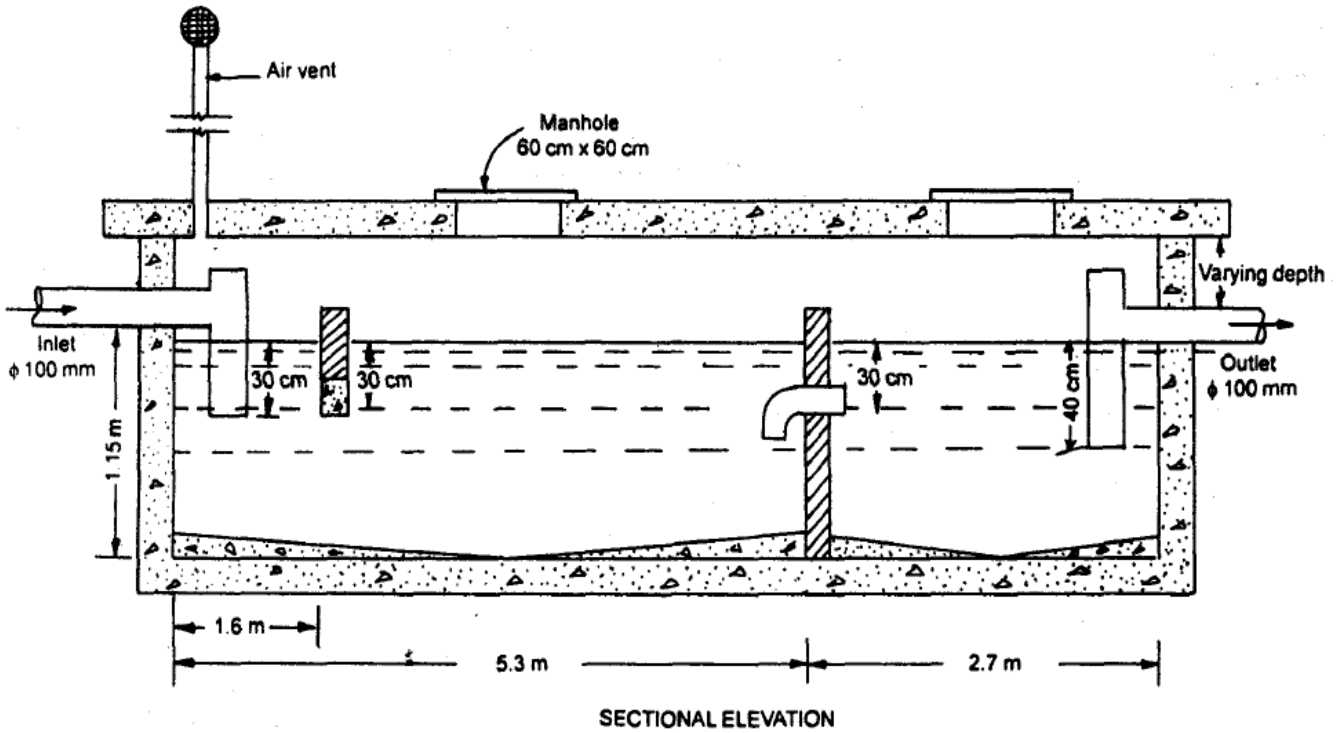
In let $= \dfrac{1 \times L}{5} = \dfrac{1 \times 8}{5} = 1.60$ m

Note: Dimensions of septic tank required for different number of users are given in table 7-B.

Table 7-B. Dimensions of Septic Tank Required for Different Number of Users

No. of people	*Simultaneous Peak discharge (l/sec)*	*Surface Area (m^2)*	*Volume of Septic Tank (m^3)*	*Length (m)*	Breadth (m)	*Depth (m)*	Remarks
5	10.65	0.98	1.113	1.5	0.75	1.2	For more than 150 users, more than one septic tank is advisable
10	21.3	1.96	2.226	2.0	1.0	1.2	
15	31.95	2.94	3.339	2.5	1.25	1.2	
20	42.6	3.92	4.452	3.0	1.50	1.2	
30	63.9	5.88	6.678	3.5	1.75	1.2	
40	85.2	7.84	8.904	4.0	2.0	1.2	
50	106.5	9.8	11.13	4.5	2.25	1.2	
60	127.8	11.76	13.36	5.0	2.50	1.2	

No. of people	Simultaneous Peak discharge (l/sec)	Surface Area (m^2)	Volume of Septic Tank (m^3)	Length (m)	Breadth (m)	Depth (m)	Remarks
70	149.1	13.72	15.582	5.5	2.50	1.2	
80	170.4	15.68	17.808	5.6	2.80	1.2	
90	191.7	17.64	20.034	6.0	3.0	1.2	
100	213.0	19.60	22.26	6.5	3.0	1.2	
150	319.8	29.44	33.41	8.0	3.75	1.2	
200	426.0	39.2	44.52	9.0	4.25	1.2	



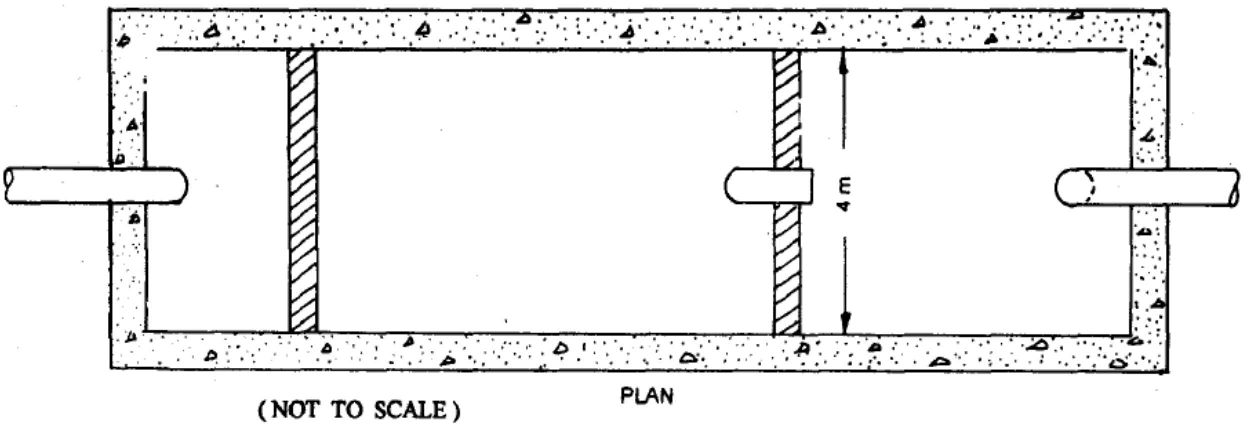


Fig. 7.3. Septic tank