Atal Mission for Rejuvenation and Urban Transformation

Ministry of Housing and Urban Affairs
Government of India

ADVISORY ON PIPE MATERIALS FOR TRANSMISSION OF WATER

Central Public Health and Environmental Engineering Organisation (CPHEEO)

Ministry of Housing and Urban Affairs
Government of India

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Amended
(July 2022)

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स्वच्छ भारत
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FOREWORD

Ministry of Housing and Urban Affairs has constituted an Expert Committee under the chairmanship of Adviser (PHEE), CPHEEO to prepare various advisories on latest technologies and best practices in water supply and waste water sector to facilitate implementation of Jal Jeevan Mission.

The Government of India has assigned top priority for providing piped water supply with an objective to provide "Nal Se Jal" to 100% households in the country. As per 2011 Census, 71% of urban households had access to piped water supply in urban areas. As per NITI Aayog's Composite Water Management Index (CMWI) – 2019, 93% of India's urban population has access to 'basic water supply'. Efforts towards universal coverage are underway under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) in 500 cities of India. The Mission was launched in 2015 by Ministry of Housing and Urban Affairs and has universal coverage of water supply as one of its three focus areas. 78 lakhs new tap connections have been provided under the Mission so far as against the assessed gap of 139 lakh connections.

As established, pipes constitute nearly 60% of the cost of any drinking water related project and thus has a critical role in delivering good quality water at consumer end. As such, they shall have to be judiciously selected from the point of view of durability, life, cost, health aspects etc. including installation and maintenance costs that are necessary to ensure the required function and performance of the piped water distribution system throughout its designed life period.

I believe that this Advisory will guide and empower the concerned stakeholders to select the appropriate pipe materials in the planning, design and implementation of water supply and sewerage projects. The Advisory will also serve the objective of 'Make in India' initiative.

I congratulate all the concerned officers of the Ministry, Chairman & all the Members of the Expert Committee, officers of CPHEEO, who have been involved in the preparation of this Advisory on pipe materials for transmission of water.

(Durga Shanker Mishra)

New Delhi
02nd June, 2020

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आवासन और शहरी कार्य मंत्रालय

GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS

अमृत
Atal Mission for Rejuvenation and Urban Transformation

Dated the 9th June, 2020

PREFACE

As per the service level benchmark data collected in 2018 across 900 cities from 6 States in India, the coverage of piped water supply was 70%, the average duration of water supply was 2.7 hours, the non-revenue water was 31% and the quality of water supply was 95% to the desired standards. It is evident from the data that there are ample problems in supplying water through the water distribution pipelinesleading to inequitable supply, high level of non-revenuewater and problems related to quality of water due to intermittent water supply.

The principal component of any water distribution network is pipes and its appurtenances, of various sizes and materials that carries water to the required point of usage. The basic requirements of good water distribution system are (i) waterquality should not get deteriorated in the pipes (ii) capable of supplying water at all the intended places with sufficient quantity & pressure (iii) fairly water-tight as to keep losses due to leakage to the minimum and (iv) distribution grid. These arrangement should be made in such a way that no consumer is left without water supply, during the maintenance of any section of the system.

The formulation, design and implementation of water supply projects is being done by the States/UTs and almost all the States/UTs have certain policy/guidelines for the selection of pipe material for water supply projects. Though the subject of pipes is robust and comprehensive and the selection is based on various criteria including techno-economic considerations, it is enjoined upon all the States/UTs to consider this advisory on pipe materials for transmission of water during the contemplation and formulation of drinking water supply projects. While planning and design of water supply and distribution system by the Water Supply Utilities/ULBs, they must ensure that the service level benchmarks notified by this Ministry in 2008 is achieved after implementation of water supply system.

I take this opportunity to congratulate the Chairman and the Members of Expert Committee for bringing out this Advisory on Pipe Materials for Transmission of Water.

(D.Thara)

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New Delhi-110011, dated the 20

EXECUTIVE SUMMARY

In Indian cities and towns, water distribution systems are historically planned and designed by the Urban Water Utilities with a focus to provide continuous water supply, but after implementation, the system is shifted to intermittent mode. This has led to poor services to customers across the country. Though the present systems operate on intermittent mode, the goal should be to ultimately achieve the world-class standard of continuous water supply with tap connections to all households with a smooth transit so as to ensure equity, quality and sustainability in water distribution which will result into customer satisfaction and also revenue generation for the Utilities/ULBs.

Therefore, the distribution network need to be planned and designed efficiently so as to achieve continuous water supply with a focus to improve service level as pipelines involve major investments in water supply projects and constitute a major portion of the assets of water utilities/ authorities. At present, large number of pipe materials for transmission of water are available in the market. The life and durability of the pipe depend on several factors like inherent strength of the pipe material, the manufacturing process with quality control, handling, transportation, laying & jointing of the pipeline etc.

The chapter on "Transmission of Water" provided in the Manual on Water Supply and Treatment, 1999, published by this Ministry has been updated with relevant information. The current advisory is the compilation of latest information on pipe materials, methods of laying & jointing, methods of testing, advantages, disadvantages etc. including recent developments and trends in the industry so as to assist the concerned stakeholders in selection of pipe material for water supply projects. The design criteria related to hydraulic design of distribution system are also provided in the advisory.

I hope that the Advisory on Pipe Materials for Transmission of Water will encourage and empower the engineers working in State Public Health Engineering Departments (PHEDs)/ Parastatals/ Boards/ Urban Local Bodies (ULBs)/ Rural Water Supply Departments etc. to suitably use and appropriately select pipe materials for water supply systems.

I would like to convey my gratitude to Shri Shubhanshu Dixit, Superintending Engineer (Tech.), PHED, Jaipur, Govt. of Rajasthan & Member of the Expert Committee for providing technical support in preparation of the advisory. I would also like to extend my sincere thanks to the other Members of the Expert Committee and the Officers of CPHEEO for reviewing the Advisory and supporting staff for their effective coordination in completing the task. I would also like to extend my appreciation to Dr. Ramakant, Deputy Adviser(PHE) for his untiring efforts in completing the Advisory.

(Dr. M. Dhinadhayalan)
Chairman of the Expert Committee

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1.0 Introduction

Water supply system broadly involves transmission of water from the sources to the area of consumption and finally at the consumer end, through free flow channels or conduits or pressure mains. Depending on topography and local conditions, conveyance may be designed for free flow (gravity flow) channel or conduit or pressure conduits. Transmission of water accounts for an appreciable part of the capital outlay and hence careful consideration of the economics is called for, before deciding on the best mode of conveyance. While water is being conveyed, it is necessary to ensure that there is no possibility of pollution from surrounding areas.

1.1 Free Flow and Pressure Conduits

1.1.1 Open Channels

Economical sections for open channels are generally trapezoidal while rectangular sections prove economical when rock cutting is involved. Uniform flow occurs in channels where the dimensions of the cross-section, the slope and the nature of the surface are the same throughout the length of the channel and when the slope is just equal to that required to overcome the friction and other losses at the velocity at which the water is flowing.

Nowadays open channels are not used in water works practice in view of the losses due to percolation and evaporation as also the possibility of pollution and misuse of water. Also they need to be taken along the gradient and therefore the initial cost and maintenance cost may be high. While open channels and canals are not recommended to be adopted for conveyance of treated water, they may be adopted for conveying raw water. Sometimes diversion channels meant for carrying floodwaters from other catchments are also used to augment the yield from the reservoirs.

1.1.2 Gravity Aqueducts and Tunnels

Aqueducts and tunnels are designed such that they flow three quarter full at required capacity of supply in most circumstances. For structural and not hydraulic reasons, gravity tunnels are generally horseshoe shaped. Gravity flow tunnels are built to shortest possible route, conserve the head and to reduce the cost of aqueducts, traversing uneven terrain. They are usually lined to conserve head and reduce seepage but they may be left unlined when they are constructed by blasting through stable rock. Mean velocities, which will not erode channels after ageing, range from 0.30 to 0.60 metres per seconds (mps) for unlined channels and 1 to 2 mps for lined channels 1 to 2 mps for lined channels.

1.1.3 Pressure Aqueducts and Tunnels

They are ordinarily circular in section. In the case of pressure tunnels, the weight of overburden is relied upon to resist internal pressure. When there is not enough counter-balance to the internal pressure, steel cylinders or other reinforcing structure, for example, provide necessary structural strength.

1.1.4 Pipelines

Pipelines normally follow the profile of the ground surface quite closely. Gravity pipelines have to be laid below the hydraulic gradient. Pipes are of cast iron, ductile iron, mild steel, pre-stressed concrete (PSC), reinforced cement concrete (RCC), GRP, asbestos cement, plastic like PVC, HDPC etc.

1.2 Hydraulics of Conduits

The design of supply conduits is dependent on resistance to flow, available pressure or head, allowable velocities of flow, scour, sediment transport (if required), quality of water and relative cost.

1.2.1 Pipe Head Loss Formulae

Part of energy is utilized to overcome friction. Since this energy is represented in terms of head of water and it is utilized, it is termed as head loss. Using the energy principle, Darcy-Weisbech derived a formula to calculate head loss. This formula requires trial and error or iterative methodology when used in analysis and design of water distribution networks. To avoid difficulty in using Darcy-Weisbech's formula, several empirical formulae were developed. However, Hazen-Williams formula for pressure conduits and Manning's formula for free flow conduits have been popularly used.

(a) Darcy-Weisbach's Formula

Darcy-Weisbach suggested the first dimensionless equation for hydraulic slope (S) as,

$$S = \frac{H}{L} = \frac{f\,V^2}{2\,g\,D} \qquad (1.1)$$

Where,

H = head loss due to friction over length L in metres
f = dimensionless friction factor
g = acceleration due to gravity, m/s^2
V = velocity, m/s
L = length, metres
D = diameter, metres

(b) Colebrook-White Formula

The Colebrook - White formula can be used for calculation of frictional coefficient

$$\frac{1}{\sqrt{f}} = -2\,\log_{10}\left[\left(\frac{\mathrm{k}}{3.7\mathrm{d}}\right) + \frac{2.51}{R_e\sqrt{f}}\right] \qquad (1.2)$$

Where

f = Darcy's friction coefficient;

R_e = Reynold's Number = Velocity x Diameter/Dynamic Viscosity;

d = Diameter of pipe;

k = Average height of Roughness projections;

Recommended values for average height of roughness projection (k) for pipe materials are shown below in Table 1.1.

Table 1.1: Recommended Values of Roughness Projection (k)

S. No	Pipe Material	Value of 'k' mm	
		New	Design
1	Metallic Pipes – Cast Iron, Galvanized & Ductile Iron (unlined)	0.15	*
2	Metallic Pipes – Mild Steel	0.06	*
3	Asbestos Cement Cement Concrete Cement Mortar or Epoxy lined Steel, BWSC, PSC, Cast Iron (CI), Ductile Iron (DI)	0.035	0.035
4	PVC, GRP HDPE/MDPE and other plastic pipes	0.003	0.003

* Reference may be made to IS: 2951 (Part I) – 1965, Reaffirmed 2017 for roughness values of aged metallic pipes.

(c) Hazen-Williams Formula

The Hazen-Williams formula is expressed as:

$$V = 0.849.C.r^{0.63}.S^{0.54} \qquad (1.3)$$

For circular conduits, the expression becomes

$$V = 4.567\times10^{-3}.C.d^{0.63}.S^{0.54} \qquad (1.4)$$

and

$$Q = 1.292\times10^{-5}.C.d^{2.63}.S^{0.54} \qquad (1.5)$$

Where

Q = discharge, cubic metre per hour

D = diameter of pipe, mm

V = velocity, mps

r = hydraulic radius, m

S = slope of hydraulic grade line and

C = Hazen-Williams coefficient.

For circular conduits of diameter D, the expression for head loss in terms of discharge can be simplifies as

$$h = 10.68\left(\frac{Q}{C}\right)^{1.852}\left(\frac{L}{D^{4.87}}\right) \quad (1.6)$$

In which L & D are in meters and Q is in m^3/s.

A chart for the Hazen-Williams formula is given in **Appendix 1.1**

(d) Manning's Formula

The Manning's formula is:

$$V = \frac{1}{n} r^{2/3} S^{1/2} \quad (1.7)$$

For circular conduits,

$$V = \frac{3.968 \times 10^{-3} \times d^{2/3} \times S^{1/2}}{n} \quad (1.8)$$

and

$$Q = 8.661 \times 10^{-7} \times \frac{1}{n} d^{8/3} \times S^{1/2} \quad (1.9)$$

Where,

Q= discharge, cubic metre per hour
S = slope of hydraulic gradient
d = diameter of pipe, mm,
r = hydraulic radius, metres,
V = velocity, mps, and
n = Manning's coefficient of roughness

For circular conduit of diameter D, the head loss can be written as

$$h = 10.29\,(Q \times n)^2\left(\frac{L}{D^{16/3}}\right) \quad (1.10)$$

L= Length of the pipe
D= diameter of pipe

A chart for Manning's formula is given in **Appendix 1.2**.

1.2.2 Coefficient of Roughness for Different Pipe Materials

In today's economy driven infrastructure, it is essential that all water utilities ensure that their financial resources are invested efficiently and hence there is an urgent need to avoid over designing of the pipelines. Despite the technological advancements, improved methods of manufacturing of all types of pipes and advent of new pipe materials, the current practice of adopting conservative Coefficient of Roughness (C values) is resulting in underutilization of the pipe flow capacities.

The coefficient of roughness depends on Reynolds number (hence on velocity and diameter) and relative roughness (K/D). For Reynolds number greater than 10^7, the friction factor 'f' (and hence the C value) is relatively independent of diameter and velocity. However, for normal ranges of Reynolds number of 4000 to 10^6 the friction factor ‘f’’ (and hence the C value) do depend on Diameter, Velocity and relative roughness.

PVC, HDPE, Glass Reinforced Plastic (GRP) and other plastic pipes are inherently smoother compared to Asbestos Cement (AC), Concrete and cement mortar/ Epoxy lined metallic pipes. Depending on the quality of workmanship during manufacture and the manufacturing process, the AC, Concrete and cement mortar/ Epoxy lined metallic pipes can be as smooth as PVC, HDPE, GRP and other plastic pipes prior to incrustation.

The metallic pipes lined with cement mortar or epoxy and Concrete pipes behave as smooth pipes and have shown C values ranging from 140 to 150 depending on diameter and velocity. Reference may be made to "Manual of Water Supply Practices", AWWA/M9 published by American Water Works Association (AWWA), third edition 2008

With a view to reduce corrosion, increase smoothness, and prolong the life of pipe materials, the metallic pipes are being provided with durable smooth internal linings. AC, Concrete and cement mortar/epoxy lined metallic pipes, PVC, HDPE, GRP and other plastic pipes may not show any significant reduction in their carrying capacity with age and therefore the design roughness coefficient values (C values) should not be substantially different from those adopted for new pipes.

However, pipes carrying raw water are susceptible to deposition of silt and development of organic growth resulting in reduction of carrying capacity of such pipes. In case of build-up of substantial growth /build-up of deposits in such pipes, they can be removed by scraping and pigging the pipelines.

Unlined metallic pipes under several field conditions such as carrying waters having tendency for incrustation and corrosion, low flow velocity and stagnant water and alternate wet and dry conditions (resulting from intermittent operations), undergo substantial reduction in their carrying capacity with age. Therefore, lower `C’ values have been recommended for design of unlined metallic pipes. As such, use of unlined metallic pipes have been largely discontinued/discouraged.

1.2.3 Friction Factor in Darcy-Weisbech Formula

The friction factor values in practice for commonly used pipe materials are given in Table 1.2.

Table 1.2: Recommended Friction Factors in Darcy-Weisbach Formula

Sl. No	Pipe Material	Diameter (mm)		Friction Factor	
		From	To	New	For Design Period of 30 Years
1	R.C.C & PSC (Cylinder & Non-Cylinder Pipes)	100	2600	0.01 to 0.02	0.01 to 0.02
2	A.C.	80	600		
3	HDPE/MDPE	20	100		
4	PVC-U	20	630		
5	PVC-O	63	1200		
6	PVC-C	15	150		
7	C.I. (for corrosive waters)	100	1600	0.01 to 0.02	0.053 to 0.03
8	C.I. (for non- corrosive waters)	100	1600		0.034 to 0.07
9	Cement mortar or epoxy lined metallic pipes (Cast iron, Ductile iron, Steel)	100	2000		0.01 to 0.02
10	Steel	100	5000	0.01 to 0.02	0.01 to 0.02
11	G.I.	15	150	0.014 to 0.03	0.0315 to 0.06
12	Bar Wrapped Steel Cylinder Pipe	250	1900	0.01 to 0.02	0.01 to 0.02
13	GRP	200	3000	0.01 to 0.02	0.01 to 0.02

(Reference may be made to IS: 2951-1965, Reaffirmed 2017 for calculation of Head Loss due to friction according to Darcy-Weisbach formula).

1.2.4 Pipe Roughness Coefficient in Hazen-Williams Formula

The values of the Hazen-Williams coefficient 'C' for new conduit materials and the values to be adopted for design purposes are shown in Table 1.3.

Table 1.3: Hazen-Williams Coefficients

Pipe Material	**Recommended C Values**	
	@New Pipes	**Design Purpose**
Unlined Metallic Pipes (discouraged)		
Cast Iron, Ductile Iron	130	100
Mild Steel	140	100
#Galvanized Iron above 50 mm dia.	120	100
#Galvanized Iron 50 mm dia and below used for house service connections.	120	55
Centrifugally Lined Metallic Pipes		
Cast Iron, Ductile Iron, Mild Steel and Bar Wrapped Steel Cylinder Concrete Pressure Pipes lined with cement mortar or Epoxy		
Up to 1200 mm dia.	140	140
Above 1200 mm dia.	145	145

Pipe Material	Recommended C Values	
	@New Pipes	Design Purpose
Projection Method Cement Mortar Lined Metallic Pipes (discouraged)		
Cast Iron, Ductile Iron, Mild Steel Pipes	130*	110**
Non Metallic Pipes		
RCC Spun concrete, Pre-stressed Concrete Up to 1200mm dia.	140	140
RCC Spun concrete, Pre-stressed Concrete Above 1200mm dia.	145	145
Asbestos Cement	150	140
PVC, GRP and other plastic pipes like MDPE, HDPE, PVC-O, PVC	150	145

@The C values for new pipes included in the Table 1.3 are determining the acceptability of surface finish of new pipelines. The user agency may specify that flow test may be conducted for determining the C values of laid pipelines.

#The quality of galvanizing should be in accordance with the relevant standards to ensure resistance to corrosion throughout its design life

** Values are adopted for pipes of diameter 500 mm and above; the range of C values may be from 90 to 125 for pipes of diameter less than 500mm.*

***In the absence of specific data, this value is recommended. However, in case authentic field data is available, higher values up to 130 may be adopted.*

1.2.5 Experimental Estimation of C_R Values

The coefficients of roughness in various pipe formulae are based on experiments conducted over a century ago. The values of Hazen Williams C, Mannings n and roughness k values in Moody's Diagram have also been used on experimental data collected in early nineteenth century. There have since been major advances in pipeline technology. Both the manufacturing processes and jointing methods have improved substantially over the years and newer pipe materials have come into use. Continued usage of roughness coefficients estimated without recognition of these advances is bound to result in conservative design of water supply systems.

Accordingly, C_R values of commonly used commercial pipe materials have been experimentally determined in a study conducted within the country. This study covered pipe diameters 100 to 1500 mm over a wide range of Reynold's Numbers (3×10^4 to 1.62×10^6) encountered in practice. The results indicate that centrifugally spun CI, RCC, AC and HDPE pipes behave as hydraulically smooth when new and hence, C_R=1 for these pipes.

The use of Hazen Williams ‘C’ as per Table 1.3 results in underutilization of above pipe material when new. The extent of underutilization varies from 13 to 40 percent for CI pipes; 23 percent for RCC and AC pipes; and 8.4 percent for HDPE and PVC pipes.

1.2.6 Manning’s Pipe Roughness Coefficient

The coefficient of roughness for use in Manning's formula for different materials (Table 1.4) may be adopted generally for design purposes unless local experimental results or other considerations warrant the adoption of any other lower value for the coefficient. For general design purposes, however, the value for all sizes may be taken as 0.013 for plastic pipes and 0.015 for other pipes.

Table 1.4: Manning's Coefficient of Roughness

Type of Lining	Condition	n
Glazed coating of enamel Timber	In perfect order a) Plane boards carefully laid b) Plane Boards inferior workmanship or aged c) Non-plane boards carefully laid d) Non-plane boards inferior workmanship or aged	0.010 0.014 0.016 0.016 0.018
Masonry	a) Neat cement plaster b) Sand and cement plaster c) Concrete, Steel troweled d) Concrete, wood troweled e) Brick in good condition f) Brick in rough condition g) Masonry in bad condition	0.013 0.015 0.014 0.015 0.015 0.017 0.020
Stone work	a) Smooth, dressed ashlar b) Rubble set in cement c) (c) Fine, well packed gravel	0.015 0.017 0.020
Earth	a) Regular surface in good condition b) In ordinary condition c) With stones and weeds d) In poor condition e) Partially obstructed with debris or weeds	0.020 0.025 0.030 0.035 0.050
Steel	a) Welded b) Riveted c) Slightly tuberculated d) Cement Mortar lined	0.013 0.017 0.020 0.011
Cast Iron & Ductile Iron	a) Unlined b) Cement mortar lined	0.013 0.011
Asbestos Cement		0.012
Unlined metallic pipes		0.015
Plastic (smooth)/ MDPE/ HDPE/PVC		0.011
Glass Fibre Reinforced Plastics (GRP)		0.009

1.2.7 Reduction in Carrying Capacity of Pipes with Age

The values of Hazen-Williams ‘C’ are at present arbitrarily reduced by about 20 to 23 percent in carrying capacity of pipes with age. The chemical and bacteriological quality of water and velocity of flow affect the carrying capacity of pipes with age.

The C_R values obtained in such studies have shown that, except in the case of CI and steel pipes while carrying corrosive water, the current practice of arbitrary reduction in ‘C’ values as per Coefficient of Roughness results in underutilization of pipe material to the extent of 38 to 71 percent for CI pipes for non-corrosive water; 46 to 93 percent for RCC pipes and 25 to 64 percent for AC and HDPE pipes.

1.2.8 Discussion on Various Formulae

(i) The Darcy-Weisbach formula is dimensionally consistent. The Hazen-Williams coefficient C is usually considered independent of pipe diameter, velocity of flow and viscosity. However, to be dimensionally consistent and to be representative of friction conditions, it must depend on relative roughness of pipe and Reynold's number. A comparison between estimates of Darcy-Weisbach friction factor f, and its equivalent value computed from Hazen-Williams C for different pipe materials brings out the error in estimation of ‘f’ up to ±45% in using Hazen Williams formula. It has been observed that for higher ‘C’ values (new and smooth pipes) and larger diameters, the error is less, whereas it is appreciable for lower ‘C’ values (old and rough pipes) and lower diameters at higher velocities.

(ii) The Hazen-Williams formula is dimensionally inconsistent, since the Hazen-Williams C has the dimension of $L^{-0.37} T^{-1}$ and therefore is dependent on velocity, diameter and other parameters. The Hazen-Williams coefficient C is usually considered independent of pipe diameter, velocity of flow and viscosity.

(iii) With a view to avoid the limitations of the Hazen Williams formula, the present trend is to use the Colebrook-White equation for estimation of friction factors and then use the Darcy-Weisbach formula for estimation of head-loss due to friction in the pipelines. This practice will yield correct results compared to the Hazen Williams formula.

(iv) The estimation of Darcy's ‘f’ for variations in velocity and diameter involves repetitive and tedious calculations. Further, there is a need for assuming a correct k value in the Colebrook-White equation for calculation of friction coefficient ‘f’ in the Darcy-Weisbach formula. Conservative assumption of ‘k’ values will also result in under-utilization of carrying capacity of the pipes. However, it is recommended that frictional losses should be estimated with Darcy-Weisbach formula by changing ‘f’ values for varying velocity and diameter combinations and assuming a correct k value in the Colebrook-White equation.

(v) If there is a choice for use of pipe friction formulae, Darcy Wiesbach yields accurate results but involves extra computational effort and therefore Hazen-Williams (HW) formula is commonly used.

(vi) It is significant to note that irrespective of the formula used for estimation of frictional resistance, it is necessary to adopt different roughness coefficient values for the various velocity-diameter combinations if the frictional resistance is to be accurately estimated involving changing the C values, k or f values for the same pipe material. In design, various velocity-diameter combinations are required.

1.2.9 Resistance due to Specials and Appurtenances

Pipeline transitions and appurtenances add to the head loss, which is expressed as velocity head as K V^2/ 2g where V and g are in m/s and m/sec^2 respectively or equivalent length of straight pipe. The values of K to be adopted for different fittings are given in Table 1.5 and equivalent length of pipe for different sizes of various fittings with K=1 are given in Table 1.6.

Table 1.5: K-Values for Different Fittings

Type of Fitting	Value of K
Sudden contractions/expansion	0.3* - 0.5
Entrance shape well rounded	0.5
Elbow 90^{o}	0.5-1.0#
45^{o}	0.4-0.75#
22^{o}	0.25-0.50#
Tee 90^{o} take-off	1.5
Straight run	0.3
Coupling/flange adapter/dismantling joint	0.3
Gate valve/sluice valve/knife gate valve (in fully opencondition)	0.3 - 0.4
Concentric/eccentric reducer and enlarger	0.15-0.25
Globe	10.0
Angle	5.0
Swing check valves/ non return valve/ reflex valve/ dual plate check valve	2.5
Venturi Meter	0.3
Orifice	1.0
Bellmouth	0.1
Radial tee	0.8
30/45 degree tee	1.0
Butterfly valve	0.4
Magnetic/ultrasonic flow meter	0.1
Discharge head elbow (bend)/subsurface deliver team for VT pump	0.5
Foot Valve	2.0
Strainer	1.5

*Varying with area ratios; **Varying with radius ratios.

Lowest values are for long radius elbows and highest values are for short radius elbows.

The minor losses in pipes can also be considered through equivalent length of straight pipe that can be added to length of pipe.

Table 1.6: Equivalent Length of Pipe for Different Sizes of Fittings with K =1

Size (mm)	Equivalent length of pipe (m)	Size (mm)	Equivalent length of pipe (m)
10	0.3	65	2.4
15	0.6	80.	3.0
20	0.75	90	3.6
25	0.9	100	4.2
32	1.2	125	5.1
40	1.5	150	6.0

1.2.10 Guidelines for Cost Effective Design of Pipelines

The cost of transmission and distribution system constitutes a major portion of the project cost. It is desirable to adopt the following guidelines:

(i) The minimum hydraulic design velocity should be maintained to avoid depositions and consequent loss of carrying capacity.

(ii) In design of distribution systems, the minimum design velocity should be selected in such a fashion so as to avoid the deposition at the bottom of the pipe which may result in deterioration of pipe quality. The maximum hydraulic velocity should not be adopted more than 3m/s to avoid the scouring in the pipelines. However, where inevitable due to minimum pipe diameter criteria or other hydraulic constraints, lower velocities may be adopted with adequate provision for scouring.

(iii) The minimum velocity shall not be less than 0.60 m/s but in exceptional cases, 0.3 m/s may also be adopted, and maximum shall be upto 3.0 m/sec for the design of transmission main and feeder mains in plain areas. For hilly regions, the velocity may be increased to additional 50% i.e. 4.5 m/s under the exceptional circumstances. The maximum flow velocity should not be adopted more than 2.5 m/s for raw water to avoid the scouring in the pipelines due to abrasion caused by suspended particles. However, in case of filtered water, as the quantity of solids (which contribute the abrasion) is negligible, maximum flow velocity to be adopted shall be 3.0 m/sec.

(iv) In all hydraulic calculations, the actual internal diameter of the pipe shall be adopted after accounting for the thickness of lining, if any, instead of the nominal diameter or outside diameters (OD).

(v) In providing for head loss due to fittings, specials and other appurtenances, actual head loss, as calculated in above paragraph, should be considered instead of making an arbitrary provision.

(vi) In pumping systems, the energy costs are heavy. These costs can be minimised only if the pumps operate at their designed duty point. Hence it is imperative that the real frictional losses in a transmission pipeline are taken as actually recorded in real operating conditions (using a single pump). Based on the real values, the design of the battery of pumps should be finalised to minimise electrical energy costs.

1.3 Pipe Materials

Pipelines are major investments in water supply projects and as such constitute a major part of the assets of water authorities. Pipes represent a large proportion of the capital invested in water supply undertakings and therefore are of particular importance. Therefore, pipe materials shall have to be judiciously selected not only from the point of view of durability, life and overall cost which includes, besides the pipe cost, the installation and maintenance costs necessary to ensure the required function and performance of the pipeline throughout its designed life time.

1.3.1 Choice of Pipe Materials

The various types of pipes are used in water supply:

I. Metallic pipes: C.I., D.I., M.S., G.I.
   (i) Unlined Metallic pipes (discontinued)
   (ii) Metallic pipes lined with cement mortar or epoxy lining;

II. Non Metallic pipes
   (i) Reinforced Concrete, Prestressed Concrete, Bar Wrapped Steel Cylinder Concrete, Asbestos Cement
   (ii) Plastic Pipes: PVC (PVC-O, PVC-U), Polyethylene, Glass Reinforced Plastic, HDPS, MDPE, etc.

The determination of the suitability in all respects of the pipes and specials, for any work is a matter of decision by the Engineer concerned on the basis of requirements for the scheme, on techno-economic criteria. It is important to consider adaptability of pipes suiting to the field conditions where bends are common in urban areas and need for providing service connections without damaging pipe characteristics. The Government policy nowadays is to provide service connections to all households i.e. 100% households/ premises/ plots/gates.

Several technical factors affect the final choice of pipe material such as internal pressures, internal coating, coefficient of roughness, hydraulic and operating conditions, maximum permissible diameter, internal and external corrosion problems, laying and jointing, type of soil, special conditions, etc.

Selection of pipe materials must be based on the following considerations:

(a) The initial carrying capacity of the pipe and its reduction with use, defined, for example, by the Hazen-Williams coefficient C. Values of C vary for different conduit materials and their relative deterioration in service. They vary with size and shape to some extent.
(b) The strength of the pipe as measured by its ability to resist internal pressures and external loads.
(c) The life and durability of pipe as determined by the resistance of cast iron and steel pipe to corrosion; of concrete and A.C. pipe to erosion and disintegration and plastic pipe to cracking and disintegration.
(d) The ease or difficulty of transportation, handling and laying and jointing under different conditions of topography, geology and other prevailing local conditions. This is particularly of hilly areas.
(e) The safety, economy and availability of manufactured sizes of pipes and specials.

(f) The availability of skilled personnel in construction and commissioning of pipelines.
(g) The ease or difficulty of repairs during operations and maintenance.

In addition to the above points, while selecting the pipe and pipe materials, health related issues should also be kept on high priority. Many of the materials used for manufacturing pipe are carcinogenic which needs to be properly examined before selection of pipe and pipe materials. The life and durability of the pipe depends on several factors including inherent strength of the pipe material, the manufacturing process along with quality control, handling, transportation, laying and jointing of the pipeline, surrounding soil conditions and quality of water.

Normally, the design period of pipelines is considered as 30 years. Where the pipelines have been manufactured properly as per specifications, designed and installed with adequate quality control and strict supervision, pipes have lasted more than the designed life provided the quality of water is non-corrosive. However, pipeline failures for various pipe materials even before the expiry of the designed life have been reported probably due to lack of rigid quality control during manufacture and installation, improper design, presence of corrosive waters, corrosive soil environment, improper bedding and other relevant factors. As pipelines are reticulated systems, the combined quality of pipes & pipelines arising out of quality pipe manufacture and sound installation, laying and jointing with strict supervision, standard jointing, bedding, back-filling and hydraulic pressure testing as per codes will determine the service delivery and life of a pipeline. The manufactured quality of pipes for quality, strength and durability are not the criteria for its service performance.

The metallic pipes are being provided with internal lining either with cement mortar or epoxy or food grade compatible material so as to reduce corrosion, increase smoothness and prolong the life. Lined metallic pipelines are expected to last beyond the normal design life of 30 years. However, the relative age of such pipes depends on the thickness and quality of lining available for corrosion. The cost of the pipe material and its durability or design life are the two major governing factors in the selection of the pipe material. The pipeline may have very long life but may also be relatively expensive in terms of capital and recurring costs and, therefore, it is necessary to carry out a detailed economic analysis before selecting a pipe material.

Underground metallic pipelines may require protection against external corrosion depending on the soil environment and corrosive ground water. Protection against external corrosion for MS pipes is provided with guniting with proper cement composition or epoxy coating, inside cement mortar lining with proper thickness or hot applied coal-tar asphaltic enamel reinforced with fibre glass fabric yarn, non-corrosive sleeves etc. Resistivity survey of the pipe alignment is most important.

The determination of the suitability in all respects of the pipeline for any work is a matter of decision by the Engineers and the community concerned on the basis of the requirements for the scheme and health issues of the human being in the service areas.

A checklist in Table 1.7 for selection of pipe material has been provided to facilitate the decision makers in selecting the economical and reliable pipe material for the given conditions.

Use of this checklist is strongly recommended for all water supply projects having components of water supply pipe network including pumping main, gravity main, distribution system and water treatment plant. The checklist can be filled up based on the merits and demerits of relevant pipe materials. It is necessary that a quantitative and qualitative assessment is made to arrive at the most economical and reliable pipe material. The project report should include provisions for addressing the less favourable attributes along with the cost estimates for the same. Risk factors should be identified and stated clearly in the project report. Risk analysis should be carried out to arrive at the correct decision in selecting the pipe material.

Table 1.7: Check List for Selection of Pipe Materials

S. No	Attribute	Type of Pipes											Remarks if any
		All PVC	AC	CI	DI	MS	PSC	GRP	HDPE/ MDPE	RCC	GI	OTHERS	
1	Impact of Human Health (Adverse/ Favourable/ Neutral)												
2	Hydraulic smoothness (C Value)												
3	Structural strength for external loads and diameter stiffness												
4	Stress calculations and factor of safety consideration in determining strength												
5	Basic material mechanical properties and ageing analysis												
6	Strength to sustain internal pressure												
7	Ease in handling, transportation and storage												
8	Capacity to withstand damage in handling and maintenance												
9	Resistance to internal corrosion												
10	Resistance to external corrosion												
11	Resistance to heat/sunlight and durability under all-weather condition												
12	Resistance to rodent attack/pilferage												
13	Sustainability in Black Cotton Soil												
14	Reliability and effective joints												
15	Reactivity of pipe material with water at different temperature and pressure												
16	Capable to absorb surge pressure (water hammer)												
17	Ease in maintenance and repairs												
18	Use experience												
19	Durability (Sustainable trouble free maintenance)												

S. No	Attribute	Type of Pipes											Remarks if any
		All PVC	AC	CI	DI	MS	PSC	GRP	HDPE/ MDPE	RCC	GI	OTHERS	
20	Consumer satisfaction												
21	Resistance to tampering by anti-social elements												
22	Economy												
23	Availability of specials												
24	Availability of skilled personnel for installation & maintenance												
25	Behaviour of pipe line — likelihood of interruptions due to leakage, bursting etc. and time for repairs												
26	**Recommended size range for**												
(i)	Rising Main												
(ii)	Gravity Main												
(iii)	Distribution Network												
(iv)	House Service Connection												

Note: Weightage - 0 to 10 numbers in relation to the significance of the attributes (10 stands for highest quality) may be considered. The cost of the pipe (Rs. per metre), beyond 300 mm diameter, should also be considered while selecting the pipe materials.

1.3.2 Check List for Specifications for Manufacture, Supply, Laying, Jointing, Testing and Commissioning of Pipelines

Water utilities often procure pipes from one manufacturer/supplier under one contract, procure the valves, fittings and appurtenance from another manufacturer/supplier under another contract and have them installed under another contract rather than entrusting the entire work of Manufacture, Supply, Laying, Jointing, Testing and Commissioning of pipelines to a single agency. This procedure is resorted to on the plea that it results in economy and saves time. But this method is no longer used in the country, the single responsibility contracts are used.

It is seen that wherever single contracts are not awarded for the entire work of Manufacture, Supply, Laying, Jointing, Testing and Commissioning of pipelines to a single agency, the responsibility for performance of the pipelines could not be assigned to any particular agency. Time delays if any, in procurement of fittings, valves and appurtenances will also affect the completion of the contract and also results in cost overruns. Quite often, at the time of commissioning, deficiencies are noticed which might be due to failure at the manufacturing stage or due to transportation handling, or laying/jointing defects or failure of fittings and valves.

Hence it is desirable that all pipeline contracts should be awarded on a single contract responsibility so that quality assurance at various stages of manufacture, supply, delivery, laying, jointing and testing is taken care of by a single agency and the timely completion also rests with a single agency; this may result in receipt of competitive offers and hence results in economy. Further, the water utility's time and resources which otherwise are spent in monitoring the performance of several small contracts can be better utilised for quality management of the contract. This may ensure economy by timely completion and quality construction.

However, it is necessary that the specifications for single contract responsibility have to be comprehensive and provide for penalty in delays and drawn so that all items of the water supply infrastructure get completed together in tandem (pipe procurement, installation, bends, service connections, testing, backfilling etc.) so that the time and cost over runs can be avoided. There will be several site specific conditions and circumstances for the pipeline installations which vary to such an extent that it is very difficult to recommend a simple/ single all-inclusive set of specifications for the pipeline contracts. A check list for drafting specifications for Manufacture, Supply, Laying, Jointing, Testing and commissioning of pipelines for procurement through a single agency is furnished. Judicious selection of items which cover cross country or city installations is required.

PART I PROCUREMENT

Section 1 - General

1.1 Scope of work
1.2 Definitions of client, contractor, engineer etc.
1.3 Drawings and documents referred to
1.4 Reference Standards
1.5 Penal clauses for failure to meet the time schedule & performance standards and requirements.
1.6 Basis for Prices; to include all pipes, fittings, valves, jointing materials, including labour, cost of factory testing, lining, coating, marking and all other incidental expenses for manufacture, transportation, insurance and delivery at site. (any exclusions/inclusions may be clearly specified)

Section 2 - Detailed Requirements - Pipes

2.1 Material for pipes (standards for materials), manufacturing operations, testing and inspection
2.2 Diameter of pipe
2.3 Wall thickness/other dimensions of the pipe
2.4 Class of pipe
2.5 Laying length
2.6 Pipe ends-flanged-socket/spigot/plain
2.7 Special pipe lengths and special fittings
2.8 Working Pressures
2.9 Pipe lining and coating both for buried and exposed pipes

Section 3 - Transportation and delivery at site

3.1 Type of trucks used for transportation-length/weight
3.2 Handling equipment for loading and unloading

Section 4 - Field joints for Pipes

4.1 Requirements for machined couplings/ends
4.2 Flanged/joints, pitch circle, blots type, gasket quality
4.3 Welded joints-runs-thickness

PART II INSTALLATION

Section 1- Instruction to Bidders

- 1.1 Procedure for invitation of bids
- 1.2 Instructions to bidders
- 1.3 Bidders proposal to include plan/programme for construction
- 1.4 Agreement and performance bonds

Section 2 - General Specifications

2.1 Definitions
2.2 Scope of Work
2.3 Payment conditions
2.4 Statutory Requirements- Payment of Wages-Policy-Environment control-safety
2.5 Personnel

Section 3 - Detailed Specifications

3.1 Time Schedule
3.2 Construction facilities - Right of way - storage space interference with other services
3.3 Work and materials
3.4 Concrete
3.5 Excavation - Bracing of excavation - Safety to public - Disposal of excess material from excavation
3.6 Maintenance, removal and reconstruction of other interfering facilities
3.7 Safeguarding of excavations and protection of property
3.8 Backfill
3.9 Resurfacing of roads within city and outside

Section 4 - Pipes

4.1 Approval of drawings for laying
4.2 Distribution along trench
4.3 Preparation of bedding
4.4 Lowering and laying
4.5 Jointing
4.6 Inspection and tests in ready to supply water condition
4.7 Bends, manholes, outlets
4.8 Joints- Flanged, bolting materials and gasket- machined ends – welded joints
4.9 Field touch up of site joints.

Section 5 – Health Impact Analysis

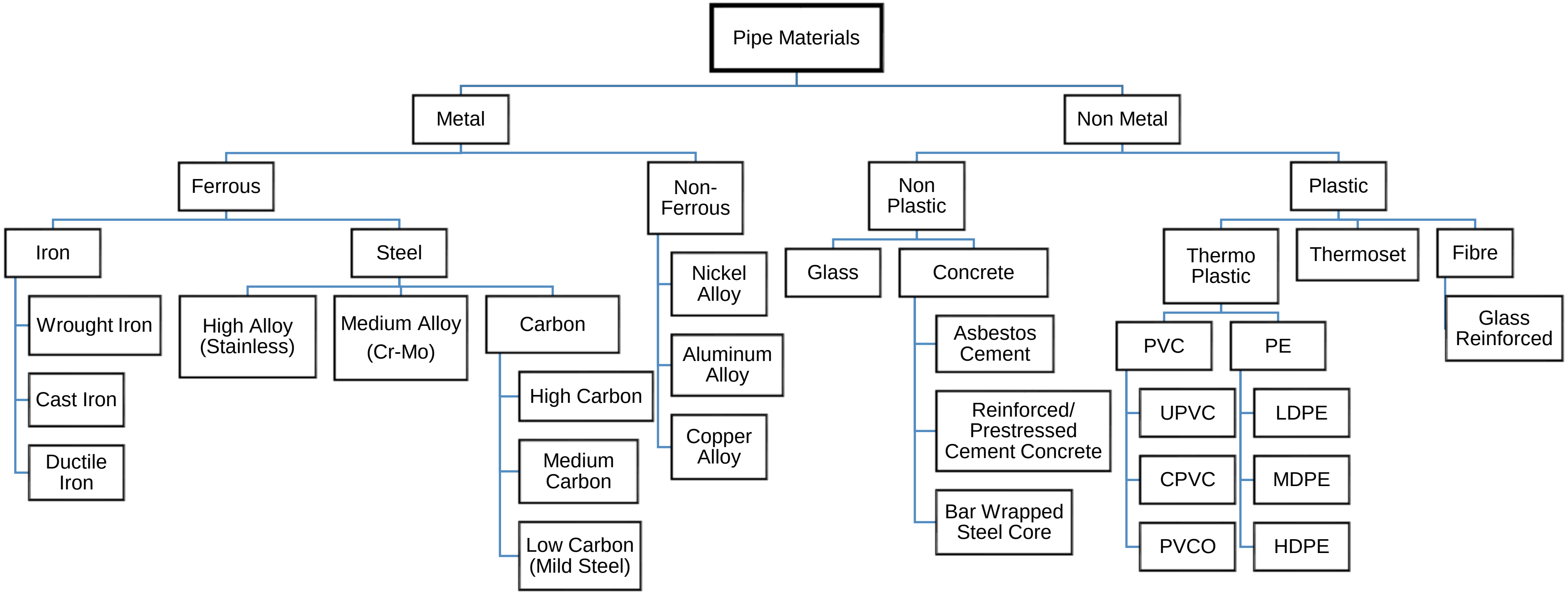
5.1 Material of food grade or its compatible
5.2 Suitability of internal coating material with health

1.4 Pipe Materials

Pipelines are major investments in water supply projects and as such constitute a major part of the assets of Water Authorities and therefore are of particular importance. Therefore, pipe materials shall have to be judiciously selected not only from the point of view of durability, life and overall cost, besides the pipe cost, the installation and maintenance costs necessary to ensure the required function and performance of the pipeline throughout its designed life time. Above to all, the health aspects of human being should also be taken into consideration while selecting the material of pipe for water supply system.

1.4.1 Classification Based on Material of Construction

Pipes found in water supply systems are generally of the following materials: cast or ‘grey’ iron, ductile iron (DI), stainless steel/ steel, polyethylene (PE), PVC (polyvinyl chloride), GRP (glass reinforced plastic), prestressed concrete, cylinder or non-cylinder (PSC), reinforced concrete cylinder (RC) and asbestos cement. A broad classification of pipes used in water supply systems based on material of construction is as below:


Pipe Materials
Metal
Non Metal
Ferrous
Non-Ferrous
Non Plastic
Plastic
Iron
Steel
Nickel Alloy
Aluminum Alloy
Copper Alloy
Glass
Concrete
Thermo Plastic
Thermoset
Fibre
Wrought Iron
Cast Iron
Ductile Iron
High Alloy (Stainless)
Medium Alloy (Cr-Mo)
Carbon
High Carbon
Medium Carbon
Low Carbon (Mild Steel)
Asbestos Cement
Reinforced/ Prestressed Cement Concrete
Bar Wrapped Steel Core
PVC
PE
UPVC
CPVC
PVCO
LDPE
MDPE
HDPE
Glass Reinforced

1.4.2 Classification Based on Structural Flexibility

Pipe-soil interaction is important for the sound structural design of buried pipelines. Flexibility of pipes is defined by capability of pipe to deflect without showing signs of structural damage. Pipes can be grouped as rigid, flexible and semi rigid based on their structural flexibility.

1.4.2.1 Rigid Pipe

Rigid pipes deflect little; their load carrying capacity is derived from ring bending strength (as determined from crushing tests) and can be increased by bedding factors for various standardized bedding and surrounds. Rigid pipes tend to attract more load than more flexible pipes, particularly in wide trench situations.

Generally, rigid pipes start showing signs of structural distress before being vertically deflected by 2 percent. Rigid pipes include reinforced non-cylinder concrete, reinforced concrete cylinder, prestressed concrete cylinder, vitrified clay, polymer concrete, cast iron, asbestos cement and cast-in-place pipes.

1.4.2.2 Flexible Pipe

Flexible and semi rigid pipes deflect under load in inverse relation to pipe stiffness and overall soil modulus. Flexible pipes derive their support primarily from passive soil resistance which develops as the pipe ovalizes under vertical load and deflects horizontally into the side fill. The contribution of pipe stiffness is small.

As a general rule, flexible pipes will deflect at least 2 percent without structural distress. Most flexible pipe material standards allow up to 5 percent deflection. Deflection is limited to 2 percent if the flexible pipe has a rigid lining and coating and 3 percent for a rigid lining and flexible coating. Flexible pipes include steel, ductile iron, thermoplastics such as polyvinyl chloride (PVC/PVC O) and high-density polyethylene (HDPE), thermosetting plastics such as fiberglass-reinforced polymer (FRP), bar-wrapped concrete cylinder pipe, and corrugated steel pipes.

1.4.2.3 Semi-Rigid Pipe

Some pipe materials exhibit characteristics of both rigid and flexible pipes, primarily controlled by their diameters, and are referred to as semi-rigid. Attempts have been made to define semi-rigid pipes as those that will deflect between 0.1 percent and 3.0 percent without causing harmful or potentially harmful cracks. Bar-wrapped concrete cylinder pipe is an example.

1.4.3 Cast Iron Pipes

1.4.3.1 General

Cast Iron (CI) pressure pipes may be classified in two categories i.e. Vertically Cast Iron (IS:1537-1976, Reaffirmed 2020) and Centrifugally Cast (Spun) Iron (IS:1536-2001, Reaffirmed 2021) pipes for water and sewage. Vertically cast iron has been largely superseded by centrifugally cast (spun) iron type up to a diameter of 1050 mm. Though the vertically cast-iron pipe is heavy in weight, low in tensile strength, and liable to defects of inner surface, it is widely used because of its good lasting qualities.

Cast Iron pipes and fittings are being manufactured in this country for several years. Due to its strength and corrosion resistance, CI pipes can be used in corrosive soils and for waters of slightly aggressive character. They are well suited for pressure mains and laterals where tapings are made for house connections. It is preferable to have coating inside and outside of the pipe.

Vertically cast-iron pipes are manufactured by vertical casting in sand moulds. The metal used for the manufacture of this pipe is not less than grade 15. The pipes shall be stripped with all precautions necessary to avoid wrapping or shrinking defects. The pipes shall be such that they could be cut, drilled or machined. Cast Iron flanged pipes and fittings are usually cast in the larger diameters. Smaller sizes have loose flanges screwed on the ends of double spigot-spun pipe.

The method of Cast Iron pipe production used universally today is to form pipes by spinning or centrifugal action. Compared with vertical casting in sand moulds, the spun process results in faster production, longer pipes with vastly improved metal qualities, smoother inner surface and reduced thickness and consequent lightweight.

Centrifugally cast-iron pipes are available in diameters from 80mm to 1050mm and are covered with protective coatings. Pipes are supplied in 3.66m and 5.5m lengths and a variety of joints are available including socket and spigot and flanged joints. The CI pipes have been classified as LA, A and B according to their thicknesses. Class LA pipes have been taken as the basis for evolving the series of pipes. Class A allows a 10% increase in thickness over class LA. Class B allows a 20% increase in thickness over class LA. For vertically cast pipes, Class LA has not been taken as standard. For special uses, Classes C, D, E etc. may be derived after allowing corresponding increases of thickness of 30, 40, 50 percent etc. over Class LA.

When the pipes are to be used for conveying potable water, the inside coating shall not contain any constituent soluble in water or any ingredient which could impart any taste or odour or impart health hazard.

Experiments in centrifugal casting of iron pipes were started in 1914 by a French Engineer which ultimately resulted in commercial production of spun pipes. Spun pipes are about 3/4 of the weight of vertically cast pipes of the same class. The greater tensile strength of the spun iron is due to close grain allowing use of thinner wall than for that of a vertically Cast-Iron pipe of equal length. It is possible by this process to increase the length of the pipe whilst a further advantage lies in the smoothness of the inner surface.

1.4.3.2 Laying and Jointing

1.4.3.2.1 Laying

Before laying the pipes, the detailed map of the area showing the alignment, sluice valves, scour valves, air valves and fire hydrants along with the existing intercepting sewers, telephone and electric cables and gas pipes will have to be studied. Care should be taken to avoid damage to the existing sewer, telephone and electric cables and gas pipes. The pipeline may be laid on the side of the street where the population is dense. Pipes are laid underground with a minimum cover of 1 metre on the top of the pipe.

Laying of pipes for water supply system has been generally governed by respective Indian Standards (IS) as well as the regulations laid down by the Municipalities and Corporations in the States/UTs. These regulations are intended to ensure proper laying of pipes giving due consideration to economy and safety of workers engaged in laying.

The pipes shall be straight. When rolled along two gantries separated by approximately two-thirds the length of the pipe to be checked, the maximum deviation from a straight line (in mm) shall not be greater than 1.25 times the length (in metres) of the pipes.

Excavation may be done by hand or by machine. The trench shall be so dug that the pipe may be laid to the required gradient and at the required depth. When the pipeline is under a roadway a minimum cover of 1.0 m is recommended for adoption, but it may be modified to suit local conditions by taking necessary precautions. However, the structural strength of the pipe, based on dead load and live load over the pipe, should also be analysed. The trench shall be so braced and drained that the workmen may work therein safely and efficiently. The discharge of the trench dewatering pumps shall be conveyed either to drainage channels or to natural drains and shall not be allowed to be spread in the vicinity of the work site.

The width of the trench at bottom between faces of sheeting shall be such as to provide not less than 200 mm clearance on either side of the pipe except where rock excavation is involved. Additional width shall be provided at positions of sockets and flanges for jointing. Depths of pits at such places shall also be sufficient to permit finishing of joints.

Ledge rock, boulders and large stones shall be removed to provide a clearance of at least 150 mm below and on each side of pipes in case of valves and fillings for pipes 600 mm in diameter or Iess, and 200 mm for pipes larger than 600 mm in diameter.

While unloading, pipes shall not be thrown down but may be carefully unloaded on inclined timber skids. Pipes shall not be dragged over other pipes and along concrete and similar pavements to avoid damage to pipes.

The pipes and fittings shall be inspected for defects and be rung with a light hammer, preferably while suspended, to detect cracks. Smearing the outside with chalk dust helps in the location of cracks. If doubt persists further confirmation may be obtained by pouring a little kerosene on the inside of the pipe at the suspected spot. If a crack is present, the kerosene seeps through and shows on the outer surface. The pipe should be properly inspected on the site. Any pipe found unsuitable before and after laying, it should shall be rejected.

1.4.3.2.2 Jointing

Several types of joints such as rubber gasket joint known as Tyton joint, mechanical joint known as Screw Gland joint, and conventional joint known as Lead joint are used.

Joints are classified into the following three categories depending upon their capacity for movement.

(a) Rigid joints

Rigid joints are those which admit no movement at all and comprise of flanged, welded and turned and bored joints. Flanged joints require perfect alignment and close fittings are frequently used where a longitudinal thrust must be taken such as at the valves and meters. The gaskets used between flanges of pipes shall be of compressed fibre board or natural or synthetic rubber. Welded joints produce a continuous line of pipes with the advantage that interior and exterior coatings can be made properly and are not subsequently disrupted by the movement of joints.

(b)Semi Rigid joints

Semi rigid joint is represented by the spigot and socket with caulked lead joint. A semi rigid joint allows partial movement due to vibration etc. The socketed end of the pipe should be kept against the flow of water and the spigot end of the other pipe is inserted into this socket. A twisted spun yarn is filled into this gap and it is adjusted by the yarning tool and is then caulked well. A rope is then placed at the outer end of the socket and is made tight fit by applying wet clay, leaving two holes for the escape of the entrapped air inside. The rope is taken out and molten lead is poured into the annular space by means of a funnel. The clay is then removed and the lead is caulked with a caulking tool.

Lead wool may be used in wet conditions. Lead covered yarn is of great use in repair work, since the leaded yarn caulked into place will keep back water under very low pressure while the joint is being made. Alternate yarn should also be explored and replaced with lead covered yarn in water supply due to adverse health impact on human being. Yarning or packing material shall also be considered for a) Spun yarn, b) Moulded or tubular natural or synthetic rubber rings, c) Asbestos rope, or d) Treated paper rope. These may be decided by the authority taking into consideration the quality of water.

(c) Flexible joints

Flexible joints are used where rigidity is undesirable such as with filling of granular medium and when two sections cannot be welded. They comprise mainly mechanical and rubber ring joints or tyton joints which permit some degree of deflection at each joint and are therefore able to stand vibration and movement. In rubber jointing special type of rubber gaskets are used to connect cast iron pipe which are cast with a special type of spigot and socket in the groove, the spigot end being lubricated with grease and slipped into the socket by means of a jack used on the other end. The working conditions of absence of light, presence of water and relatively cool uniform temperature are all conducive to the preservation of rubber and consequently this type of joint is expected to last as long as the pipes. Hence, rubber jointing is to be preferred to lead jointing.

1.4.3.2.3 Fittings

All pipes, fittings, valves and hydrants shall be carefully lowered into the trench by means of derrick, ropes, chain pulley blocks or other suitable tools and equipment depending on the weight and length of the pipes to prevent damage to pipe materials and protective coatings and linings.

All lumps, blisters and excess coating material shall be removed from socket and spigot end of each pipe and outside of the spigot and inside of the socket shall be wire-brushed and wiped clean and dry and free from oil and grease before the pipe is laid. After placing a length of pipe in the trench, the spigot end shall be centred in the socket and the pipe forced home and aligned to gradient. The pipe shall be secured in place with approved back fill material packed on both sides except at socket.

In general, the socket end should face the upstream while laying the pipeline on level ground however, the socket end should face the downstream subject to the strength of the joint and workmanship as per the guidelines. When the pipeline runs uphill, the socket ends should face the up gradient. When the pipes run beneath the heavy loads, suitable size of casing pipes or culverts may be provided to protect the casing of pipe. High pressure mains need anchorage at dead ends and bends as appreciable thrust occurs which tend to cause draw and even “blow out” joints. Where thrust is appreciable concrete blocks should be installed at all points where movement may occur.

Anchorages are necessary to resist the tendency of the pipes to pull apart at bends or other points of unbalanced pressure, or when they are laid on steep gradients and the resistance of their joints to longitudinal or shear stresses is either exceeded or inadequate. They are also used to restrain or direct the expansion and contraction of rigidly joined pipes under the influence of temperature changes. Anchor or thrust blocks shall be designed in accordance with IS:5330-1984 Reaffirmed 2020.

1.4.3.3 Testing of the Pipeline

After a new pipe has been laid, jointed and backfilled shall be subjected to the Pressure test and Leakage test at a pressure to be specified by the Authority for a duration of two hours.

After laying and jointing, the pipeline must be pressure tested to ensure that pipes and joints are sound enough to withstand the maximum pressure likely to be developed under working conditions.

1.4.3.3.1 Testing of Pressure Pipes

The field test pressure to be imposed should be not less than the maximum of the following:

(a) One and half (1 & ½) times the maximum sustained operating pressure.
(b) One and half (1 & ½) times the maximum pipeline static pressure.
(c) Sum of the maximum static pressure and the maximum surge pressure, subject to a maximum equal to the work test pressure for any pipe fittings incorporated.

If the visual inspection satisfies that there is no leakage, the test can be passed. Where the field test pressure is less than 2/3 the work test pressure, the period of test should be increased to at least 24 hours. The test pressure shall be gradually raised at the rate of 1 $kg/cm^2/min$ (0.1 $N/mm^2/min$). The field test pressure should wherever possible be not less than 2/3 work test pressure appropriate to the class of pipe except in the case of spun iron pipes and should be applied and maintained for at least four hours.

If the pressure measurements are not made at the lowest point of the section, an allowance should be made for the difference in static head between the lowest point and the point of measurement to ensure that the maximum pressure is not exceeded at the lowest point. If a drop in pressure occurs, the quantity of water added in order to re-establish the test pressure should be carefully measured. This should not exceed

0.1 litre per mm of pipe diameter per KM of pipeline per day for each 30 metre head of pressure applied. In case of gravity pipes, maximum working pressure shall be 2/3 work test pressure.

1.4.3.3.2 Procedure for Leakage Test

A leakage test shall be conducted concurrently with the pressure test. The allowable leakage IS:3114-1994, Reaffirmed 2019, during the maintenance stage of pipes carefully laid and well tested during construction, however should not exceed;

$$qL=\frac{ND\sqrt{P}}{3.3} \qquad (1.11)$$

Where,

qL= Allowable leakage, cm^3/hour

N = No. of joints in the length of pipe line

D = Diameter, mm

P = The average test pressure during the leakage test, kgf/cm^2

Where any test of pipe laid indicates leakage greater than that specified as per the above formula, the defective pipe(s) or joint(s) shall be repaired/replaced until the leakage is within the specified allowance.

1.4.3.3.3 Testing of Non-Pressure Conduits

In case of testing of non-pressure conduits, the pipeline shall be subject to a test for of 2.5 meters head of water at the highest point of tile section under test for 10 minutes. The leakage or quantity of water to be supplied to maintain the test pressure during the period of 10 minutes shall not exceed 0.2 litres/mm dia of pipes per kilometer length per day.

1.4.3.4 Advantages & Disadvantages

The advantages of pipe are:

- Good lasting qualities.
- Good Strength, strong and durable.
- Good corrosion resistance if coated can be used in soils and for water of slightly aggressive character.
- well suited for pressure mains and laterals where tapping are made for house connections.

The disadvantages of pipe are:

- heavy weight, and consequent high transport costs.
- short length, leading to higher laying and jointing cost.
- low tensile strength.
- liability to defect of inner surface.
- Likely to break during transportation and jointing

1.4.4 Ductile Iron Pipes

1.4.4.1 General

Ductile iron, also called nodular iron or spheroidal graphite iron, is characterized by the presence of graphite in nodular or spheroidal form in the resultant casting. It differs from cast iron by greater tensile strength and its significant elongation at break. Benefits of lower-cost production can be expected in a case where natural resources are used, allowing the disposal cost to be reduced. For a given nominal diameter, ductile iron pipes are duly designed with a larger internal diameter in order to reduce the head loss on energy pumping and the operation cost such as the electric power usage cost.

The DI pipes have excellent properties of machinability, impact resistance, high wear and tear resistance, high tensile strength, ductility and corrosion resistance. DI pipes having same composition of CI pipe, it will have same expected life as that of CI pipes. The DI pipes are strong, both inner and outer surfaces are smooth, free from lumps, cracks blisters and scars. Ductile Iron pipes stand up to hydraulic pressure tests as required by service regulations. The DI pipes are available in the range of 80 mm to 1200 mm diameter; in lengths of 5.5 to 6 m. For diameter more than 1000 mm, necessary precaution should be adopted for proper jointing. For use and laying of DI pipes, {IS 12288:1987, Reaffirmed 2017)} may be referred.

1.4.4.2 Laying and Jointing

1.4.4.2.1 Laying

Pipes should be lowered into the trench with tackle suitable for the weight of pipes. For smaller sizes, up to 250 mm nominal bore, the pipe may be lowered by the use of ropes but for heavier pipes, either a well-designed set of shear legs or mobile crane should be used. When lifting gear is used, the positioning of the sling to ensure a proper balance, should be checked when the pipe is just clear of the ground. If sheathed pipes are being laid, suitable wide slings or scissor dogs should be used. All construction debris should be cleared from the inside of the pipe either before or just after a joint is made.

It is recommended that above ground installations of spigot and socket pipes be provided with one support per pipe, the supports being positioned behind the socket of each pipe. Pipes should be fixed to the supports with mild steel straps so that axial movement due to expansion or contraction resulting from temperature fluctuation, is taken up at individual joints in the pipeline. In addition, joints should be assembled with the spigot end withdrawn 5 to 10 mm from the bottom of the socket to accommodate these thermal movements. Detailed specification on DI pipes may be referred at {IS 8329: 2000 (Reaffirmed 2020)}

The width of the trench at bottom between the faces of sheeting shall be such as to provide not less than 200 mm clearance on either side of the pipe except where rock excavation is involved. Trenches shall be of such extra width, when required, as will permit the convenient placing of timber supports, strutting and planking, and handling of specials.

Special consideration should be given to the depth of the trench. In agricultural land, the depth should be sufficient to provide a cover of not less than 900 mm so that the pipeline will not interfere with the cultivation of the land. In rocky ground, rough grazing or swamps, the cover may be reduced provided the water in the pipeline is not likely to freeze due to frost.

Where pipes are to be bedded directly on the bottom of the trench, it should be levelled and trimmed to permit even bedding of the pipeline. Where excavation is through rocks or boulders, the pipeline shall be bedded on concrete bedding or on at least 150 mm of fine grained material or other means are used to protect the pipe and its coating. Different types of trench conditions are shown below;

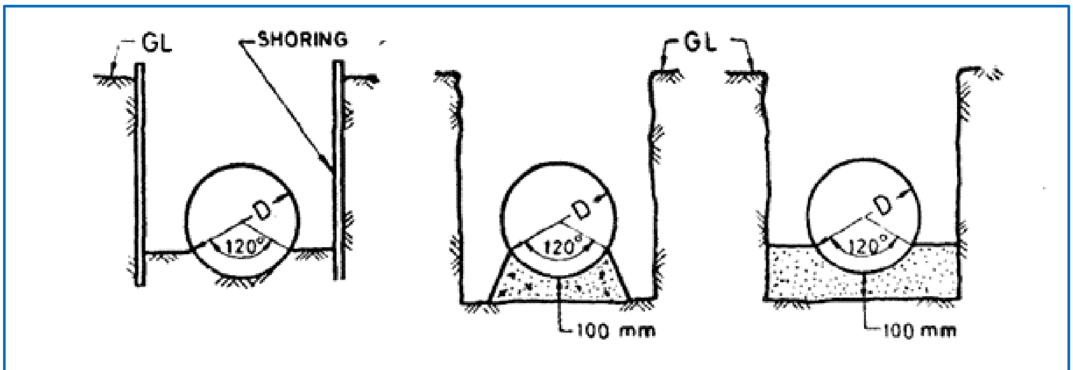


Figure 1: Different types of Trench Conditions

For the purpose of backfilling, the depth of the trench shall be considered as divided into the following three zones from the bottom of the trench to its top:

a. Zone A: From the bottom of the trench to the level of the centre line of the pipe,
b. Zone B; From the level of the centre line of the pipe to level 300 above the top of the pipe, and
c. Zone C: From a level 300 mm above the top of the pipe to the top of the trench.

All back-fill material shall be free from cinders, ashes, slag, refuse, rubbish, vegetable or organic material, lumpy or frozen material, boulders, rocks or stone or other material, which in the opinion of the authority, is unsuitable or deleterious. However, material containing stones up to 200 mm as their greatest dimension may be used in Zone C, unless specified otherwise herein.

Sand used for back-fill shall be a natural sand, graded from fine to coarse. The total weight of loam and clay in it shall not exceed 10 percent. All material shall pass through a sieve or aperture size 2.00 mm {IS: 2405 (Part II)-1980, Reaffirmed 2018)} and not more than 5 percent shall remain on IS Sieve or aperture size 0.63 mm.

Gravel used for back-fill shall be natural gravel, having durable particles graded from fine to coarse in a reasonably uniform combination with no boulders or stones larger than 50 mm in size. It shall not contain excessive amount of loam and clay and not more than 15 percent shall remain on a sieve of aperture size 75 micron.

For more details on back filling and pipeline anchoring, {IS:12288-1987, (Reaffirmed 2017)} may be referred.

1.4.4.2.2 Jointing

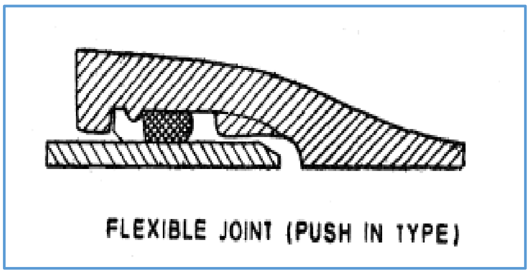
All pipelines having unanchored flexible joints require anchorage at changes of direction and at dead ends to resist the static thrusts developed by internal pressure. Dynamic thrusts caused by flowing water act in the same direction as static thrusts.

Three main types of joints are used with ductile iron pipes and fittings (IS 8329-2000):

a) Socket and spigot flexible joints:
   (i) Push-on joint
   (ii) Mechanical joints;
b) Rigid flanged joint
c) Restrained joint

The spigot and socket flexible joint should be designed to permit angular deflection and axial movement to compensate ground movement and thermal expansion & contraction. They incorporate gasket of elastomeric material and the joints may be of the simple push-on type or mechanical joints. Flexible joints require to be externally anchored at all changes in direction such as at bends, etc., and at blank end to resist the thrust created by internal pressure and to prevent the withdrawal of spigots.

In case of push-on-joints if any, shall be suitably chamfered to facilitate smooth entry of spigot in the socket of the pipes or fittings fitted with rubber gasket. Push-on-joint fittings are normally not used for sizes above DN 1 600. The material of rubber gaskets for use with mechanical joints and push-on-joints shall conform to {IS: 5382-2018}.



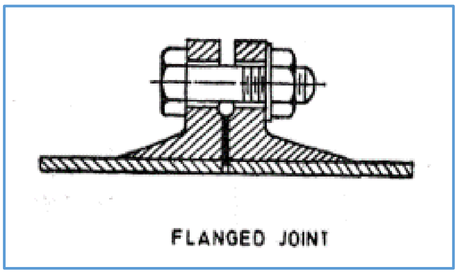


Figure 2: Flexible Joint (Push in type) and Flanged Joint

Rubber gaskets used with push-on-joints or mechanical joints shall conform to (IS 5382). Material of rubber gaskets for push-on mechanical or flanged joints shall be compatible with the fluid to be conveyed at the working pressure and temperature. Rubber gaskets for mechanical joint for conveyance of town gas may be suitably protected so that the elastomer does not come in direct contact with the gas. While conveying potable water the gaskets should not deteriorate the quality of water and should not impart any bad taste or foul odour.

The dimensions and tolerances of the flanges of pipes and fittings shall be such, so as to ensure the interconnection between all flanged components (pipes, fittings. valves) of the same DN and PN and adequate joint performance. Flanged joints are made on pipes having a machined flange at each end of the pipe. The seal is usually effected by means of a flat rubber gasket compressed between two flanges by means of bolts which also serve to connect the pipe rigidly. Gaskets of other materials, both metallic and non-metallic, are used for special applications.

In case of flange and mechanical joint casting, the flange shall be at right angle to the axis of the joint. The bolt holes shall be either cored or drilled. The centre of bolt holes circle shall be concentric with the bore circle and shall be located off the centre line. Where there are two or more flanges, the bolt holes shall be correctly aligned between them. The flanges shall be plain faced or with raised boss over the contact surface with a tool mark finishing having a pitch of 1(±) 0.3 mm, serrations may be spiral or concentric.

An alternative method of providing thrust restraint is the use of restrained joints. A restrained joint is a special type of push-on or mechanical joint that is designed to provide longitudinal restraint. Restrained-joint systems function in a manner similar to thrust blocks, in so far as the reaction of the entire restrained unit of piping with the soil balances the thrust forces.

Procedure for jointing will vary according to the type of joint being used. Basic requirements for all types are:

a) Cleanliness of all parts,
b) Correct location of components,
c) Centralization of spigot within socket, and
d) Strict compliance with manufacturer’s jointing instructions.

Where the pipeline is likely to be subjected to movement due to subsidence or temperature variations, the use of flexible joints is recommended. A gap should be left between the end of the spigot and the back of the socket to accommodate such movement.

1.4.4.2.3 Fittings

The ductile iron fittings are manufactured conforming to (IS 9523-2000, Reaffirmed 2020), for ductile iron fittings. The frequency of testing is related to the system of production and quality control at production level. The maximum batch size shall be 4 MT of crude castings, excluding the risers.

Mechanical tests shall be carried out during manufacture by batch sampling system. The samples, being representative of finished product, are tested for tensile strength, elongation and hardness to verify mechanical requirements. One test for castings produced during 24 hours shall be adequate. The results obtained shall be taken as to represent all the fittings of all sizes made during that period.

For checking Brinell hardness test may be carried out on the test bar. Fittings shall be supplied in either ‘as cast’ condition or ‘heat treated’ condition.

For hydrostatic test, the fittings shall be kept under pressure for 10 seconds. They shall withstand the pressure test without showing any sign of leakage, sweating or other defect of any kind. The test shall be conducted before the application of surface coating.

When the pipe used under the conditions for which they are designed, in permanent or in temporary contact with water intended for human consumption, ductile iron pipes and their joints shall not have detrimental effects on the properties of the water for its intended use.

1.4.4.3 Testing of the Pipelines

After a new pipeline is laid and jointed, hydraulic testing shall be done for:

a) mechanical soundness and leak tightness of pipes and fittings;
b) leak tightness of joints; and
c) soundness of any construction work, in particular that of the anchorages.

Hydrostatic Testing may be performed for the completed pipeline either in one length or in sections; the length of section depending upon:

(i) availability of suitable water,
(ii) number of joints to be inspected, and
(iii) difference in elevation between one part of the pipeline and another.

Where the joints are left uncovered until after testing, sufficient material should be backfilled over the centre of each pipe to prevent movement under the test pressure. Progressively as experience is gained, lengths of about 1.5 km or more, should be tested in one section, subject to consideration of length of trench which can be left open in particular circumstances.

As per ISO 10802: 2020, the test pressure at the lowest point of the test section shall be not less than the limit specified in a) or b), whichever is greater.

a) For PW ≤ 10 bar: PST = 1.5 × PW
b) For PW > 10 bar: PST = PW + 5
c) The maximum PW: PST = PMDc

Where,
PW: highest pressure that occurs at a time and a point in the pipeline when operating continuously under stable conditions, without surge;
PST: pressure to which a pipeline or a pipeline section is subjected for testing purposes;
PMDc: maximum operating pressure of the system or of the pressure zone fixed by the designer considering future developments including surge in case of surge is calculated (pumping & water mains).

If the test is not satisfactory, the fault should be found and rectified. Where there is difficulty in locating a fault, the section under test should be sub-divided and each part tested separately. Methods employed for finding leaks include:

(i) Visual inspection of each joint if, not covered by the backfill;
(ii) Use of a bar probe to detect signs of water in the vicinity of joints, if backfilled;
(iii) Aural inspection using a stethoscope or listening stick in contact with the pipeline;
(iv) Use of electronic listening device which detects and amplifies the sound or vibrations due to escaping of water, actual contact between the probe and the pipe is not essential;
(v) Injection of a dye into the test water-particularly suitable in water-logged ground; and
(vi) Introduction of nitrous oxide in solution into the test water and using an infrared gas concentration indicator to detect the presence of any nitrous oxide that has escaped through the leak.

1.4.4.4 Advantages & Disadvantages

The advantages of pipe are:

- High resistance against breakage due to impact;
- High tensile strength, comparable to that of mild steel so that the pipes can be used for higher working pressure and it counters water hammer effectively;

- Traditional corrosion resistance, comparable to that of cast iron;
- Lighter in mass as compared to cast iron pipes and
- Strong material properties and flexibility of joints contribute to prevent leakages.
- A comprehensive range of fittings makes easy incorporation of branches, service connections etc. with well-developed mains and leakage detection systems.

The disadvantages of pipe are:

- Centrifugally cast pipe coatings required for protection against aggressive external operating environments.
- Risk of stray current corrosion.

1.4.5 Galvanised Iron (GI) Pipes

1.4.5.1 General

Galvanized Iron (GI) Pipes are manufactured using mild steel strips of Low Carbon Steel Coils. The strips are passed through a series of fin rolls to give them a circular shape. The slit ends of the strips are then welded together by continuously passing high frequency electric current across the edges. The welded steel pipes are then passed through sizing sections where any dimensional deviations are corrected. The pipes are then cut into desired lengths by automatic cutting machines. The tubes are then pressure tested for any leaks. The galvanization and varnishing of pipes are done as per specific requirements. Further details may be referred in [{IS 4736: 1986 (Reaffirmed 2021)}, {IS 1239 Part 1): 2004} and {IS 1239 (Part 2): 2011}].

The GI Pipes are generally used for distribution of treated or raw water. These pipes are cheaper, light weight, and easy to transport. The health aspects should be given highest priority before selecting the pipe material for drinking water supply purposes as the pipe material is highly corrosive. It is not preferably to use GI pipes for house service connection.

The GI pipes are available in size range of 15 mm nominal bore to 150 mm outside diameter. 15mm nominal bore to 150mm nominal bore in the different classes of tubes like light, medium and heavy depending on wall thickness, are distinguished by color bands such as light tubes (yellow), medium tubes (blue) and heavy tubes (red).

1.4.5.2 Laying & Jointing

All screwed tubes are supplied with pipe threads conforming to {IS 554:1999}. Tubes are supplied screwed with taper threads and fitted with one socket having parallel thread. The socket conforms to all requirements of {IS 1239 (Part 2): 2011}. Pipes are generally joined using screwed joints. All threads for screw joints shall be clean, machine cut, and all pipes shall be reamed before erection. Each length of pipe as erected shall be up-ended and rapped to dislodge dirt and scale. Screwed joint shall be made up with good quality thread compound and applied to the male thread only. After having been set up a joint must not be backed off unless the joint is completely broken, the threads cleaned, and new compound applied. Flange joints may be used if necessary. For pipe laid under ditches, pipe bedding shall be compacted for the entire length of the pipe, good alignment shall be preserved and fittings may be used where necessary. Tubulars, sockets and fittings shall be galvanized before screwing.

1.4.5.3 Testing of the Pipelines

Hydrostatic test is carried out at a pressure of 5 MPa and the same is maintained for at-least 3 seconds.

Each tube shall be tested for leak tightness as an in-process test at manufacturer's works either by hydrostatic test or alternatively by eddy current test. Hydrostatic test shall be carried out at a pressure of 5 MPa and the same maintained for at least 3 and shall not show any leakage in the pipe. Mass of zinc coating shall be determined in accordance with IS 4736: 1986 (Reaffirmed Year :2021). The test for uniformity of zinc coating shall be done in accordance with IS 2633: 1986 (Reaffirmed Year :2021).

The adhesion of zinc coating on fittings shall be determined by pivoted hammer test in accordance with IS 2629:1985 (Reaffirmed Year :2006. The zinc coating shall be reasonably smooth and free from such imperfections as flux, ash and dross inclusions, bare patches, black spots, pimples, lumpiness, runs, rust stains, bulky white deposits and blisters.

1.4.5.4 Advantages & Disadvantages

Advantages of pipe are:

- Higher durability and longevity
- Weld consistency and integrity
- Amenable to rigorous fabrication
- Superior finish and anti - rust coating
- Greater corrosion resistance
- Superior bend ability and ease of cutting and threading.

Disadvantages of pipe are:

- Galvanized iron should never be used underground unless properly covered, which can be inconvenient for many jobs.
- It often hides significant defects beneath the zinc coating on the steel.
- Galvanized iron pipes may contain lead, which corrodes quickly and reduces the lifespan of the piping.
- Galvanized iron may leave rough patches inside pipes, resulting in serious failures and stoppages that can be expensive to repair.

1.4.6 Steel Pipes

1.4.6.1 General

Steel pipes shall be manufactured with the steel produced by the open hearth or electric furnace or one of the basic oxygen processes. Other process may also be used by agreement between the purchaser and the manufacturer. The pipes shall be manufactured by the processes of Seamless pipes, electric resistance welded pipes, submerged arc welded pipes. The thickness of the steel pipe is controlled due to the need to make the pipe stiff enough to keep its circular shape during storage, transport, laying and also to take the load of trench back filling and vehicles. Injurious defects in pipe wall, provided their depth does not exceed one third of the specified wall thickness, shall be repaired by welding.

Steel pipes of smaller diameter can be made from solid bar sections by hot or cold drawing processes and these tubes are referred to as seamless. But the larger sizes are made by welding together the edges of suitably curved plates, the sockets being formed later in a press (IS 3589: 2001, Reaffirmed 202022). The thickness of a steel pipe is however always considerably less than the thickness of the corresponding vertically cast or spun iron pipe. Owing to the higher tensile strength of the steel pipes (IS 3589:2001), it is possible to make steel pipe of lower wall thickness and lower weight. Specials of all kinds can be fabricated without difficulty to suit the different site conditions.

1.4.6.2 Laying and Jointing

1.4.6.2.1 Laying

The trench shall be so dug that the pipe may be laid to the required alignment and at required depth. When the pipeline is under a roadway, a minimum cover of 1.0 m is recommended, but it may be modified to suit local conditions by taking necessary precautions. The trench shall be shored, wherever necessary, and kept dry so that the workman may work therein safely, and efficiently. The discharge of the trench dewatering pumps shall be conveyed either to drainage channels or to natural drains, and shall not be allowed to be spread in the vicinity of the worksite. Open-cut trenches shall be sheeted and braced as required by any governing state laws and municipal regulations and as may be necessary to protect life, property or the work. For all pipelines laid above ground, provision for expansion and contraction on account of temperature variation should be made either by providing expansion joints at predetermined intervals or by providing loops where leakage through expansion joints cannot be permitted.

Trenching includes all excavation which is carried out by hand or by machine. The width of the trench shall be kept to a minimum consistent with the working space required. At the bottom between the faces, it shall be such as to provide not less than 200 mm clearance on either side of the pipe. The bottom of the trench shall be properly trimmed to permit even bedding of the pipeline. For pipes larger than 1,200 mm diameter in earth and murum the curvature of the bottom of the trench should match the curvature of the pipe as far as possible. Where rock or boulders are encountered, the trench shall be trimmed to a depth of at least 100 mm below the level at which the bottom of the barrel of the pipe is to be laid and filled to a like depth with lean cement concrete or with non-compressible material like sand of adequate depth to give the curved seating. For details on laying of welded steel pipe I.S. 5822-1986, Reaffirmed 2019 may be referred to.

Anchors should be provided on the pipeline at the position of line valves or sectionalizing valves, at the blank flange, at the tapers and at the mid-point between two consecutive expansion joints, in the case of above ground pipeline. Supports should be designed to support the pipeline without causing excessive local stresses. Due allowance shall be made for the weight of water, hydrostatic head, frictional resistance at the supports, etc. Proper bearing surface, such as flat base, roller and rocker, should be provided where controlled movements are required.

The internal design pressure shall not be less than the maximum pressure to which the pipeline is likely to be subjected including allowance for surge pressure, if any. The pipe selected shall be strong enough to withstand the effect of partial vacuum corresponding to one-third the atmospheric pressure which may occur within the pipe and due to any pressure exerted by water or soil around it.

Buried steel pipelines are liable to external corrosion and should be protected by the use of suitable coatings and shall be in accordance with IS 10221: 1982, Reaffirmed 2016. Pipelines laid above ground are liable to atmospheric corrosion and should be adequately protected.

1.4.6.2.2 Jointing

The requirements for mild steel pipes up to 150 mm nominal diameter are covered in {IS 1239 (Part 1): 2004, Reaffirmed 2014] and the requirements for mild steel and wrought steel fittings are covered in {IS 1239 (Part 2) : 2011, Reaffirmed 2021}. These pipes can be jointed by means of socket and screw or by welding. The requirements for steel pipes with diameters greater than 150 mm are covered in {IS 3589: 1991, Reaffirmed 2022}. The requirements for spiral welded pipes are given in (IS 5504: 1997, Reaffirmed 2018}. Higher diameter steel pipes and spiral welded pipes are joined by welding only.

Small size mild steel pipes have got threaded ends with one socket. They are lowered down in the trenches and laid to alignment and gradient. The jointing materials for this type of pipes are white lead and spun yarn. The white lead is applied on the threaded end with spun yarn and inserted into socket of another pipe. The pipe is then turned to tighten it. While laying, the pipes already stocked along the trenches are lowered down into the trenches with the help of chain pulley block. The formation of bed should be uniform. The pipes are laid true to the alignment and gradient before jointing. The ends of these pipes are butted against each other, welded and a coat of rich cement mortar is applied after welding.

Steel pipes may be joined with flexible joints or by welding but lead or other filler joints, hot or cold, are not recommended. The welded joint is to be preferred. In areas prone to subsidence this joint is satisfactory but flexible joints must be provided to isolate valves and branches. When welding is adopted, plain-ended pipes may be joined by butt welds or sleeved pipes by means of fillet welds. For laying long straight lengths of pipelines, butt joint technique may be employed. The steel pipes used for water supply include hydraulic lap welded, electric fusion welded, submerged arc welded and spiral welded pipes. The latter are being made from steel strip.

It must be borne in mind, however, that steel mains need protection from corrosion internally and externally. Against internal corrosion, steel pipes are given epoxy lining or hot applied coal tar/asphalt lining or rich cement mortar lining at works or in the field by the centrifugal process. The outer coating for underground pipeline may be in cement-sand guiniting or hot applied coal-tar asphaltic enamel reinforced with fibreglass fabric yarn. The other materials may also be adopted for internal lining which should not provide adverse impact on health.

If the pipes are joined by a form of flexible joint, it provides an additional safeguard against failure. Steel pipes being flexible are best suited for high dynamic loading.

1.4.6.2.3 Fittings

The manufacturer shall carry out the specified tests applicable to each type of pipe, and he shall, if required by the purchaser, supply a certificate stating that the pipes comply with the specified requirements.

Where the purchaser requires tests, the number of pipes on which mechanical tests shall be performed, shall be as follows:

(i) Up to and including 101.6 mm outside diameter - 1 pipe in each 400 tubes as made
(ii) Over 101.6 mm outside diameter - 1 pipe in each 200 pipes as made

If the number of samples specified in this clause, when applied to a particular order necessitates a number of pipes which includes a fraction, the fraction shall be treated as unity.

Tensile test should be carried out in accordance with (IS:1894-1972) on one of the following at the manufacturer's option:

a. Length cut from the end of the selected pipe (the ends being for grips or flattened where necessary), and
b. Longitudinal strip cut from the pipe and tested in the curved condition, or a test piece cut circumferentially, and flattened before testing. For welded pipes, the test piece shall not include the weld.

The welded joints shall be tested in accordance with procedure laid down in {IS 3600 (Part 1): 1985. One test specimen taken from at least one field joint out of any 10 shall be subjected to test.

For steel tubes, tubulars and other wrought Steel fittings, {IS 1239 (Part I): 2004, Reaffirmed 2014} may be referred to.

1.4.6.3 Testing of the Pipelines

Before putting it into commission, the welded pipeline shall be tested both for its strength and leakage. Each valved section of the pipe shall be slowly filled with clean water and all air shall be expelled from the pipeline through hydrants, air valves and blow-offs fixed on the pipeline. Before starting the pressure test, the expansion joints should be tightened.

1.4.6.3.1 Pressure Test

The field test pressure to be imposed should be not less than the greatest of the following:

a. 1 times the maximum sustained operating pressure,
b. 1 times the maximum pipeline static pressure, and
c. Sum of the maximum static pressure and surge pressure subject to the test pressure.

Where the field test pressure is less than two-thirds the test pressure, the period of test should be at least 24 hours. The test pressure shall be gradually raised at the rate of nearly 0.1 N/mm^2 per minute.

Each valve section of pipe shall be filled with water slowly and the specified test pressure, based on the elevation of lowest point of the linear section under test and corrected to the elevation of the test gauge, shall be applied by means of a pump connected to the pipe in a manner satisfactory to the authority.

Under the test pressure no leak or sweating shall be visible at all section of pipes, fittings; valves, hydrants and welded joints. Any defective pipes, fittings, valves or hydrants discovered in consequence of this pressure test shall be removed and replaced by sound material and the test shall be repeated until satisfactory to the Authority.

1.4.6.4 Advantages & Disadvantages

The advantages of pipe are:

- High Elastic - Due to their elasticity, steel pipes adopt themselves to changes in relative ground level without failure and hence are very suitable for laying in ground liable to subsidence.
- Strength - Compared to cast iron pipes of the same size, steel pipes are light in weight. Steel pipes perform well in unusual circumstances, such as non-uniformbedding, settling soils, or when subjected to external loads due to their longitudinal strength.
- Easy Installation - Easy installation of steel pipes is an advantage over cast iron pipes of similar strength. Steel pipes have smooth outer surfaces which makes installation using micro-tunneling possible.
- High Flow Capacity - Steel pipes have low frictional resistance to the flow of water. The thin walls of steel pipe generate a larger inside diameter which allows greater flow capacity.
- Leak Resistance - Risk of leaking mainly exists at the joints. Since steel pipes can be welded at the joints, the risk of leaking is much less.
- Long Service Life - Service life of steel pipes depends on rate of corrosion and internal abrasion. Impurities in water cause pipe abrasion to occur more rapidly.
- Reliability - Reliability is a factor which can assure that pipe can tolerate any unprecedented event such as flood, soil movement, earthquake, etc. Steel is considered tough because of wide ductile range and ultimate stress resistance.
- Versatility - A versatile pipe material will easily adapt to required modifications. If there are any changes in the bedding of the pipe, the beam strength of the steel can compensate.
- Economy - Economical pipe material is a material which is easy to transport and install and which costs less to maintain. Due to its light weight and longer sections, steel can be transported and installed cost-effectively and also reduces the cost of joining considerably.

The disadvantages of pipe are:

- Steel pipes required epoxy inside and 3LPE from outside and cathodic protection of whole pipeline.
- Welding joints for steel water pipe are complicated and require skilled labour.
- Steel pipe is susceptible to internal tuberculation and external corrosion, and issubjected to electrolysis, if not properly protected.
- Use of anti-corrosion products increases the price of production and maintenance of steel pipe.
- Air vacuum valves are necessary in large diameter pipes to prevent collapse, which adds to budgeted costs of installation.

1.4.7 Asbestos Cement Pipes

1.4.7.1 General

Chrysotile based Asbestos Cement (AC) pipes are made of a mixture of Chrysotile asbestos paste (only contains 8-10%) and cement (50%), clay (30-35%) and fly ash, wood, pulp, etc. which are not considered harmful for human health. Even here the asbestos fibres are locked with cement matrix particles and there is no scope for its disintegration/spreading in the air in normal circumstances. The paste is compressed by steel rollers to form a laminated material of great strength and density. Its carrying capacity remains substantially constant as when first laid, irrespective of the quality of water. It can be drilled and tapped for connecting but does not have the same strength or suitability for threading, as iron and any leakage at the thread will become worse as time passes. However, this difficulty can be overcome by screwing the ferrules through malleable iron saddles fixed at the point of service connections, as is the general practice.

AC pipes are manufactured from classes 10 to 25 and nominal diameters of 80mm to 600mm with the test pressure of 10 to 25 Kg/cm^2. AC pipe can meet the general requirements of water supply undertakings for rising main as well as distribution main. It is classified as class 10, 15, 20 and 25, which have test pressures 10, 15, 20 and 25 Kg/cm^2 respectively. Working pressures shall not be greater than 50% of test pressure for pumping mains and 67% for gravity mains.

These pipes are not suitable for use in sulphate soils. Due to expansion and contraction of black cotton soil, usage of these pipes may be avoided as far as possible in Black Cotton soils, except where the depth of B.C. soil is clearly less than 0.9 metre below ground level.

Storage shall be done on firm level and clean ground and wedges shall be provided at the bottom layer to keep the stack stable. The stack shall be in pyramid shape or the pipes laid lengthwise and cross-wise in alternate layers. The pyramid stack is advisable in smaller diameter pipes for conserving space in storing them. The height of the stack shall not exceed 1.5 m. Cast iron detachable joints and fittings shall be stacked under cover and separated from the asbestos cement pipes and fittings.

1.4.7.2 Laying and Jointing

1.4.7.2.1 Laying

The pipes shall have a minimum soil cover of 750 mm when laid under foot paths and sidewalks, 900 mm when laid under roads with light traffic or under cultivated soils and 1·25 m when laid under roads with heavy traffic. When the soil has a poor bearing capacity and is subject to heavy traffic, the pipes shall be laid on a concrete cradle. An extra trench depth of 100 mm shall be provided for each jointing pit.

The pipes shall be lowered into the trenches either by hand passing or by means of two ropes. One end of each rope shall be tied to a wooden or steel peg driven into the ground and the other end shall be held by men which when slowly released will lower the pipe into the trench. The width of the trench should be uniform throughout the length and greater than the outside diameter of the pipe by 300mm on either side of the pipe. The depth of the trench is usually kept 1 meter above the top of the pipe. For heavy traffic, a cover of at least 1.25 meter is provided on the top of the pipe.

In unstable soils, such as soft soils and dry lumpy soils it shall be checked whether the soils can support the pipe-lines and if required suitable special foundation shall be provided. In places where rock is encountered, cushion of fine earth or sand shall be provided for a depth of 150 mm by excavating extra depth of the trench, if necessary, and the pipes laid over the cushion. Where the gradient of the bed slopes is more than 30^0 it may be necessary to anchor a few pipes against their sliding downwards

The excavation of the trench shall be so carried out that the digging of the trenches does not get far ahead of the laying operations. By doing this, the risk of falling of sides and flooding of trenches shall be avoided. The walls of the trench shall be cut generally to a slope of ¼:1 or ½:1 depending on the nature of the soil. If the trench bottom is extremely hard or rocky or loose stony soil, the trench should be excavated at least 150 mm below the trench grade.

Prior to being placed in the trench, pipes should be visually inspected for evidence of damage as any damage to the pipe may impair its strength or integrity consequently. Before use the inside of the pipes will have to be cleaned. The lighter pipes weighing less than 80Kg can be lowered in the trench by hand. If the sides of the trench slope too much, ropes must be used. The pipes of medium weight upto 200Kg are lowered by means of ropes looped around both the ends. One end of the rope is fastened to a wooden or steel stack driven into the ground and the other end of the rope is held by men and is slowly released to lower the pipe into the trench. After their being lowered into the trench they are aligned for jointing. The bed of the trench should be uniform. Utmost care must be taken while loading, transportation, unloading, stacking and carrying to the site to avoid damage to the pipes.

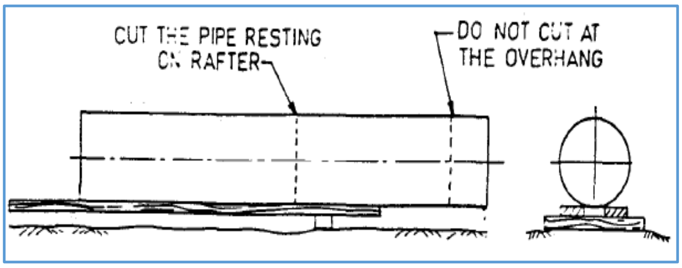


Figure 3: Cutting of AC Pressure Pipes

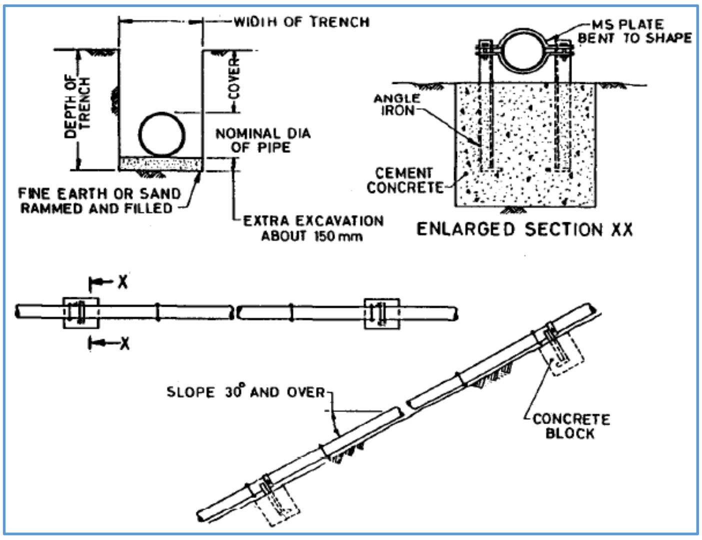


Figure 4: Laying of AC Pressure Pipes in Rocks

1.4.7.2.2 Jointing

Before commencing jointing, the pipes shall be cleaned; the joints and the ends of the pipe shall be cleaned, preferably with a hard wire brush to remove loose particles.

There are two types of joints for AC pipes.

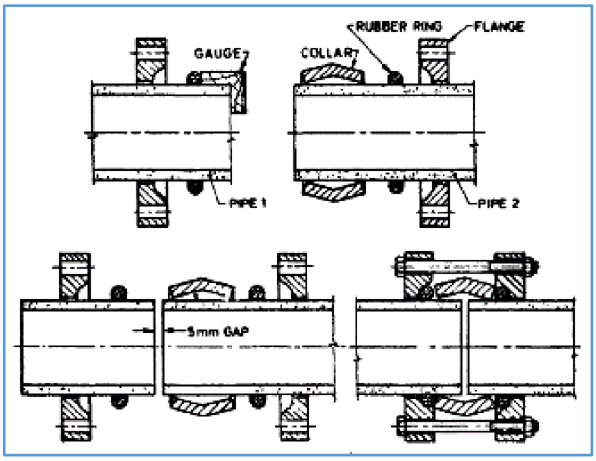
a) Cast iron detachable joint, (CID) and
b) AC coupling joint.

Cast Iron Detachable Joints

This consists of two cast iron flanges, a cast iron central collar and two rubber rings along with a set of nuts and bolts for the particular joint. For this joint, the AC pipes should have flush ends. For jointing a flange, a rubber ring and a collar are slipped to the first pipe in that order; a flange and a rubber ring being introduced from the jointing of the next pipe. Both the pipes are now aligned and the collar centralized and the joints of the flanges tightened with nuts and bolts.

Asbestos Cement Coupling Joint

This consists of an A.C. Coupling and three special rubber rings. The pipes for these joints have chamfered ends. These rubber rings are positioned in the grooves inside the coupling, then grease is applied on the chamfered end and the pipe and coupling is pushed with the help of a jack against the pipe. The mouth of the pipe is then placed in the mouth of the coupling end and then pushed so as to bring the two chamfered ends dose to each other. Wherever necessary, change over from cast iron pipe to AC pipes or vice-versa should be done with the help of suitable adapters. I.S. 6530 – 1972, Reaffirmed 2017, may be followed for laying A.C. pipes.



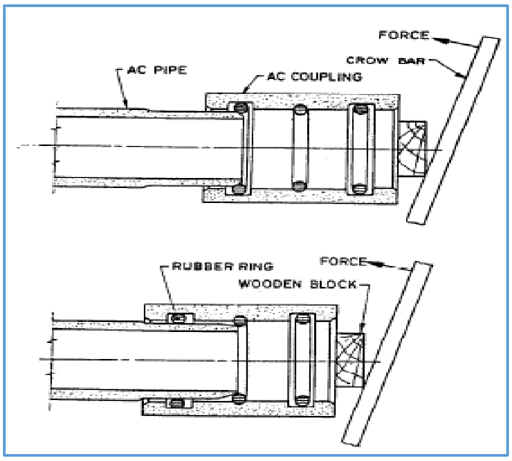


Figure 5: Cast Iron Detachable Joints Figure 6: Asbestos Cement Coupling Joint

1.4.7.2.3 Fittings

Asbestos cement pipes always absorb a certain amount of water. Therefore, after the line is filled, it should be allowed to stand for 24 hrs before pressure testing, and the line shall be again filled.

When a fitting is used to make a vertical bend, it shall be anchored to, a concrete thrust block designed to have enough weight to resist the upward and outward thrust. Similarly, at joints, deflected in vertical plane, it shall be ensured that the weight of the pipe, the water in the pipe and the weight of the soil over the pipe provide resistance to upward movement. If it is not enough, ballast or concrete shall be placed around the pipe in sufficient weight to counteract the thrust.

Pipes on the slope need to be anchored only when there is a possibility of the backfill around the pipe sloping down the hill and carrying the pipe with it. Generally, for slopes up to 30^0 good well drained soil, carefully tampered in layers of 100 mm under and over the pipe, right up to the top of the trench will not require anchoring.

Normally when pipeline is laid, a certain number of cast iron fittings such as tees, bends, reducers etc, and special fittings such as air and sluice valves are required. All cast iron fittings shall be plain ended to suit the outside diameter of asbestos cement pressure pipes and to the class and diameter of pipe manufactured. When using such cast iron fittings, they are jointed by cast iron detachable joints only. For any cast iron specials having flanges, they are jointed in the pipeline with cast iron flange adaptors having one end flanged and the other plain ended.

1.4.7.3 Testing of the Pipelines

After all sections have been jointed together on completion of section testing, a test on the complete pipeline should be carried out. This test should be carried out at a pressure not less than the working pressure of the pipeline, care being taken to ensure that the pressure at the lowest point in the pipeline does not exceed the maximum. During the test, an inspection should be made of all work which has not been subjected to sectional tests. The test pressure shall be gradually raised at the rate of approximately one kg/cm^3/min. The duration of the test period if not specified shall be sufficient to make a careful check on the pipeline section. After the test has been completed, the trench shall be filled back.

The procedure for the pressure testing as adopted is as follows:

a) At a time one section of the pipeline between two sluice valves is taken up for testing. The section usually taken is about 500 meters long.
b) One of the valves is closed and the water is admitted into the pipe through the other, manipulating air valves suitably. (If there are no sluice valves in between the section, the end of the section can be sealed temporarily with an end cap having an outlet which can serve as an air relief vent of for filling the fine as may be required. The pipeline after it is filled should be allowed to stand for 24 hours before pressure testing).
c) After filling, the sluice valve is closed and the pipe section is isolated.
d) Pressure gauges are fitted at suitable intervals on the crown into the holes meant for the purpose.
e) The pipe section is then connected to the delivery side of a pump through a small valve.
f) The pump is then operated till the pressure inside reaches the designed value which can be read from the pressure gauges fixed.
g) After the required pressure has been attained, the valve is closed and the pump disconnected.
h) The pipe is then kept under the desired pressure during inspection for any defect, i.e. leakages at the joints etc. The water will then be emptied through scour valves and defects observed in the test will be rectified.

1.4.7.4 Advantages & Disadvantages

The advantages of pipe are:

- The inside surface of pipe is smooth.
- The joining of pipes is very good and flexible.
- The pipes are anti-corrosive and cheap in cost.
- Light in weight to handle and transport.
- Least storage cost as it can be stored in open space at work site and also anti-theft due to its no resale value.

The disadvantages of pipe are:

- Not suitable for black cotton soil and sulphate contain soil.
- Cannot be used in hilly areas.

1.4.8 Reinforced Cement Concrete Pipes (RCC)

1.4.8.1 General

RCC pipes used in water supplies are classified as P1, P2 and P3 with test pressures of 2.0, 4.0, and 6.0 Kg/cm^2 respectively. For use as gravity mains, the working pressure should not exceed 2/3 of the test pressure. For use as pumping mains, the working pressure should not exceed half of the test pressure.

Generally concrete pipes have corrosion resistant properties similar to those of prestressed concrete pipes although they have their own features which significantly affect corrosion performance. Reinforced concrete pipes either spun or vibrated cast shall be designed such that the maximum tensile stress in the circumferential steel due to specified hydrostatic test pressure does not exceed the limit of 125 N/mm^2 in the case of mild steel rods, 140 N/mm^2 in the case of hard-drawn steel wires and high strength deformed steel bars and wires. Concrete pipes are made by centrifugal spinning of vibratory process. Centrifugally spun pipes are subjected to high rotational forces during manufacture with improved corrosion resistance properties. The line of development most likely to bring concrete pressure pipes into more general acceptance is the use of P.S.C. pipes which are widely used to replace reinforced concrete pipes.

1.4.8.2 Laying and Jointing

1.4.8.2.1 Laying

The concrete pipes should be carefully loaded, transported and unloaded avoiding impact. Free working space on either side of the pipe shall be provided in the trench which shall not be greater than 1/3 the dia of the pipe but not less than 150mm on either side. Pipes should be lowered into the trench with tackle suitable for the weight of pipes, such as well-designed shear slings with chain block or mobile crane. While lifting, the position of the sling should be checked when the pipe is just clear off the ground to ensure proper balance.

Laying of pipes shall proceed upgrade of a slope. If the pipes have spigot and socket joints the socket ends shall face upstream. The pipes shall be joined in such a way to provide as little unevenness as possible along the inside of the pipe. Where the natural foundation is inadequate, the pipes shall be laid in a concrete cradle supported on proper foundation or any other suitably designed structure. If a concrete cradle is used, the depth of concrete below the bottom of the pipes shall be at least ¼ the internal diameter of pipe with the range of 100mm to 300mm. It shall extend upto the sides of the pipe at least to a distance of ¼ the dia for larger than 300mm.

The pipe shall be laid in the concrete bedding before the concrete has set. Trenches shall be back filled immediately after the pipe has been laid to a depth of 300 mm above the pipe subject to the condition that the jointing material has hardened (say 12 hours at the most). The backfill material shall be free from boulders, roots of trees etc. The tamping shall be by hand or by other hand operated mechanical means. The water content of the soil shall be as near the optimum moisture content as possible. Filling of trench shall be carried on simultaneously on both sides of the pipe to avoid development of unequal pressures. The back fill shall be rammed in 150 mm layers upto 900 mm above the top of the pipe.

Where gradient steeper than 1 in 6 is contemplated consideration should be given to the construction of suitable transverse anchor blocks. For gradients between 1 in 7 and 1 in 12, the need for transverse anchor blocks will depend on ground conditions. For slopes flatter than 1 in 12, there is seldom need to provide anchor blocks.

1.4.8.2.2 Jointing

Joints may be of any of the following types

(i) Bandage joint
(ii) Spigot and socket joint (rigid and semi-flexible)
(iii) Collar joint (rigid and semi-flexible)
(iv) Flush joint (internal and external)

In all pressure pipelines, the recesses at the ends of the pipe shall be filled with jute braiding dipped in hot bitumen. The quantity of jute and bitumen in the ring shall be just sufficient to fill the recess in the pipe when pressed hard by jacking or any other suitable method.

The number of pipes that shall be jacked together at a time depends upon the dia of the pipe and the bearing capacity of soil. For small pipe upto 250mm dia, six pipes can be jacked together at a time. Before and during jacking, care should be taken to see that there is no offset at the joint.

Loose collar shall be set up over the joint so as to have an even caulking space all round and into this caulking space shall be rammed 1:1.5 mixture of cement and sand just sufficiently moistened to hold together in the form of a clod when compressed in the hand. The caulking shall be so firm that it shall be difficult to drive the point of a penknife into it. The caulking shall be employed at both the ends in a slope of 1:1. In the case of non-pressure pipes the recess at the end of the pipes shall be filled with cement mortar 1: 2 instead of jute braiding soaked in bitumen. It shall be kept wet for 10 days for maturing.

1.4.8.2.2.1 Rigid Joints

In this, the water seal is affected by cement mortar or similar material which will not allow any movement between the two pipes.

Socket and Spigot Joint : The annular space between socket and spigot is filled with cement mortar (1:2). This joint is used for low pressure pipeline.

Collar Joint : Collars of 150 to 200 mm wide cover the joint between two pipes. A slightly damp mixture of cement and sand is rammed with caulking tool.

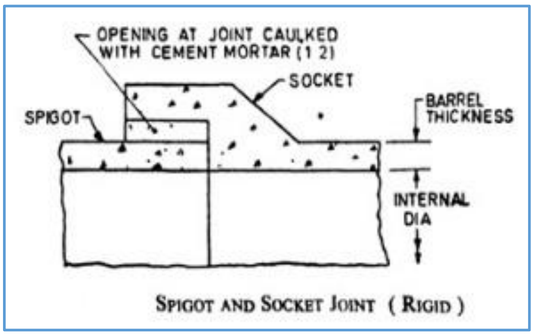


Figure 7: Spigot and Socket Joint

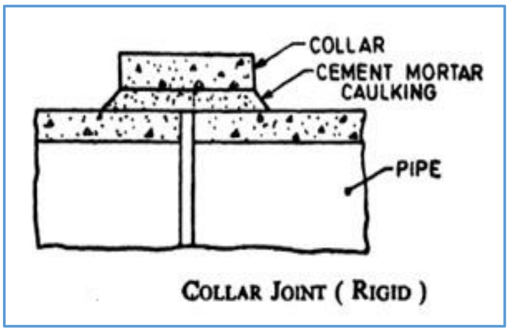
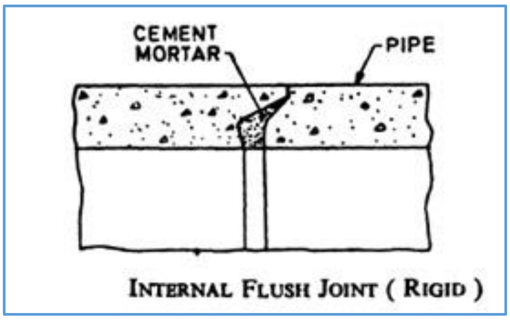


Figure 8: Collar Joint (Rigid)

Flush Joint

Internal Flush joint - This joint is generally used for culvert pipes of 900 mm diameter and over. The ends of the pipes are specially shaped to form a self-centring joint with an internal jointing space 1-3 cm wide. The finished joint is flush with both inside and outside with the pipe wall. The jointing space is filled with cement mortar mixed sufficiently dry to remain in position when forced with a trowel or rammer.

External Flush Joint - This joint is suitable for pipes which are too small for jointing from inside. Great care shall be taken in handling to ensure that the projecting ends are not damaged as no repairs can be readily effected from inside the pipe. Details of the joint are shown in figure below.



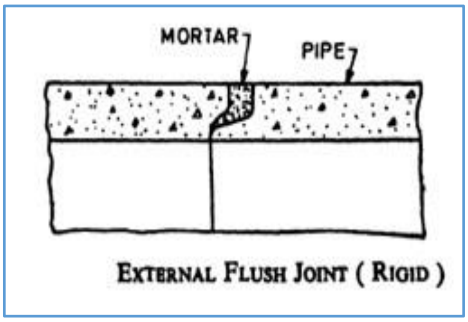


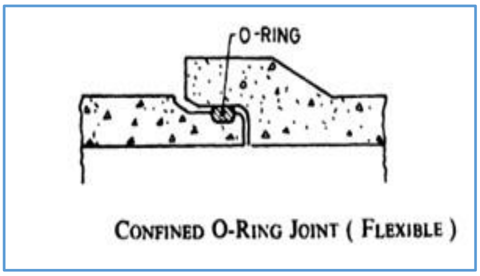
Figure 9: Internal and External Flush Joint

1.4.8.2.2.2 Flexible Joints

The water seal is effected because of compact pressure between the sealing rubber ring (or similar material) and the pipe surface. These are mainly two types.

Roll on Joint - A rubber ring (circular in cross-section) is placed at or near the end of the spigot and rolls along it as the spigot enters the socket.

Confined Gasket - Rubber ring of circular cross -section is held in the groove formed on the spigot. Sometimes, the cross-section is in the shape of lip. The lips are opened due to water pressure which ensures water seal. For assembly of this joint a lubricant has to be applied to the sliding surfaces. The lubricant washes off when the pipe is in service.



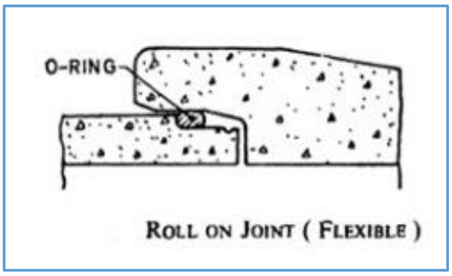


Figure 10: Confined O-ring joint and Roll on Joint

All pipelines should be tested before being brought into service. When testing the pipeline hydraulically, the line shall be kept filled completely with water for a week. The pressure shall then be increased gradually to full test pressure as indicated above at Testing of the Pipeline section under Cast Iron Pipe and maintained at this pressure during the period of test with the permissible allowance indicated therein. For concrete pipe testing, reference may be made to {IS 3597: 1998 (Reaffirmed 2018)}.

1.4.8.4 Advantages & Disadvantages

The advantages of pipe are

- Good corrosion resistance
- Widespread availability
- High Strength
- Good load supporting capacity

The disadvantages of pipe are

- Require careful installation to avoid cracking
- Heavy
- Susceptible to attack from aggressive soils
- Poor adaptability in installation

1.4.9 Prestressed Concrete Pipes (PSC)

1.4.9.1 General

While Reinforced Cement Concrete (RCC) pipes can cater to the needs where pressures are up to 6 kg/cm^2 and CI and steel pipes cater to the needs of higher pressures around 24 kg/cm^2, the Prestressed Concrete (PSC) pipes cater to intermediate pressure range, while RCC pipes would not be suitable.

The strength of a PSC pipe is achieved by helically winding high tensile steel wire under tension around a concrete core thereby putting the core into compression. When the pipe is pressurized the stresses induced relieve the compressive stress but they are not sufficient to subject the core to tensile stresses. The prestress wire is protected against corrosion by a surround of cementitious cover coat giving at least 18mm thick cover. The PSC pipes are suited for water supply mains where pressures in the range of 6 kg/cm^2 to 20 kg/cm^2 are encountered.

Two types of PSC pipes are in use:

(i) **Cylinder type:** Consists of a concrete lined steel cylinder with steel joint rings welded to its ends wrapped with a helix of highly stressed wire and coated with dense cement mortar or concrete. Prestressed Concrete Cylinder pipe has the following two general types of construction:
   a) a steel cylinder lined with a concrete core or
   b) a steel cylinder embedded in a concrete core.

In either type of construction, manufacturing begins with a full length welded steel cylinder. Joint rings are attached to each end and the cylinder is hydrostatically tested to ensure water-tightness. A concrete core with a minimum thickness of one-sixteenth times the pipe diameter, or as per IS 784-1983 (Reaffirmed 2018), is placed either by the centrifugal process, radial compaction, or by vertical casting. After the core is cured, the pipe is helically wrapped with high strength, hard drawn wire using a stress of 75 percent of the minimum specified tensile strength. The wrapping stress is calculated on the basis of 75% the value of minimum ultimate tensile strength as per IS 1785-2013. The wire spacing is accurately controlled to produce a predetermined residual compression in the concrete core. The wire is embedded in a thick cement slurry and coated with a dense mortar that is rich in cement content.

Size Range: Effective length of cylindrical pipe shall be upto 7.0m. However, for pipes of diameter upto and including 300mm, the effective length shall not exceed 3.0m. Nominal internal diameter for cylindrical pipes is varying from 200mm to 2500mm (IS 784-2019).

The technology for manufacture of these pipes is now available with some of the Indian manufacturers.

(ii) **Non cylinder type:** Consists of a concrete core which is pre-compressed both in longitudinal and circumferential directions by a highly stressed wire. The wire wrapping is protected by a coat of cement mortar or concrete.

Physical behaviour of PSC pipes under internal and external load is superior to RCC pipes. The PSC pipe wall is always in a state of compression which is the most favourable factor for permeability. These pipes can resist high external loads. The protective cover of cement and mortar which covers the tensioned wire wrapping by its ability to create and maintain alkaline environment around the steel inhibits corrosion. PSC pipes are joined with flexible rubber rings.

The deflection possible during laying of main is relatively small and the pipes cannot be cut to size to close gaps in the pipeline. Special closure units (consisting of a short double spigot piece and a plain ended concrete lined/ anti-corrosive food grade paint steel tube with a follower-ring assembled at each end) are manufactured for this purpose. The closure unit (minimum length 1.27m) must be ordered specially to the exact length.

Specials such as bends, bevel pipes, flanged tees, tapers and adapters to flange the couplings are generally fabricated as mild steel fittings lined and coated with concrete/ anti corrosive food grade paint. It is worthwhile when designing the pipeline to make provision for as many branches as are likely to be required in the future and then to install sluice valves or blank flanges on these branches. It is possible to make connections to the installed pipeline by emptying, breaking out and using a special closure unit.

1.4.9.2 Laying and Jointing

PSC pressure pipes are provided with flexible joints, the joints being made by the use of rubber gasket. They have socket spigot ends to suit the rubber ring joint. The rubber gasket is intended to keep the joint water tight under all normal conditions of service including expansion, contraction and normal earth settlement. The quality of rubber used for the gasket should be waterproof, flexible and should have a low permanent set.

Unless otherwise specified, joints between pipes shall be of spigot and socket type with rubber ring or with steel joint rings embedded at ends for site welding. In case of pipes for culverts, joints may be spigot and socket, roll on gasket joint, confined gasket joint or flush joint. The rubber ring joint design shall take into consideration the tolerance for rubber cord, tolerance for socket and spigot diameters, allowable deflection at joint and permanent set in the rubber ring.

The sealing rings shall be of such size that when jointed, it shall provide a positive seal within the recommended range of maximum joint deflection not more than two splices in each ring shall be permitted.

The steel for fabricated steel plate specials, is cut, shaped and welded so that the finished special has the required shape and internal dimension. Adjacent segments are jointed by butt welding. Before lining and coating, the welding of specials shall be tested by use of hot oil or dye penetrant according to IS 3658: 1999, Reaffirmed 2020 and defects, if any shall be rectified. The steel plate thickness for specials shall be as given in IS 1916. In die penetration test, a white wash is applied over the weld on one side of the cylinder, on other side when coloured paraffin or similar product is applied over the weld, no coloured spot shall appear on the whitewash before 4 hrs if any coloured spots appear before 4 hrs, weld shall be repaired and retested.

The special shall be jointed to the pipe by same rubber ring joint as for pipes or by caulking with mortar. For this purpose, steel collars shall be welded to steel specials to allow caulking of joint with mortar. This is allowed only upto working pressure of 3kg/cm^2.

1.4.9.3 Testing of Pipelines

The pressure testing of PSC pipes is the same as mentioned above at Testing of the Pipeline section under Cast Iron Pipe. However, the quantity of water added in order to re-establish the test pressure should not exceed 3 litres (instead of 0.1 litres) per mm dia, per km per 24 hours per 30m head for non-absorbent pipes as per the {IS 783:1985, Reaffirmed 2022}.

1.4.9.4 Advantages & Disadvantages

The advantages of pipe are:

- Good corrosion resistance
- Widespread availability
- High Strength
- Good load supporting capacity

The disadvantages of pipe are:

- Require careful installation to avoid cracking
- Heavy
- Susceptible to attack from aggressive soils
- Poor adaptability in installation

1.4.10 Bar/Wire Wrapped Steel Cylinder Pipes with Mortar Lining and Coating

1.4.10.1 General

Bar/Wire Wrapped Steel Cylinder Pipes with Mortar Lining and Coating are available in diameters of 250 mm to 1900 mm and higher diameter pipes can be designed for working pressures upto 25 kgs/cm^2. Effective length of pipes shall be 4m to 8m. Longer length pipes can also be custom made. The manufacturer shall declare the length of pipe for any given design and the tolerance shall be applicable to that.

Manufacture of Bar/ Wire Wrapped Steel Cylinder Pipes with Mortar Lining and Coating begins with fabrication of a thin steel pipe cylinder. Thicker steel joint rings are welded at both ends. Each pipe is hydrostatically tested. A cement mortar lining is placed by centrifugal process inside the cylinder. After the lining is cured by steam or water, mild steel rod is wrapped on the cylinder using moderate tension in the bar. The wrapping is to be done under controlled tension ensuring intimate contact with the cylinder. The cylinder and bar wrapping are covered with a cement slurry and a dense mortar coating that is rich in cement. The coating is cured by steam or water.

A welded steel sheet cylinder, which may be with steel socket and spigot rings welded to its ends for rubber ring joints or with steel rings welded to its ends for welded joints, lined with cement mortar centrifugally applied within the steel cylinder and spigot ring, with reinforcement consisting of continuous steel bar/wire helically wound around the outside of the cylinder and securely fastened by welding to the steel socket and spigot/ joint rings, and subsequently coated with dense cement mortar covering the steel cylinder and bar/wires except for necessarily exposed socket and spigot joints rings.

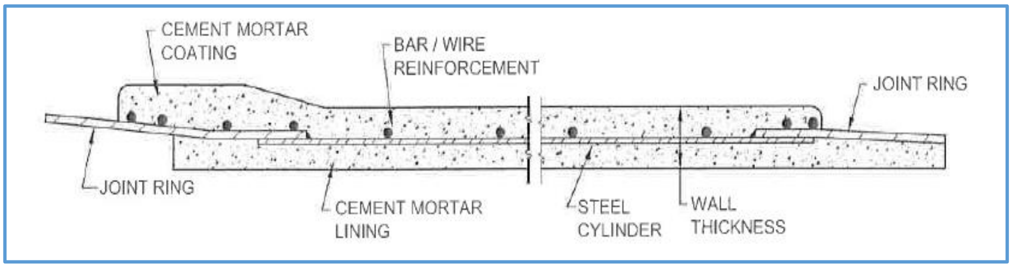


Figure 11: Typical Longitudinal Section

The purchaser may specify the application of an external or internal bituminous epoxy or other approved coating to be applied. When the pipes are to be used for carrying potable water, the inside lining shall not contain any constituents soluble in such water or any ingredient which could impart any taste or odour to the potable water.

1.4.10.2 Laying and Jointing

The standard joint consists of steel joint rings and a continuous solid rubber ring gasket. The field joint can be over lapping/sliding, butt welded or with confined rubber ring as per the client’s requirement. In the case of welded & rubber joints, the exterior joint recess is normally grouted and the internal joint space may or may not be pointed with mortar.

The wall thickness shall not be less than the design thickness by more than 5 percent or 5 mm whichever is greater. The manufacturer shall declare the wall thickness for any given design. Tolerance on length of pipe shall be +2.5 percent and -1 percent of the specified length. The cement mortar coating shall provide a minimum cover of 19 mm over the bar/ wire reinforcement or 25 mm over the cylinder, whichever is greater. (as per IS 15155:2020).

1.4.10.3 Testing of Pipelines

Hydrostatic Test for Steel Cylinder of Pipe - Each steel cylinder, with joint rings welded to its ends, shall be tested by the manufacturer to a hydrostatic pressure not less than that determined by the following formula:

$$P = \frac{2St_y}{D_{yi}} \qquad (1.12)$$

Where:

P= Minimum hydrostatic test pressure, N/mm^2;

S= Stress in pipe wall during hydrostatic test, N/mm^2, which shall be 0.75 times the specified minimum yield stress of the steel used, or as specified by the purchaser;

t_y= Cylinder thickness, mm; and

D_{yi} = Inside diameter of steel cylinder, mm.

The test pressure shall be held for 1 min to observe the weld seams. There shall be no leaks. Any leaks in the welded seam, shall be repaired, after which the pipe section shall be re-tested hydrostatically. If on re-test a section shows any leaks in the welded seams, it shall be repaired and re-tested. Surge pressure is to be controlled within 25 percent of pump head.

1.4.10.4 Advantages and Disadvantages

The advantages of pipe are:

- Pipes are having semi-rigid or semi-metallic properties and resistant to impact.
- Stiffer than conventional steel pipes
- Less expensive bedding cost than and side support required
- Corrugated surface increases its structural stability.
- Cheaper and low maintenance pipes.

The disadvantages of the pipe are:

- Heavier than pipes like DI, HDPE, DWC, PVC, GRP pipes which makes it difficult to handle.
- Rough handled may damage the outer coat or inner lining.

1.4.11 Plastic Pipes

Plastic pipes are produced by extrusion process followed by calibration to ensure maintenance of accurate internal diameter with smooth internal bores. These pipes generally come in lengths of 6 meters. A wide range of injection moulded fittings, including tees, elbows, reducers, caps, pipe saddles, inserts and threaded adapters for pipe sizes upto 200mm are available.

In house installations plastic pipes cannot be used for electrical earthing being a non-conductive material. In colder climates plastic pipes cannot be softened by conventional and electric equipment. Where pumps are used with plastics pipes, starting and stopping are the occasions when damage may occur. The water hammer causes compression of the water in the pipe and consequently results in stretching of the pipe and where necessary, pressure relief devices should be included in the pipe lines. Accurate records of laying of plastic pipes are very essential as they cannot be located by conventional electronic pipe locators.

In order to take care of the possible deteriorating effect by direct sunlight, it should be prevented by direct exposure to sunlight. For carefully executed installations using properly manufactured plastic pipes, no taste and odour problems should normally be encountered while in operation. The quality of plastic pipes should also be checked for its suitability from bacteriological point of view.

1.4.11.1 PVC Pipes

1.4.11.1.1 General

The PVC pipes are much lighter than conventional pipe materials. Because of their lightweight, PVC pipes are easy to handle, transport, and install. Solvent cementing technique for jointing PVC pipe lengths is cheaper, more efficient and far simpler. PVC pipes do not become pitted or tuberculated and are unaffected by fungi and bacteria and are resistant to a wide range of chemicals. They are immune to galvanic and electrolytic attack, a problem frequently encountered in metal pipes, especially when burned in corrosive soils or near brackish waters. PVC pipes have elastic properties and their resistance to deformation resulting from earth movements is superior compared to conventional pipe materials especially AC. Thermal conductivity of PVC is very low compared to metals. Consequently, water transported in these pipes remains at a more uniform temperature.

Rigid PVC pipes weigh only 1/5th of conventional steel pipes of comparable sizes. PVC pipes are available in sizes of outer dia. 20, 25, 32, 50, 63, 75, 90, 110, 140, 160, 250, 290, and 315mm at working pressures of 2, 5 ,4, 6, 10 Kg/cm^2 as per IS 4985 – 1988, Reaffirmed 2015. The wall of the plain pipe shall not transmit more than 0.2 percent of the visible light falling on it when tested in accordance with {IS 12235 (Part 1-19): 2004, Reaffirmed 2019}.

Since deterioration and decomposition of plastics are accelerated by ultraviolet light and frequent changes in temperature which are particularly severe in India, it is not advisable to use PVC pipes above ground. The deterioration starts with discolouration, surface cracking and ultimately ends with brittleness, and the life of the pipe may be reduced to 15-20 years.

Because of their lightweight, there may be a tendency for the PVC pipes to be thrown much more than their metal counterparts. This should be discouraged and reasonable care should be taken in handling and storage to prevent damage to the pipes. Under no circumstances, pipes should be dragged along the ground. Pipes should be given adequate support at all times. These pipes should not be stacked in large piles, especially under warm temperature conditions, as the bottom pipes may be structurally distorted thus giving rise to difficulty in pipe alignment and jointing. For temporary storage in the field, where racks are not provided, care should be taken that the ground is level, and free from loose stones. Pipes stored thus 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. It is advisable to follow the practices mentioned as per {IS 7634 (Part 1): 1975, Reaffirmed 2017} and {IS 7634 (Part 3):2003, Reaffirmed 2018}.

1.4.11.1.2 Laying and Jointing

1.4.11.1.2.1 Laying

The trench bottom should be carefully examined for the presence of hard objects such as flints, rock, projections or tree roots. In uniform, relatively soft fine grained soils found to be free of such objects and where the trench bottom can readily be brought to an even finish providing a uniform support for the pipes over their lengths, the pipes may normally be laid directly on the trench bottom. In other cases, the trench should be cut correspondingly deeper and the pipes laid on a prepared under-bedding, which may be drawn from the excavated material if suitable.

The trench bed must be free from any rock projections. The trench bottom where it is rocky and uneven a layer of sand or alluvial earth equal to 1/3 dia of pipe or 100mm whichever is less should be provided under the pipes.

As a rule, trenching should not be carried out too far ahead of pipe laying. The trench should be as narrow as practicable. This may be kept from 0.30m over the outside diameter of pipe and depth may be kept at 0.60-1.0m depending upon traffic conditions. Pipe lengths are placed end to end along the trench. The glued spigot and socket jointing technique as mentioned later is adopted. The jointed lengths are then lowered in the trench and when sufficient length has been laid, the trench is filled.

In laying, long lengths of pipe, prefabricated double socketed connections are frequently used to join successive pipe lengths of either the same or one size different. The socket in this case must be formed over a steel mandrel. A short length of pipe is flared at both ends and used as the socket connection. The mandrel used is sized such that the internal dia. of the flared socket matches the outer dia. of the spigot to be connected.

If trucks, lorries, or other heavy traffic will pass across the pipeline, concrete tiles 600x 600mm of suitable thickness and reinforcement should be laid about 2.0m above the pipe to distribute the load. If the pipeline crosses a river, the pipe should be buried at least 2.0m below bed level to protect the pipe. Individual pedestal approach may also be followed in case of long stretch of the river. The pipeline may also be laid down attached with the bridge piers across the river.

For bending, the cleaned pipe is filled with sand and compacted by tapping with wooden stick and pipe ends plugged. The pipe section is heated with flame and the portion bent as required. The bend is then cooled with water, the plug removed, the sand poured out and the pipe (bend) cooled again. Heating in hot air over hot oil bath, hot gas or other heating devices are also practiced. Joints may be heat welded, or flamed or with rubber gaskets or made with solvent cement. Threaded joints are also feasible but arc not recommended.

1.4.11.1.2.2 Jointing

Socket and spigot joint is usually preferred for all PVC pipes upto 150mm in dia. The socket length should at least be one and half times the outer dia. for sizes upto 100mm dia. and equal to the outer dia. for larger sizes.

Jointing of PVC pipes can be made in following ways:

(i) Solvent cement
(ii) Rubber ring joint
(iii) Flanged joint
(iv) Threaded joint

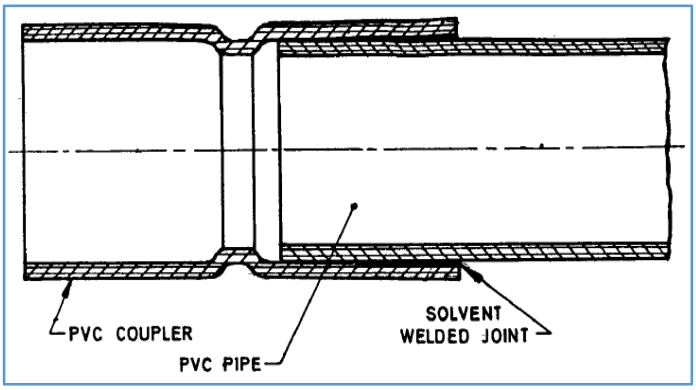


Figure 12: PVC Solvent Welded Joint

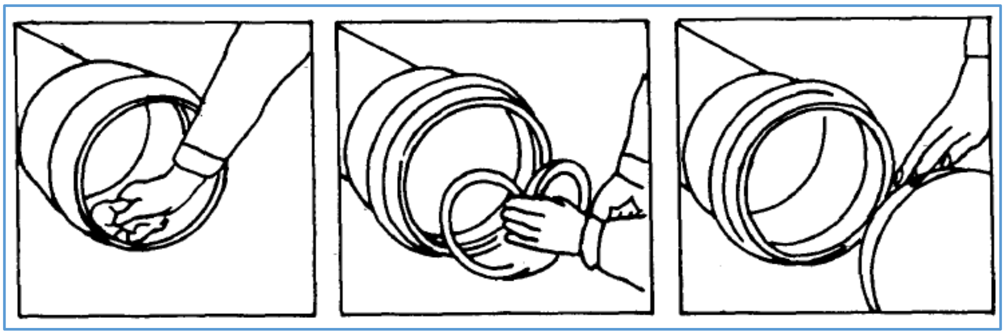


Figure 13: Sealing Ring Joint Assembly

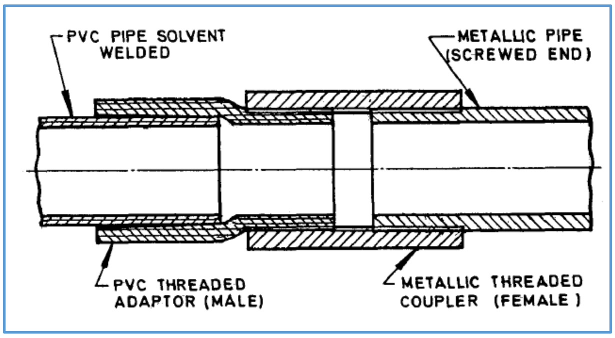


Figure 14: Threaded Joints with PVC

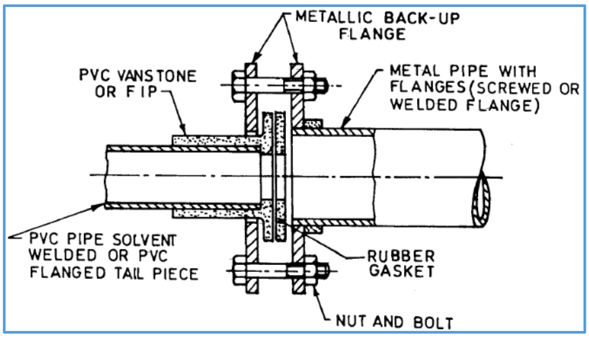


Figure 15: Flanged Joints with PVC

For pipe installation, solvent gluing is preferable to welding. The glued spigot socket connection has greater strength than can ever be achieved by welding. The surfaces to be glued are thoroughly scoured with dry cloth and preferably chamfered to 30^o. If the pipes have become heavily contaminated by grease or oil, methylene cement is applied with a brush evenly to the outside surface of the spigot on one pipe and to the inside of the socket on the other. The spigot is then inserted immediately in the socket upto the shoulder and thereafter a quarter (90^o) turn is given to evenly distribute the cement over the treated surface. The excess cement which is pushed out of the socket must be removed at once with a clean cloth. Jointing must be carried out in minimum possible time, time of making complete joint not being more than one minute. Joints should not be disturbed for at least 5 minutes. Half strength is attained in 30 minutes and full in 24 hours. Gluing should be avoided in rainy or foggy weather, as the colour of glue will turn cloudy and milky as a result of water contamination.

Normally, PVC pipes should not be threaded. For the connections of PVC pipes to metal pipes, a piece of a special thick wall PVC connecting tube threaded at one end is used. The other end is connected to the normal PVC pipe by means of a glued spigot and socket joint. Before installation, the condition of the threads should be carefully examined for cracks and impurities. Glue can be used for making joints leak proof. Yarn and other materials generally used with metal pipe and fittings should not be used. Generally, it is advisable to use PVC as the spigot portion of the joint.

For further details on laying & jointing of PVC pipes, reference may be made to {IS 4985 -2000, Reaffirmed 2015}, {IS 7634 (Part 1):1975 Reaffirmed 2017}, {IS 7634 (Part 2): 2012, Reaffirmed 2017], {IS 7634 (Part 3):2003, Reaffirmed 2018}.

1.4.11.1.3 Testing of pipelines

The pressure testing method which is commonly in use is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as same as mentioned above at testing of the pipeline section under cast iron pipe.

After the specified test time has elapsed, usually one hour, a measured quantity of water is pumped into the line to bring it to the original test pressure, if there has been loss of pressure during the test. The pipe shall be judged to have passed the test satisfactorily if the quantity of water required to restore the test pressure of 30m for 24 hours does not exceed 1.5 litres per 10 mm of nominal bore for a length of 1.0 Km.

1.4.11.1.4 Advantage and Disadvantage

The advantages of pipe are:

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

The disadvantages of pipe are:

- Deteriorating effect by direct sunlight
- Water hammer causes stretching of the pipe
- Non-conductive material

1.4.11.2 Unplasticized Polyvinyl Chloride (UPVC) Pipes

1.4.11.2.1 General

The UPVC pipe is a plastic pipe made of polyvinyl chloride (PVC) resin and containing no plasticizer. Plastics belong to the group of newer pipe materials. With the development of chemical industry technology, it is now able to produce non-toxic grade pipes, so it has the function of usually polyvinyl chloride, and it has added some excellent functions, specifically its corrosion resistance and softness, so it is especially suitable for water supply networks. UPVC pipes are highly economical in comparison to pipes made from other materials. Plastic pipes offer high corrosion resistance to aggressive chemical media. Moreover, due to very smooth surfaces, the pipes are not prone to crust formation on the internal surface, which can have a detrimental effect on the water carrying capacity of the pipe. The pipes shall not have any detrimental effect on the composition of water flowing through them.

Pipes made from cast iron, fabricated steel and other materials are in use for a long time in various applications. Pipes for supplying drinking water are mostly made of polyethylene (PE) or polyvinyl chloride (PVC). Unplasticised PVC pipes are greatly used for transportation of water. It is an extruded product from a blend of polymer resin and various additives.

1.4.11.2.2 Laying & Jointing

1.4.11.2.2.1 Laying

Prolonged exposure of the pipes to sunlight must be avoided. Pipes must be protected from ultra-violet light (sunlight), which would otherwise cause discoloration and can reduce the impact strength of the pipe.

The depth of the trench shall be minimum 1.0m. The width of the trench should be uniform throughout the length and greater than the outside diameter of the pipe by 300mm on either side of the pipe. It should be ensured that the pipe have been laid along the central line of the trench. The trench bottom shall be constructed to provide a firm, stable and uniform support for the full length of the pipeline. There should not be any sharp objects on the trench surface while laying the pipeline. Any large rocks, hard pan, or stones larger than 20 mm should be removed to permit a minimum bedding thickness of 100-150 mm under the pipe.

Place the pipe and fittings into the trench using ropes or by hand or mechanical means. The pipes should not be thrown into the trench or allow any part of the pipe to take an unrestrained fall onto the trench bottom.

Laying of the pipes in the trench after ensuring that bell holes have been provided for at the appropriate places in the bedding (pipes of diameter 110 mm or less, with no live load application, do not require bell holes in the trench bottom). The trenches should be refilled carefully after testing of the pipeline. The pipes should be laid with the spigots entered into the sockets in the same direction as the intended flow of water.

1.4.11.2.2.2 Jointing

Commonly used joints are (i) Solvent welded joints; (ii) Elastomeric sealing ring joints;

(iii) Mechanical compression joints; (iv) Flanged joints; (v) Screwed or threaded joints; and (vi) Union coupled joints.

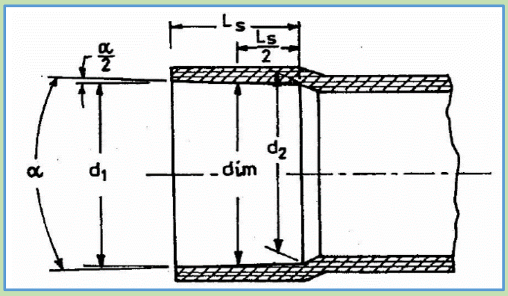
Sockets formed on the ends of the pipes shall be reasonably parallel to the axis of the pipe. The minimum length of any socket shall be given by the expression

$$L_s = 0.5dn + 6mm \qquad (1.13)$$

where

L = minimum socket length, and

dn = nominal outside diameter of the pipe.



Where

D_{im} = diameter at mid-point of socket length;

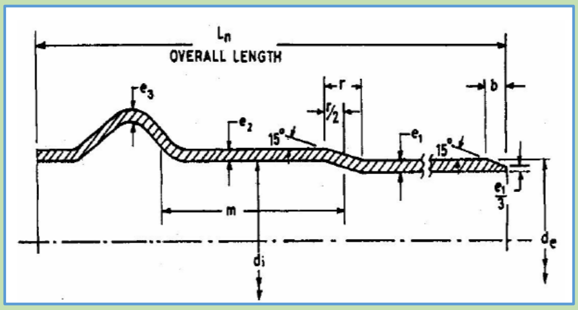
D_1 = diameter at mouth;

D_2 = diameter at root;

L_s = socket length; and

α = total included angle of taper

Figure 16: Socket Dimensions for Solvent Cement Joints



Where

m = minimum depth of engagement;

D_e = outer diameter at any point; and

D_i = inner diameter of socket, measured at mid-point of socket length, m

Figure 17: Sockets for use with Elastomeric Sealing Rings

The ends of the pipes meant for solvent cementing (both plain and bell ended) shall be cleanly cut and shall be reasonably square to the axis of the pipe or may be chamfered at the plain end. Pipes with plain end(s) to be used for elastomeric sealing ring type joints shall be chamfered at approximately 15^{o} to the axis of the pipe. Approximately two thirds of the full wall thickness shall be chamfered.

1.4.11.2.3 Testing of pipelines

Pressure testing method which is commonly in use is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as mentioned in IS 4985: 2000, Reaffirmed 2015.

1.4.11.2.4 Advantages & Disadvantages

The advantages of pipe are

- Very lightweight
- Easy to install
- Economical
- Good corrosion resistance
- Smooth surface reduces friction losses
- Long pipe sections reduce leakage/ infiltration potential
- Flexible

The disadvantages of pipe are

- Susceptible to chemical attack especially solvents
- Strength affected by sunlight
- Not suitable for above ground installations
- Require great care during laying
- Susceptible to damages due to external pressure and blows in above ground level application.

1.4.11.3 Oriented Polyvinyl Chloride (OPVC) Pipes

1.4.11.3.1 General

Amorphous polymer of PVC in which the molecules are located randomly. However, under certain conditions of pressure, temperature, and speed by stretching the material, it is possible to orient the polymer molecules in the same direction. The result is a plastic with a layered structure called as Oriented Poly vinyl chloride Pipes of highest Orientation Class 500 with homogeneous Socket Elastomeric sealing ring.

It is a new technology for manufacturing pipes, which involves process of controlling circumferential and axial orientation of molecular structure resulting in formation of laminar structure of the material used in the pipe construction, commonly named as Oriented - Polyvinyl Chloride (OPVC). It is manufactured as per Indian Standard IS 16647:2017. Manufacturing of pipes by this technology increases performance and strength of pipes.

The piping system is intended for the conveyance of cold water under pressure and is suitable for conveyance of water, including potable water, up to and including 45^{o}C and pressurized sewer systems especially in those applications where special performance requirements are needed, such as impact loads and pressure fluctuations, up to pressure of 2.5 MPa. The pipes are manufactured for the different sizes in India i.e. 110mm, 160mm, 200mm, 250mm, 315mm and 400mm with pressure ratings of PN 12.5, PN 16, PN 20 and PN 25. Proper fittings (PVC-O fittings or metal fittings compatible with PVC-O pipes) should be used with PVC-O pipes for better performance.

The material from which the pipe is produced shall consist substantially of unplasticized polyvinyl chloride to which may be added only those additives that are needed to facilitate the manufacture of the pipe and the production of sound and durable pipe of good surface finish, mechanical strength and opacity under conditions of use. Store the pipes horizontally on a flat surface and place supports every 1.5 m to avoid the bending of the product. Do not stack pipes more than 1.5 m height, as this can damage lower pipes or even the upper pipes can fall.

1.4.11.3.2 Laying & Jointing

When checked without magnification glass, the internal and external surfaces of the pipe shall be smooth, clean, and free from scoring, cavities and other surface defects. The ends of the pipe shall be either cut cleanly and reasonably square to the axis of the pipe or chamfered at the plain end at approximately 15° to the axis of the pipe. The pipes shall be supplied with the length not less than the declared nominal pipe length. It is recommended that the nominal pipe length to be supplied may be 6m, 10m and 12m. The pipes may be supplied in other lengths where so agreed upon between the manufacturer and the purchaser.

Before placing the pipe, a sand bed should be prepared (a fine granular material may be used instead of sand) with a thickness from 10 cm to 15 cm. The pipe should be well aligned and levelled. The trench shall be free of stones at the bottom and at the sides. Stones smaller than 10 - 20 mm are allowed, but it cannot be the main size of the ground particles. The pipe shall lie on the sand bed. Once the pipe is placed, chamberlain sides shall be filled with the selected material and compacted to achieve >95 percent Proctor normal (P.N.). The trench shall be filled with the selected material and compacted laterally until the upper part of the pipe is buried at least 30 cm. Minimum width of the trench based on nominal diameter of pipes to be laid and/or depth of trench is specified in {IS 16647: 2017}. As a rule of thumb, when there is no road traffic involved, the pipes crown will be at a minimum depth of 0.6 m; with road traffic, the minimum depth is 1.0m.

Assembly details are as under:

a. Remove the protection caps, if any.
b) Verify that the pipe is clean and in good condition. Paying attention to the sockets and spigot ends.
c) Check that the chamfer is correct and free of cracks.
d) Verify that the seal is in its place, clean and free of foreign materials (stones, sand, etc).
e) Lubricate the chamfer of the spigot and the seal with joint lubricant.

f) Line up the pipe as much as possible horizontal and vertically.

g) Insert only the chamfer edge of the socket, just to support the pipe but leaving the socket lip free.

h) In the case of pipes with nominal diameter ≤250 mm, a firm and dry push should be given to seize the momentum produced by the free movement in the lip of the socket and introduce it until the mark is hidden into the socket.

i) When installing diameters >250 mm, one should use mechanical means to introduce the pipe using materials such as wood, hoists, tackles or slings.

1.4.11.3.3 Testing of pipelines

Testing shall be performed only after the pipeline has been properly filled, flushed, and purged of all air. The specified test pressure shall be applied by means of an approved pumping assembly connected to the pipe properly and to prevent pipe movement, the contractor shall have placed enough backfill prior to filling and testing of the pipe. If necessary, the test pressure shall be maintained by additional pumping for the specified time during which the system and all exposed pipe, fittings valves and hydrants shall be carefully examined for leakage. All visible leaks shall be stopped. All defective elements shall be repaired or removed and replaced. The test shall be repeated until the test requirements have been met. Pressure testing method which is commonly in use is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as mentioned in (IS 16647: 2017).

Resistance to hydrostatic pressure shall be verified using the induced stresses derived from the analysis of the test data in accordance with (IS 16462:2017). For a period of 10 hrs. at 27^{o}C and 1000 hrs. at 27^{o}C, the 99.5 percent LPL value shall be taken as the minimum stress level. The test shall be carried out not earlier than 24 hrs. after the pipes have been manufactured. (IS 16647:2017)

1.4.11.3.4 Advantages & Disadvantages

The advantages of pipe are:

- <u>Greater lightness and easy handle:</u> The manufacturing system of the pipes delivers both health & safety and economic savings during the pipe installation process.
- <u>Excellent flexibility:</u> The high flexibility of the pipes enables withstanding large deformations without suffering structural damages.
- <u>Greater hydraulic capacity:</u> Between 15% - 40% higher than pipes made of other materials with the same outer diameter.
- <u>Higher chemical resistance:</u> PVC-O is immune to corrosion so it does not require any coating or special protection what would result in cost savings.
- <u>Higher hydrostatic resistance:</u> These pipes can endure internal pressures up to twice the nominal pressure conventional pipes can withstand.

- Higher resistance against water hammers: The lower celerity figure of the pipes virtually eliminates the possibility of breakages that can occur during the process of opening/closing valves or when starting pumping operations. This will also protect all the elements of the network against potential damages produced by water hammers.

The disadvantages of pipe are:

- Susceptible to chemical attack especially solvents
- Pipes are also suitable for above ground applications with suitable covering and proper anchoring as strength is affected by sunlight

1.4.11.4 Chlorinated Polyvinyl Chloride (CPVC) Pipes

1.4.11.4.1 General

The material from which the pipe is produced shall consist substantially of chlorinated polyvinyl chloride (CPVC) to which may be added only those additives that are needed to facilitate the manufacture of the pipe and the production of sound and durable pipe of good surface finish, mechanical strength and opacity under conditions of use.

The chlorinated polyvinyl chloride polymer from which the pipe compound is to be manufactured shall have chlorine content not less than 66.5 percent. The chlorinated polyvinyl chloride pipe compounds containing additives such as modifiers, lubricants, fillers, etc, from which the pipes are to be manufactured, shall have a density between 1450 kg/m^3 and 1650 kg/m^3, when tested in accordance with {IS-13360 (Part 3/ Sec1): 1995, Reaffirmed 2018}.

The outside diameter and outside diameter at any point shall be measured according to the method given in {IS 12235 (Part 1): 2004, Reaffirmed 2019}. The difference between the measured maximum outside diameter and measured minimum outside diameter in the same cross-section of pipe (also called tolerance on ovality) shall not exceed the greater of the following two values:

(a) 0.5 mm, and
(b) 0.012 dn rounded off to the next higher 0.1 mm.

The wall of the plain pipe shall not transmit more than 0.1 percent of the visible light falling on it when tested in accordance with IS 12235 (Part 3): 2004, Reaffirmed 2019. The ends of the pipes meant for solvent cementing shall be cleanly cut and shall be reasonably square to the axis of the pipe or maybe chamfered at the plain end.

1.4.11.4.2 Laying & Jointing

CPVC pipes of all sizes are packed in polyethylene packing rolls and both the ends of the, packed roll are sealed with air bubble film cap in order to provide protection during handling and transportation. Visually inspect pipe ends before making the joint. Use of a chamfering tool will help to identify any cracks, as it will catch on to any crack.

Pipe may be cut quickly and efficiently by several methods. Wheel type plastic tubing cutters are preferred. Ratchet type cutter or fine tooth saw are another options. However, when using the ratchet cutter be certain to score the exterior wall by rotating the cutter blade in circular motion around the pipe. Do this before applying significant downward pressure to finalize the cut. This step leads to a square cut. Cutting tubing as squarely as possible provides optimal bonding area within a joint.

When making a joint, apply a heavy, even coat of cement to the pipe end. Use the same applicator without additional cement to apply a thin coat inside the fitting socket. Do not allow excess cement to puddle in the fitting and pipe assembly. This could result in a weakening of the pipe wall and possible pipe failure when the system is pressurized.

When making a transition connection to metal threads, use a special transition fitting or CPVC male threaded adapter whenever possible. Do not over torque plastic threaded connections. Hand tight plus one-half turn should be adequate. Hang or strap CPVC systems loosely to allow for thermal expansion. Do not use metal straps with sharp edges that might damage the tubing.

1.4.11.4.3 Testing of Pipeline

When subjected to internal hydrostatic pressure test in accordance with the procedure given in {IS 12235 (Part 8): 2004, Reaffirmed 2019}, the pipe shall not fail during the prescribed test duration. The temperatures, duration and hydrostatic (hoop) stress for the test shall conform as per {IS 12235 (Part 8): 2004, Reaffirmed 2019}, the test shall be carried out not earlier than 24 hrs. after the pipes have been manufactured.

1.4.11.4.4 Advantages and Disadvantages

The advantages of pipe are:

- Light weight and easy for transportation;
- Requires fewer tools for installation and maintenance;
- Lack of plasticizers which discourages microbial growth;
- Corrosion and abrasion Resistance;
- Reground into pellets and recycled; and
- Reduces heat loss due to lower thermal conductivity.

The disadvantages of pipe are:

- High thermal expansion coefficient; and
- Slightly costlier than other PVC pipes.

1.4.11.5 Polyethylene Pipes

1.4.10.5.1 General

Among the recent developments is the use of High-Density Polyethylene pipes. These pipes are not brittle and as such a hard fall at the time of loading and unloading etc. may not do any harm to it. Polyethylene is a tough resilient material which may be handled easily. Abrasion resistance is much higher compared to Metal or concrete pipes. However, because it is softer than metals, it is prone to damage by abrasion and by objects with a cutting edge. The pipes are highly resistant to notches and scratches and therefore widely used in trenchless installation like Horizontal Direction Drilling (HDD) where damage possibility is very high, apart from joint integrity.

Polyethylene pipes incorporated with 2-2.5% of finely dispersed Carbon black has unlimited resistance against sunlight and can deliver lifetime service above ground. HDPE materials have excellent resistance against strong acids, alkalis and salts and most chemicals, which are commonly packed in HDPE drums and barrels. They do not undergo galvanic corrosion hence there is no need for any coating or cathodic protection. As there is no corrosion, the water quality in HDPE pipes is most secured as corrosion products do not get added to it.

1.4.11.5.2 Laying and Jointing

1.4.11.5.2.1 Laying

The pipe line may be laid alongside of the trench and jointed there outside the trench. Hence the trench size is relatively small (no man entry trench is needed), which saves lot of civil work, installation time and cost. There after the jointed pipeline shall be lowered into the trench carefully without causing undue bending. The pipeline shall be laid inside the trench with a slack of up to 2 m/100 m of pipe line. The trench depth should be OD+300mm.

Polyethylene pipe requires no special bed preparation for laying the pipe underground, sieved, excavated material is good enough, except that there shall be no sharp objects around the pipe. However, while laying in rocky areas suitable sand bedding should be provided around the pipe and compacted.

Polyethylene pipes are non-metallic, so once buried, metal detector type locators are ineffective. To facilitate locating a buried PE pipe, metallic locating tapes or copper wires can be placed alongside the pipe. Locating tapes/wires are placed slightly above the crown of the above before the final back fill.

1.4.11.5.2.2 Jointing

Polyethylene pressure piping systems jointed by butt welding, electro fusion and flanges do not require external joint restraints or thrust block joint anchors.

Commonly used joints are as follows:

(i) Fusion welding:
   a) Butt fusion welding;
   b) Socket fusion welding; and
   c) Electro fusion welding;

(ii) Insert type joints;

(iii) Compression fittings/push fit joints;

(iv) Flanged joints; and (v) Spigot and socket joints.

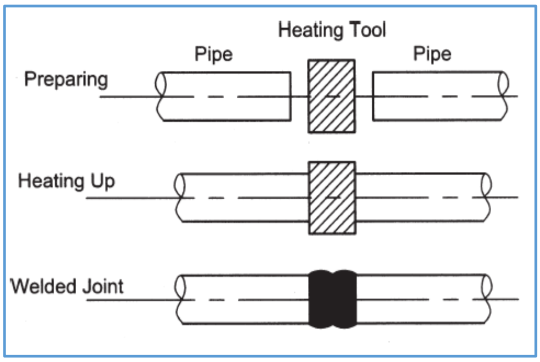
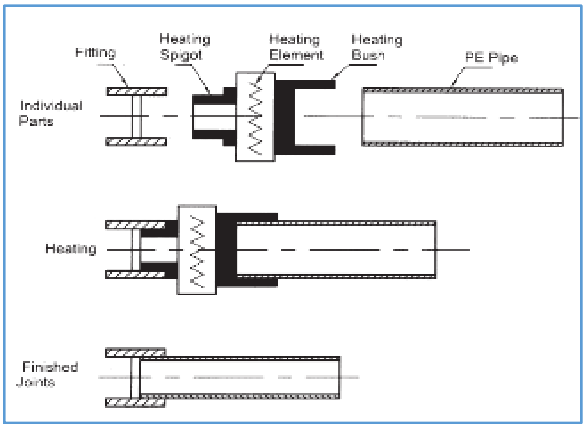


Figure 18: Butt Fusion Welding Procedure



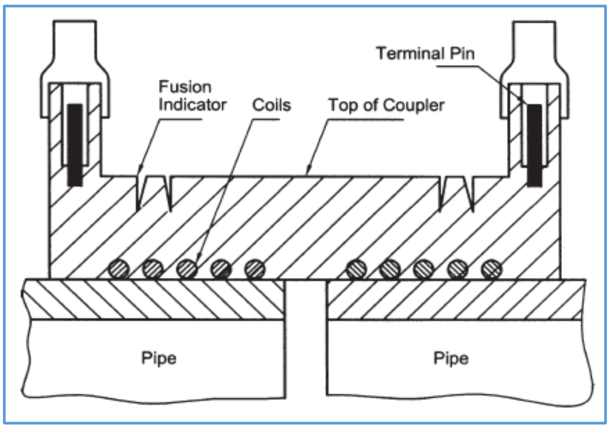
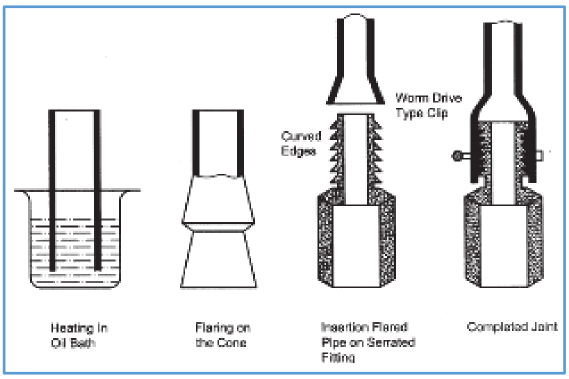


Figure 19: Socket Fusion Jointing Procedure   Figure 20: Electro Fusion Process



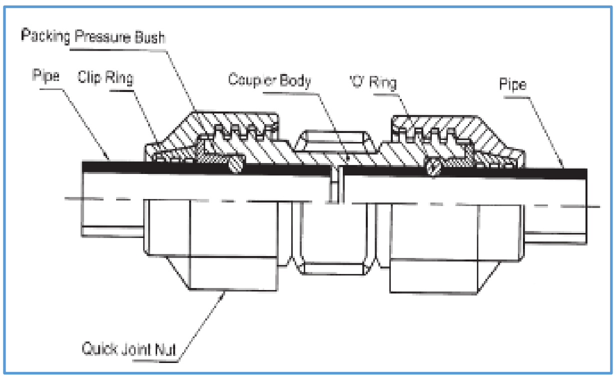


Figure 21: Insert Type Joints   Figure 22: Polypropylene Compression Coupler Socket

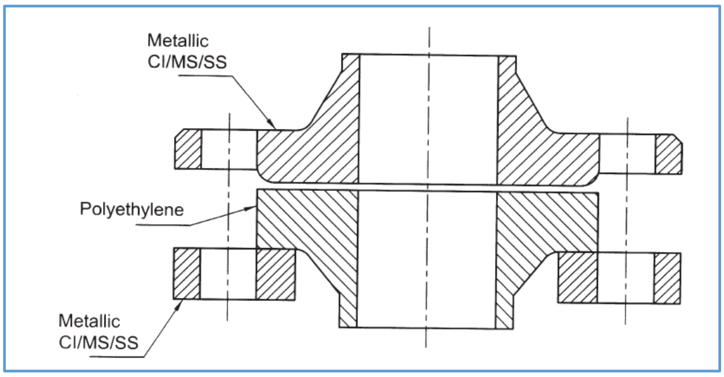


Figure 23: Typical Flanged Joint

1.4.11.5.3 Testing of pipelines

Pressure testing method which is commonly in use is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to appropriate test pressure. The pressure testing may be followed as mentioned in {IS 7634 (Part 2): 2012, Reaffirmed 2017}, {IS 4984:2016)}.

1.4.11.5.4 Advantages & Disadvantages

Advantages of pipe are:

- Cost effective, long term and permanent
- Flexible, fatigue, surge and crush resistant
- Supply in long coil or 12 m length to reduce jointing.
- Corrosion and chemical resistant.
- Light in weight, easy to install offshore by floatation.
- Pipes are recyclable.

Disadvantages of pipe are:

- Vulnerable to chemical exposure.
- Reduction in strength due to exposed sunlight.

1.4.12 High Density Polyethylene (HDPE) Pipes

1.4.12.1 General

HDPE pipe is a type of flexible plastic pipe used for water supply systems. It is made from the high density polyethylene) which is suitable for high pressure pipelines.

The material used for the manufacture of pipes should not constitute toxic hazard, should not support microbial growth and should not give rise to unpleasant taste or odour, cloudiness or discoloration of water. The percentage of anti-oxidant used shall not be more than 0.3 percent by mass of finished resin.

Among the recent developments is the use of High-Density Polyethylene pipes. These pipes are not brittle and as such a hard fall at the time of loading and unloading etc., may not do any harm to it. HDPE pipes as per {IS 4984: 2016} can be joined with detachable joints and can be detached at the time of shifting the pipeline from one place to another. Though for all practical purposes HDPE pipes are rigid and tough, at the same time they are resilient and conform to the topography of land when laid over ground or in trenches. They can withstand movement of heavy traffic. This would not cause damage to the pipes because of their flexural strength.

1.4.12.2 Laying & Jointing

1.4.12.2.1 Laying

HDPE pipes conforming to IS 4984: 2016, as they are UV protected (due to carbon black content in the pipe), may be stored either in open or covered. The pipeline may be laid alongside of the trench and jointed there. There after the jointed pipeline shall be lowered into the trench carefully without causing undue bending. The pipeline shall be laid inside the trench with a slack of up to 2 m/100 m of pipeline. Trench width and depth shall be as per {IS 7634 (Part 2): 2012, Reaffirmed 2017}.

Polyethylene pipe requires no special bed preparation for laying the pipe underground, except that there shall be no sharp objects around the pipe. However, while laying in rocky areas suitable sand bedding should be provided around the pipe and compacted. Polyethylene pressure piping systems jointed by butt welding, electro fusion and flanges do not require external joint restraints or thrust block joint anchors. In all cases, 150 mm above the top of the crown of the pipe is to be compacted either by mechanical or manual means. Wherever road crossing with heavy traffic is likely to be encountered, a concrete pipe encasing is recommended.

1.4.12.2.2 Jointing

The commonly used jointing and welding are described in the above section and may be referred at {IS 7634 (Part 2): 2012, Reaffirmed 2017}.

The properties of HDPE pipes are aligned to standards IS 4984:2016, IS 14333, IS 14885 and various other ISO and BIS standards for laying and installations. The principle of fusion welding is to heat the two pipe surfaces to a designated temperature and then fuse them together by application of sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion without the use of any external adhesive/ jointing materials. Butt fusion welding machines can be manual (for diameters up to 125 mm), hydraulic or pneumatic. However, a locking system to hold the fusion force is to be ensured in all the systems, and the equipment shall be protected against exerting over-pressure on the pipe. It shall be able to maintain the required interface force on the pipe or fittings end as long as necessary.

The pipes used for the fabrication of HDPE fittings for potable water supplies and the outside diameters and corresponding wall thicknesses of fittings at the free ends for weld shall comply with {IS 4984-2016 (Reaffirmed Year: 2021)}. The outside diameters shall be the average of two measurements taken at right angles. The wall thickness shall be measured with a ball ended micrometer. Resulting dimension shall be expressed to 0.1mm.

1.4.12.2.3 Testing of Pipeline

A fitting duly plugged, when subjected to a hydraulic proof test of twice the recommended working pressure at ambient temperature and for a period of one hour shall not show any sign of localized swelling, leakage or weeping, and shall not burst during the prescribed test duration.

The internal and external surfaces of the pipes shall be smooth, clear and free from grooving and other defects. The ends shall be cleanly cut and shall be square with axis of the pipes. Slight shallow longitudinal grooves or irregularities in the wall thickness shall be permissible, provided that the wall thickness remains within the permissible limits.

Ovality shall be measured as the difference between maximum outside diameter and minimum outside diameter measured at the same cross section of the pipe, at 300 mm away from the cut end. For pipes to be coiled, the ovality shall be measured prior to coiling. For coiled pipes, however, re-rounding of pipes shall be carried out prior to the measurement of ovality.

1.4.12.3 Advantages & Disadvantages

The advantages of pipe are:

- Lightweight
- Easy to install
- Economical
- Good corrosion resistance
- Smooth surface reduces friction losses
- Long pipe sections reduces leakage/ infiltration potential
- Flexible

The disadvantages of pipe are:

- Susceptible to chemical attack especially solvents
- Strength affected by sunlight
- Not suitable for above ground installations

1.4.13 Medium Density Polyethylene (MDPE) Pipes

1.4.13.1 General

Medium Density Polyethylene Pipes (MDPE) by definition have a density between 0.926-0.940gms/cc. A MDPE grade for pipes should have PE80 pressure classification for conveying potable water. The medium density polyethylene pipes are now being manufactured in India conforming to ISO specifications (ISO 4427 and BS 6730-1986) for carrying potable water. However, BIS is not available for these pipes. The MDPE pipes are being used for consumer connection pipes as an alternative to GI pipes. The polyethylene material does not constitute toxic hazard and does not support any microbial growth. Further, it does not impart any taste, odour or colour to the water.

MDPE pipes are colour coded black with blue strips in sizes ranging from 20 mm to 110 mm dia for pressure class of PN3.2, PN4, PN6, PN10 and PN16. The maximum admissible working pressures are worked out for temperature of 20 degrees centigrade (ISO4427: 2019). The pipes arc supplied in coils and minimum coil diameter is about 18 times diameter of the pipe.

MDPE compression fittings made of PP, AABS, UPVC are also available in India for use with MDPE pipes. The materials used for the fittings are also suitable for conveying potable water like MDPE pipes. The jointing materials of fittings consists of thermoplastic resins of Polyethylene type, NBR 'O' ring of nitrile and clamp of polypropylene, copolymer body, zinc plated steel reinforcing ring, nuts and balls of special NBR gasket.
The MDPE pipes are lightweight, robust and non-corrodible and hence can be used as alternative material for consumer connections. Since the pipes are supplied in coils, there will be no joints under the roads and bends are avoided resulting in fast, simple and efficient jointing.

MDPE is a popular material for urban water supply and is lightweight, strong and flexible. MDPE pipes can be used for:

- Water distribution for town, rural & irrigation projects
- Cold water plumbing reticulation
- Household water connections from the main supply
- Compressed air lines

1.4.13.2 Laying and Jointing

MDPE compression fittings made of PP, AABS, UPVC are available in India for use with MDPE pipes. The material used for the fittings shall also be suitable for conveying potable water. The joining material of fitting consist of thermoplastic resin of polyethylene type, NBR ‘O’ ring of nitrile and clamp of Polypropylene, copolymer body, zinc plated steel reinforcement ring, nut & balls of special NBR gasket. Push fit compression fittings are typically used for sizes 20-63mm.

1.4.13.3 Advantages & Disadvantages

The advantages of pipes are:

- Very smooth inner surface ensures no scaling and choking.
- Has less friction loss and gives better flow at lower heads.
- Easy to transport and store as the pipes available in 100, 200 and 300m coils.
- No wastage of pipe as it can be cut to requirement at site.
- Less number of joint as the pipe is flexible and easy to repair.
- Easy tapping with specialty tapping joints.
- Tools-off installation possible with precision made fittings.
- Resistance to inorganic acids, alkalis and salts, hydrocarbon gasses.

The disadvantages of pipe are

- Susceptible to chemical attack especially solvents
- Strength may be affected by sunlight

1.4.14 Glass Fibre Reinforced Plastic (GRP) Pipes

1.4.14.1 General

Glass Fibre Reinforced Plastic (GRP) pipes are now being manufactured in India conforming to IS 12709: 1994, Reaffirmed 2019. Five pressure classes of pipes namely, PN 3, PN 6, PN 9, PN 12 and PN 15 correspond to the working pressure ratings of 3.06, 6.12, 9.18, 12.24 and 15.30 kg/sq.m, respectively. Stiffness is the prime design criteria in the case of underground pipes. GRP pipe stiffness is classified into four classes, depending on the type of installation, overburden above the crown of the pipe and the soil conditions, GRP pipe stiffness is classified into four classes viz. A, B, C, D. The specials are made out of the same pipe material i.e. Glass Fibre Reinforced Plastic (GRP).

GRP 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. These pipes can resist external and internal corrosion whether the corrosion mechanism is galvanic or chemical in nature.

1.4.14.2 Laying and Jointing

1.4.14.2.1 Laying

Pipes shall be supplied in nominal length of 6 m, 9 m and 12 m. A maximum of 10 percent of the pipe section may be supplied in random lengths. Lengths other than those specified may be supplied as agreed between the purchaser and the manufacturer. The tolerance on nominal lengths shall he within ± 25 mm. Wall thickness shall be measured to an accuracy of 0.1 mm.

The width of the trench at top of the pipe should not be greater than necessary to provide adequate room for joining the pipe in the trench and for compacting the backfill in the zone of the pipe at the side thereof. If necessary, bell holes are permissible at the joints.

GRP pipes being light in weight, can be easily loaded or unloaded by slings, pliable stripes or ropes. A pipe can be lifted with only one support point or two support points, placed about 4 metre apart. Excavation of trench and back filling of materials is similar to that in the case of CI and MS pipes.

The surface at the trench grade should be continuous, smooth and free of big rocks more than 1.5 times the thickness of the pipe if rounded, or more than 1.0 times-the thickness of the pipe if they have sharp edges and may cause point loading on the pipe. When ledge rock, hard pan, big rocks, timber or other foreign materials are to be found, it is advisable to pad the trench bottom with sand or compacted fine grained soils at least 150 mm thick so as to provide an adequate foundation.

The pipe should be uniformly and continuously supported through its whole length with firm stable bedding material. Pipe bedding material should be sand or gravel as per the requirements on the backfill material. The bedding should be placed so as to give complete contact between the bottom of the trench and the pipe and backfilling should be compacted to provide a minimum compaction corresponding to 90% maximum dry density. Lift should normally not be greater than 30 cm in height and the height differential on each side of the pipe should be limited to this amount so as to prevent lateral movement of the pipe.

1.4.14.2.2 Jointing

All joints installed or constructed in the field shall be assembled only by trained technicians. After the completion of pipe installation at site, the pipeline should be tested for 1.5 times the working pressure for 30 minutes with water. All pipe joints shall be water-tight. All joints that are found to leak by observation or during testing shall be repaired and retested.

The pipes are joined as per the techniques; Double bell coupling (GRP) for GRP to GRP; Flange joint (GRP) for GRP to valves, CA pipes or flanged pipes, mechanical coupling (steel) for GRP to GRP / steel pipe and Butt - strap joint (GRP) for GRP to GRP.

Pipes are joined by using double bell couplings in following manner.

(i) Double bell coupling grooves and rubber gasket rings should be thoroughly cleaned to ensure that no dirt or oil is present.
(ii) Lubricate the rubber gasket with the vegetable oil based soap which is supplied along with the pipes and insert it in the grooves.
(iii) With uniform pressure, push each loop of the rubber gasket into the gasket groove. Apply a thin film of lubricant over the gaskets.
(iv) Apply a thin film of lubricant to the pipe from the end of the pipe to the back-positioning stripe.
(v) Lift manually or mechanically the double bell coupling and align with the pipe section,
(vi) Push the coupling onto the pipe by using levers. For large dia pipe, the coupling may be pushed mechanically with even force on the coupling ring.
(vii) Apply a thin film of lubricant over the pipe to be pushed into the coupling just assembled until the stripes on the pipe are aligned between the edge of the coupling.

Thus pipes are coupled together and the rubber gasket acts as a seal making the joint leak-prof. Joint types are normally adhesive bonded, however reinforced overlay and mechanical types such as flanged, threaded, compressed couplings or commercial/ proprietary joints are available.

Unrestrained joints of pipe capable of withstanding internal pressure but not longitudinal forces.

- Coupling or Socket and Spigot Gasket Joints provided with groove(s) either on the spigot or in the socket to retain an elastomeric gasket(s) that shall be the sole element of the joint to provide water tightness.
- Mechanical Couplings

Restrained joints capable of withstanding internal pressure and longitudinal forces,

- Joints similar to Coupling or Socket and Spigot Gasket Joints with supplemental restraining elements;
- Butt Joint - with laminated overlay;
- Socket-and-Spigot -with laminated overlay;
- Socket-and-Spigot - adhesive bonded;
- Flanged; and
- Mechanical.

1.4.14.3 Testing of Pipeline

Working hydraulic pressure in the system shall not exceed the pressure class of the pipe. When surge pressure is considered the maximum pressure in the system due to working pressure plus surge pressure, the same shall not exceed 1.4 times the pressure class of pipe. Other type of tests may be referred to {IS 12709: 1994, Reaffirmed 2014}.

1.4.14.4 Advantages & Disadvantages

The advantages of pipe are

- High Strength to weight ratio;
- Corrosion resistant;
- Light weight compare to metallic and concrete pipes; and
- Longer length and hence minimum joints enable faster installation.

The disadvantages of pipe are

- High material cost
- Brittle, require careful installation
- High installation cost

1.5 Structural Strength of Pipes

1.5.1 General Consideration

The stresses in a pipe are normally induced by internal pressure, external loading, surge forces and change of temperature, although torsional stresses can also arise. Internal pressure induces circumferential and longitudinal stresses, the latter developing where the line changes in size or direction, or has a closed end. A pipe is usually chosen so as to carry the circumferential stress without extra strengthening or support but if the joints cannot safely transmit the longitudinal stress, anchorages or some other means of taking the load must be provided. Longitudinal stress is absorbed by friction between the outside surface of the pipe and the material in which the line is buried.

External loads generally arise from the weight of the pipe and its contents and that of the trench filling from superimposed loads, including impact from traffic, from subsidence and from wind loads in the case of pipes laid above ground. If a pipe is laid on good and uniform continuous bed and the cover does not greatly exceed the normal, no special strengthening to resist external loading is generally necessary. Loading likely to arise from subsidence is best dealt with by the use of flexible joints and steel pipes. External loading becomes important usually when a line is laid on a foundation providing uneven support (e.g. across a sewer, trench or in rock under deep cover) or is subjected to heavy superimposed surface loads at less than normal cover. The necessity of stronger pipes can often be avoided by careful bedding and trench filling to give additional support. The importance of good bedding under and around the pipe upto at least the horizontal diameter cannot be overemphasized and in some cases concreting may be required.

Excessive distortion of a steel pipe may cause failure of its protective coating but can be limited by the use of strengthening rings. This problem is only likely to arise in very large mains. Distortions at flexible joints can cause leakage.

When a pipeline has to be laid above ground over some obstruction, such as waterway or railway, it may either be carried on a pipe-bridge or be supported on pillars. In the latter case, the pipe ends must be properly designed to resist shear, if the full strength of the pipe as a beam is to be realized. A small diameter pipe is usually thick enough to span short lengths with its ends simply supported, but as diameter (>900mm) and lengths of span increase, the problem becomes more complex and the ends must be supported in saddles or restrained by ring girders.

The temperature of the water in a transmission main varies during the year. In case, the temperature changes fairly quickly, long lengths of rigid mains are to be avoided. Provision of expansion joints to take care of these stresses is necessary. Thrust and anchor blocks are provided to keep the pipe curve in position. In small mains, i.e. the mains with spigot and socket lead joints, the joints themselves allow sufficient movement, although some recaulking may be occasionally necessary. On large steel pipelines with welded joints expansion can be allowed to give a longitudinal stress in the pipes, when first laid.

In case of PVC pipelines, it should be noted that the coefficient of expansion of PVC is eight times greater than steel and considerable movement can take place in long lengths of rigidly joined pipelines.

Structurally, closed conduits must resist a number of different forces singly or in combination like internal pressure, unbalanced pressures at bends, contractions, and closures, water hammer, external live and dead loads, own weight between external supports (piers or hankers) and temperature induced expansion and contraction.

1.5.2 Cross Section

The selection of the optimum cross section of a transmission main depends upon both hydraulic performance and structural behaviour because hydraulic capacity is a direct function of the hydraulic radius, full circles or half circles possess the highest hydraulic capacity, by virtue of their largest hydraulic radius or smallest frictional surface for a given area. Hence circular cross sections are preferred for closed conduits and the semi-circular ones for open conduits whenever structural conditions permit. The cross sections preferred next are those in which circles or semicircles can be inscribed. The following cross sections are generally used:

a) Trapezoids approaching half a hexagon as nearly as maintainable slopes permit, for canals in earth,

b) Rectangles with widths equal to twice the depths for canals in rock and flumes of masonry or wood,
c) Semi-circles for flumes of wood staves or steel,
d) Horseshoe for grade aqueducts and grade tunnels.

Material high in tensile strength with circular cross sections withstand satisfactorily the internal pressures; external pressures due to earth or rock, not counterbalanced by internal pressures are resisted best by horse shoe sections of materials possessing high compressive strength. The hydraulic properties of horse shoe sections are only slightly poorer than those of circles. Moreover, their relatively flat invert makes for easy transport of excavation and construction material, in and out of the aqueduct.

1.5.3 Depth of Cover

One metre cover on pipeline is normal and generally sufficient to protect the lines from external damage. When heavy traffic is anticipated, depth of cover has to be arrived at taking into consideration the structural aspect, dead load and live load over the laid pipelines and other aspects. When freezing is anticipated, 1.5m cover is recommended. Proper compaction process for compacting the earth of filling materials above to the laid pipelines should also be practiced.

1.6 Economical Size of Conveying Main

1.6.1 General Considerations

When the source is separated by a long distance from the area of consumption, the conveyance of the water over the distance involves the provision of a pressure pipeline or a free flow conduit entailing an appreciable capital outlay. The most economical arrangement for the conveyance of water is utmost important.

The available ground level from the source of water to the service area (city/town) and the ground profile in between generally help to decide the feasibility of free flow conduit. Once this is decided, the material of the conduit is to be selected keeping in view the local costs and the nature of the terrain to be traversed. Even when a fall is available, a pumping or force main independently or in combination with gravity main could also be considered. Optimization techniques need to be adopted for taking decision on most economical systems.

The most economical size for the conveyance main will be based on a proper analysis of the following factors:

a) The period of design considered or the period of loan repayment, if it is greater than the design period, for the project and the quantities to be conveyed during different phases of such period.

b) The different pipe sizes against different hydraulic slopes which can be considered for the quantity to be conveyed.
c) The different pipe materials which can be used for the purpose and their relative costs as laid in position.
d) The duty, capacity and installed cost of the pump sets required against the corresponding sizes of the pipelines under consideration.
e) The recurring costs on
   (i) Energy charges for running the pump sets, renewable energy should also be adopted to conserve the conventional energy,
   (ii) Staff for operation of the pump sets, automation of the mechanical and electrical items should also be adopted,
   (iii) Repairs and renewals of the pump sets,
   (iv) Miscellaneous consumable stores, and
   (v) Replacement of the pump sets installed to meet the immediate requirements, by new high energy efficient pump (power savings) sets at an intermediate stage of design period. The full design period or the repayment period may be 30 years or more while the pump sets are designed to serve a period of 15 years.

1.6.2 Evaluation of Comparable Factors

Every alternative, when analysed on the above lines, could be evaluated in terms of cost figures on a common comparable basis by:

(i) Capital cost of the most suitable pipe material as laid and joined and ready for service, including cost of valves and fittings and all ancillaries to the pipeline.

(ii) (a) Capital cost, as installed, of the necessary pump sets corresponding to the pipeline size in (i) above.
(b) The amount which should be invested at present such as would yield with compound interest, the amount necessary to replace the pumpsets in (ii) (a) at the end of their useful life with bigger pumpsets for once or often to cater to the requirements during the design period or the loan repayment period.

(iii) Energy charges; if the pump sets in (ii) (a) are designed to serve for, say 15 years, the daily pumpage will vary from the initial requirements to the intermediate demand after 15 years. The energy charges will be based on the average of these two daily pumpages, leading to an average annual expenditure on energy charges on such basis.

The replacing of pumps under (ii) (b) will, likewise, involve annual recurring energy charges for the average of the demands during the subsequent 15 years period for the project design or the loan repayment period whichever is greater.

(iv) The two annual recurring costs should be capitalized for inclusion as a part of the present investment. For this purpose, it is necessary to derive:

a) The amount of the present investment which would yield an annuity for 15 years equal to the annual energy charges on the initial pump sets,
b) The amount of present investment: which would commence to yield, over the subsequent 15years period, the annual energy charges for the replaced pump sets in (ii) (b), and
c) Apart from the energy charges, the other recurring annual charges comprising the cost of operation and maintenance staff, ordinary repairs and miscellaneous consumable stores.

The present investment which would yield an annuity equal to such annual recurring charges throughout the design period, or loan repayment period (if it exceeds the former), would represent the capitalized cost, for inclusion as part of the total investment now required.

(v) The addition of the present investment figures as worked out under (i), (ii) (a), (ii) (b), (iii) and (iv) would represent the total capital investment called for in respect of each alternative involving a specific pipeline size and the corresponding pumpsets. A comparison of the total investment so required in respect of the several alternatives examined would indicate the most economical pipeline size to be adopted for any particular project.

(vi) In all the above computations, the rate of interest plays an important role and for proper comparison, it may be taken as the rate demanded for the loan repayment.

1.6.3 Scope of Sinking Fund

In the methods of comparison outlined above, any provision for a sinking fund to replace the pipeline or the pumpsets at the end of the design or loan repayment period where needed has been advisedly not included. It would tantamount to the present generation paying in advance for the amenities for the next generation, in addition to paying for its own amenities through the design period of 30 years. Such a procedure is neither equitable nor expedient, particularly when local finances are unable to shoulder the financial commitments even against the initial installations of such projects.

1.6.4 Pipeline Cost under Different Alternatives

There are three independent factors bearing on the problem viz., the design period usually limited to a maximum of 30 years, the loan repayment period of 30 - 40 years and the life of the pipeline which may be anything from 30 to 100 years. There is one particular pipe size for which cost should be minimum, considering its capital and maintenance charge, for the loan repayment period. The size of the pipe will be larger if the period considered is the life of the pipeline and this larger size would appear to be less economical if the period is restricted to the loan repayment period.

The sale price for the water will have to be based on the financial obligations on the repayment of the loan and the maintenance costs. The period of repayment of the loan thus enters into the question and the consumer will have to pay a higher price if the comparison is based on the life time of the pipe and not on the loan repayment period or the design period, as the case may be.

The life period of the pipeline as also other components would become a more rational factor when the project is financed entirely from perpetual public debts to be incurred by the promoters and the community pays back in perpetuity against loans raised from time to time for additions, alternations and expansions needed.

Whether the pipe size is based on the loan repayment period or the lifetime of the pipe, its utility to the community will be there even after repayments of the loan. Since the incidence of the financial burden on the consumer will be less in the former case, the method is to be preferred.

1.6.5 Recurring Charges - Design Period vs. Perpetuity

Annual recurring charges on energy and operation and maintenance are perpetuity, irrespective of the design period or the life of the pipeline. Their capitalized value is restricted to the design period or the loan repayment period whichever is greater, as reflecting the commitment involved relevant to such period for a proper comparison between alternatives. Otherwise a possible method may be adopted considering an initial investment which would yield an interest to meet such recurring charges in perpetuity. It is, however, more rational to consider capitalization of the recurring charges over the design or loan repayment period.

1.6.6 Capitalisation vs. Annuity Methods

In Section 1.6.2, the comparison suggested was on the basis of present capitalized value. As an alternative, the capital installation cost of the pipeline could be converted into an annuity for the design period, or loan repayment period whichever is greater, in the same way as a loan discharged through annuities and such annuity added on to the other annual recurring charges for a total comparison between the alternatives.

1.6.7 Selection Principles

The above method suggested for Evaluation of Comparable Factors would give a comparative idea of the total capital investment involved whereas the Capitalisation vs. Annuity Methods would indicate the annuities involved as between the alternatives. A better concept is perhaps afforded by the former method.

The most economical size of a main can be arrived by evaluating the capital and operation & maintenance cost (capitalized value) for different diameters. Mathematical solution is also possible (**Appendix 1.3**). The objective (cost) function is formulated to ensure desired system performance. Several optimization techniques are available for minimizing the objective function. One of the simpler methods is one in which its (objective function) first partial derivatives with respect to the several decision variables are set equal to zero. The resulting system of equations is solved exactly or approximately and the principal minors of the determinant of second partial derivatives are investigated to ascertain whether a maximum or minimum is involved.

While determining the type of the pipe material to be used, alternative alignments, cost of cross drainage works, cost of valves, specials and other appurtenances, should all be considered to determine the most economical size for the conveying main.

1.7 Pipeline in Colder Climates

Selection of pipe material in colder climate shall take into consideration the following issues;

- Freeze-Back Forces: Excessive pore water pressure trapped between the permafrost layer and winter frost layer can deform or collapse pipe.
- Potential Freeze Damage: Pipes should, if freezing risk is high, be capable of being thawed and returned to service without loss of strength.

Unless piping can be installed below the seasonal frost line, some form of freeze protection is mandatory. Factory-applied polyurethane is recommended for both buried and above grade pipes.

UPVC Pipe becomes brittle in the cold and can shatter when frozen. PVC is not recommended for use where there is a chance of the pipe being exposed to freezing conditions. UPVC pipe shall be buried to depths unlikely to experience freezing temperatures.

HDPE is preferred where there is a high risk of freezing. HDPE can normally be thawed and returned to service without damage to the pipe. It is corrosion resistant and not affected by extreme cold.

Ductile iron is preferred where there is thaw settlement potential and/or where pipe bedding support is marginal.

1.8 Installation Cost Considerations

Installation costs make up a major part of the total cost of a project. Differences in the cost of the actual pipe do not change the total cost of the project much. However, the following factors should be considered concerning installation costs and the choice of pipe:

- Weight of the pipe: A pipe that is lightweight can be handled easier and faster.
- Ease of assembling: Push-on joints can be assembled much faster than bolted joints.
- Pipe strength: If one type of pipe requires special bedding to withstand external pressures while another pipe does not, the choice can impact installation costs significantly.

1.9 Health Aspects

While selecting the pipe material for drinking water supply systems, following need to be kept in consideration;

- A leaking distribution system increases the likelihood of safe water leaving the source or treatment facility becoming contaminated before reaching the consumer. The pipe shall be strong enough to withstand external & internal forces without any damage.
- The pipe material or inner lining shall not have any constituent which may be unsuitable for human consumption especially the inner surface.
- Certain pipe materials which may be unsafe for human health are increasingly not utilized or being phased out such as Lead, Copper, etc.

1.10 Applicability

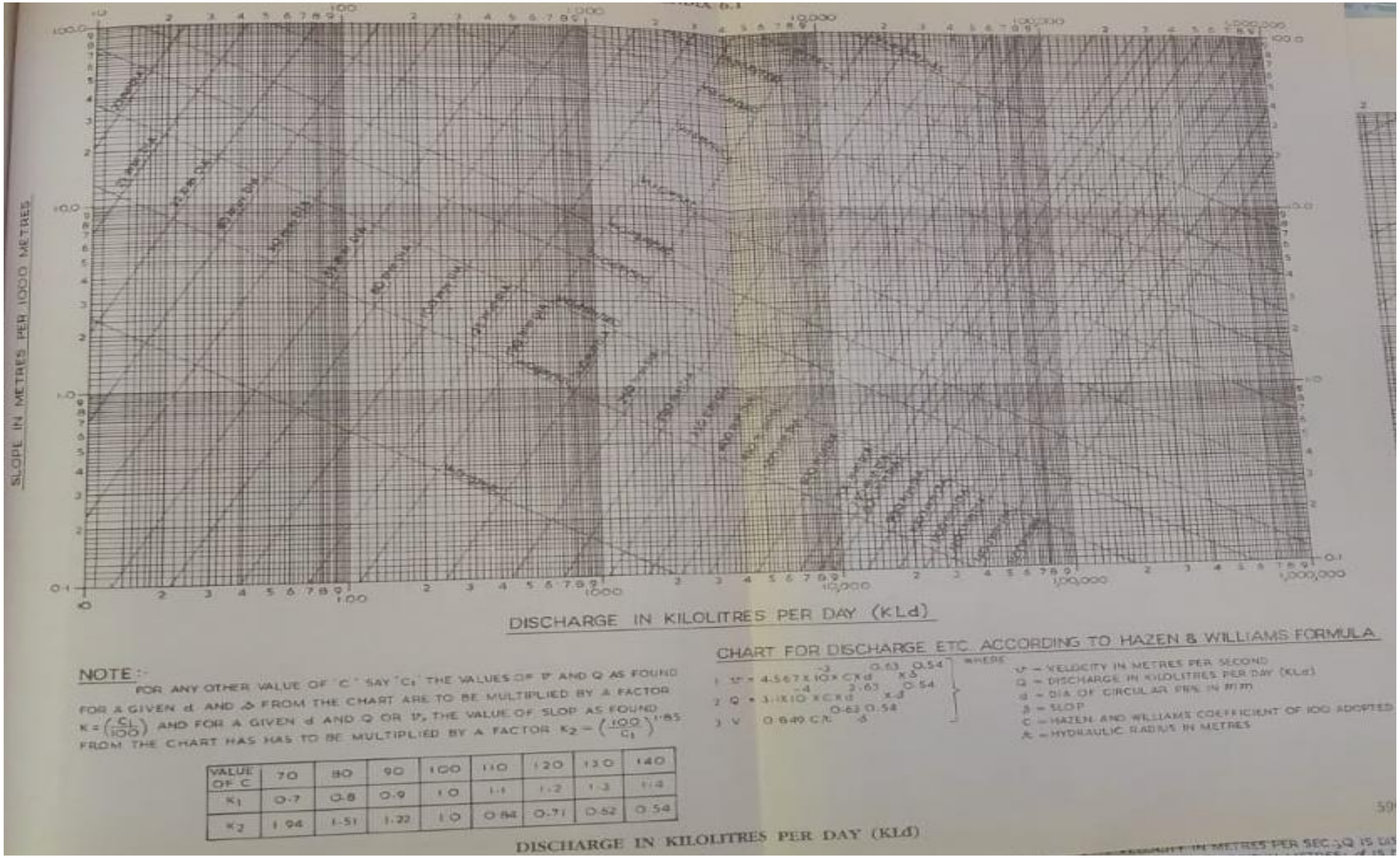
The applicability of different pipe materials varies with each site and the system requirements. The pipe material must be compatible with the soil and groundwater chemistry. The pipe material must also be compatible with the soil structure and topography of the site, which affects the pipe location and depth, the supports necessary for the pipe fill material, and the required strength of the pipe material.

The following list shows background information to be used in determining what type of pipe best fits a particular situation:

- Maximum pressure conditions (force mains);
- Overburden, dynamic, and static loading;
- Lengths of pipe available;
- Soil conditions, soil chemistry, water table, stability;
- Joining materials required;

- Installation equipment required;
- Joint tightness/thrust control;
- Size range requirements;
- Field and shop fabrication considerations;
- Compatibility with existing systems;
- Thrust Blocks, Anchor blocks, Valve Chambers and other required structures to be included;
- Valves (number, size, and cost);
- Corrosion/cathodic protection requirements; and
- Maintenance requirements.

Appendix-1.1


SLOPE IN METRES PER 1000 METRES
DISCHARGE IN KILOLITRES PER DAY (KLd)
CHART FOR DISCHARGE ETC. ACCORDING TO HAZEN & WILLIAMS FORMULA
NOTE :-
FOR ANY OTHER VALUE OF 'C' SAY 'C1' THE VALUES OF V AND Q AS FOUND FOR A GIVEN d AND S FROM THE CHART ARE TO BE MULTIPLIED BY A FACTOR K = (C1/100) AND FOR A GIVEN d AND Q OR V, THE VALUE OF SLOP AS FOUND FROM THE CHART HAS HAS TO BE MULTIPLIED BY A FACTOR K2 = (100/C1)^1.85
VALUE OF C | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140
K1 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4
K2 | 1.94 | 1.51 | 1.22 | 1.0 | 0.84 | 0.71 | 0.62 | 0.54
WHERE
V – VELOCITY IN METRES PER SECOND
Q – DISCHARGE IN KILOLITRES PER DAY (KLd)
d – DIA OF CIRCULAR PIPE IN mm
S – SLOP
C – HAZEN AND WILLIAMS COEFFICIENT OF 100 ADOPTED
R – HYDRAULIC RADIUS IN METRES
DISCHARGE IN KILOLITRES PER DAY (KLd)

Appendix-1.2

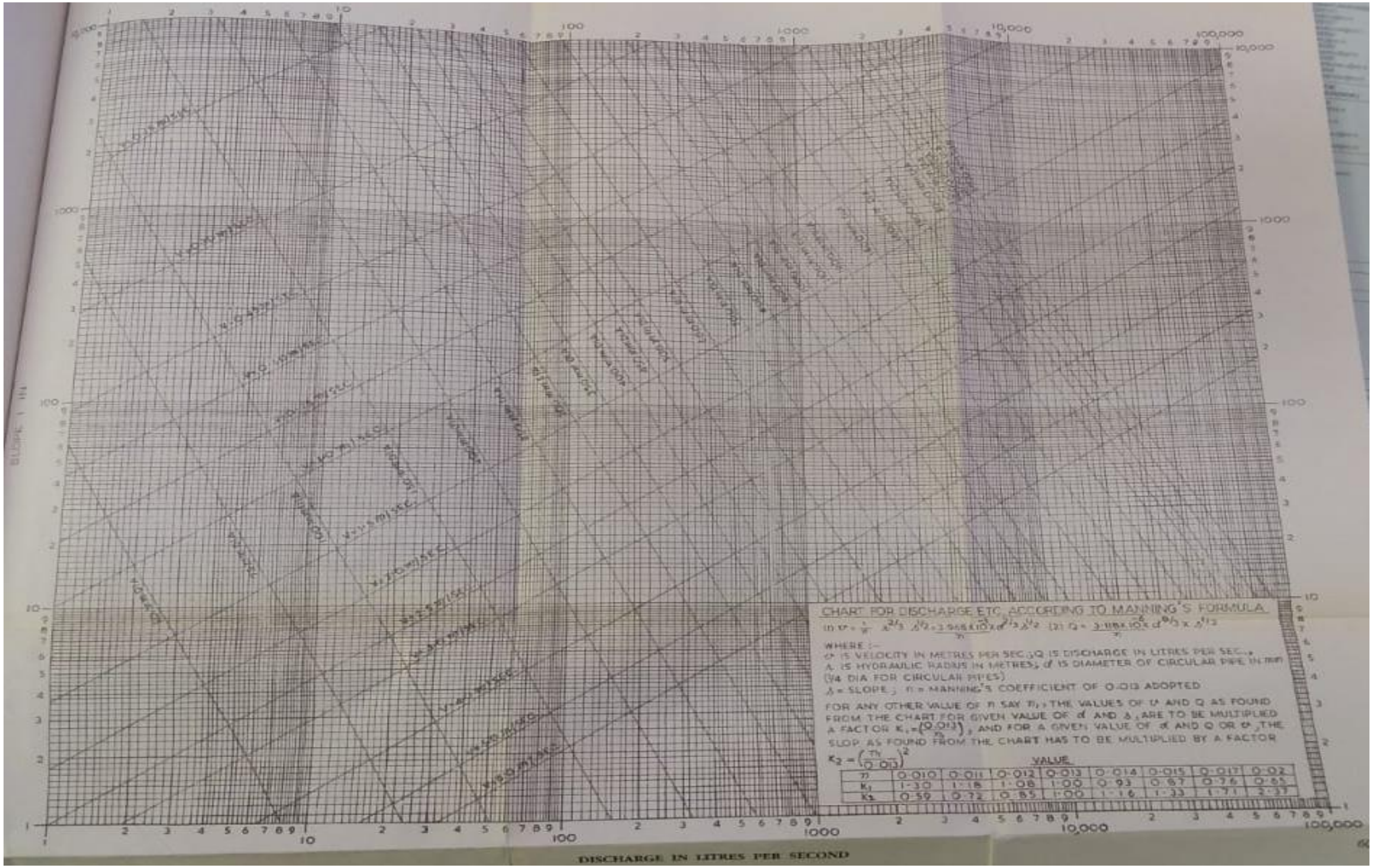


CHART FOR DISCHARGE ETC. ACCORDING TO MANNING'S FORMULA
WHERE :-
IS VELOCITY IN METRES PER SEC.; Q IS DISCHARGE IN LITRES PER SEC.,
IS HYDRAULIC RADIUS IN METRES; d IS DIAMETER OF CIRCULAR PIPE IN mm
(1/4 DIA FOR CIRCULAR PIPES)
= SLOPE ; n = MANNING'S COEFFICIENT OF 0.013 ADOPTED
FOR ANY OTHER VALUE OF n SAY n1, THE VALUES OF v AND Q AS FOUND FROM THE CHART FOR GIVEN VALUE OF d AND s, ARE TO BE MULTIPLIED A FACTOR K1 = (0.013/n1), AND FOR A GIVEN VALUE OF d AND Q OR v, THE SLOP AS FOUND FROM THE CHART HAS TO BE MULTIPLIED BY A FACTOR K2 = (n1/0.013)^2
VALUE
n 0.010 0.011 0.012 0.013 0.014 0.015 0.017 0.02
K1 1.30 1.18 1.08 1.00 0.93 0.87 0.76 0.65
K2 0.59 0.72 0.85 1.00 1.16 1.33 1.71 2.37
DISCHARGE IN LITRES PER SECOND
SLOPE 1 IN

Appendix-1.3

DESIGN FOR ECONOMIC SIZE OF PUMPING MAIN

PROBLEM:- Design an economic size of pumping main, given the following data:

1)	Water requirements	Year	Discharge
	Initial	Start	5 MLD
	Intermediate	At 15th Year	7.5 MLD
	Ultimate	At 30th Year	10 MLD
2)	Length of pumping main	7000m	
3)	Static head for pump	50m	
4)	Design period	30 years	
5)	Combined efficiency of pumping set	60%	
6)	Cost of pumping unit	Rs. 2000 per kw	
7)	Interest rate	10 %	
8)	Life of electric motor and pump	15 years	
9)	Energy charges	Rs. 1 per unit	
10)	Design value of 'C' for C.I. pipes	100	

Solution		1^{st} 15 years	2^{nd} 15 years
1	Discharge at installation	5 MLD	7.5 MLD
2	Discharge at the end 15 years	7.5 MLD	10.0 MLD
3	Average discharge	5+7.5/2 =6.25 MLD	7.5+10.0/2 =8.75MLD
4	Hours of pumping for discharge at the end of 15 years	23	23
5	Average hours of pumping for average discharge	(23/7.5)× 6.25 = 19.17	(23/10)×8.75 =20.12

6. K.W required at 60% combined efficiency of pumping set

$$\frac{7.5\times10^{6}\times H_{1}\times100\times24}{60\times60\times24\times102\times60\times23}=KW_{1} \qquad \frac{10\times10^{6}\times H_{2}\times100\times24}{60\times60\times24\times102\times60\times23}=KW_{2}$$

$1.48H_1 \quad = KW_1 \qquad\qquad 1.972H_2 = KW_2$

KW required = $(Q \times H)/102 \times 1/\eta \times 24/X$

Where,

Q = Discharge at the end of 15 years in 1ps

H = Total head in m for dischgarge at the end of 15 years

η = Combined efficiency of pumping set

X = Hours of pumping for discharge at the end of 15 years

7. Annual cost in Rs. of electrical energy @ Rs. 1 per unit (KWX average hours of pumping × average days per year × 1.00)

$= KW_1 \times 19.17 \times 365.24 \times 1.00$ $\quad$ $KW_2 \times 20.12 \times 365.24 \times 1.00$

$= 7001.65\ KW_1$ $\quad$ $= 7348.63 KW_2$

8. Pump Cost Captilised

$P_n = C = P_o (1 + r)^n$

$P_o = C/(1+r)^n$

Where,

P_o = Initial Capitalised investment

C = Amount needed after 15 years, to purchase the second stage Pumping set.

r = Rate of compound interest

= 10% per year

n = No. of years = 15

$P_o = C/(1+0.1)^{15} = C/4.177$

9. Energy Charges Capitalised

$C_c = C_R\ \{(1-(1+r)^{-n})/n\}$

For values n =15 and r =10%

$C_c = 7.606\ C_R$

(C_c) 1st stage = 7.606 (C_R) 1st stage and

(C_c) 2nd stage =7.606 (C_R) 2nd stage

Present energy charges (C_P) for second stage capitalised value

$C_p = (C_c)$2nd stage/4.177

10. Table I, II,III show the calculations to arrive the most economical pumping main size for the given data

List of Standards Relating to Water Supply

Sl. No	Standard / Reference	Title/Description
GENERAL		
1	IS 1172: 1983 Reaffirmed Year : 2017	Code of basic requirements for water supply drainage and sanitation (third revision)
2	IS 2065: 1983 Reaffirmed Year : 202	Code of practice for water supply in buildings (second revision)
3	IS 456: 2000 Reaffirmed Year : 2021	Code of practice for plain and reinforced concrete (third revision)
4	IS 457: 1957 Reaffirmed Year : 2014	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures.
5	IS 1343: 2012 Reaffirmed Year : 2017	Code of practice for prestressed concrete (first revision).
6	SP 35 : 1987	Handbook on water supply and drainage with special emphasis on plumbing
7	IS 3370	Code of practice for concrete structure for the storage ofliquids
8	IS 3370 (Part 2): 1965 Reaffirmed Year : 2019	Reinforced concrete structures
9	IS 3370 (Part 3): 1967 Reaffirmed Year : 2018	Prestressed concrete structures
10	IS 5330: 1984 Reaffirmed Year : 2020	Criteria for design of anchor block for penstocks with expansion joints (first revision)
11	IS 7357: 1974 Reaffirmed Year : 2020	Code of practice for structural design of surge tanks
12	IS 6295: 1986 Reaffirmed Year : 2017	Code of practice for water supply and drainage in highaltitudes and/or sub-zero temperature regions (first revision)
13	IS 4880	Code of practice for design of tunnels conveying water
14	IS 4880 (Part 1): 1987 Reaffirmed Year : 2013	General design
15	IS 4880 (Part 2): 1976 Reaffirmed Year : 2020	Geometric design(first revision)
16	IS 4880 (Part 3): 1976 Reaffirmed Year : 2020	Hydraulic design (first revision)
17	IS 4880 (Part 4): 1971 Reaffirmed Year : 2020	Structural design of concrete lining in rock
18	IS 4880 (Part 5): 1972 Reaffirmed Year : 2020	Structural design of concrete lining in soft strata and soils
19	IS 4880 (Part 6): 1971 Reaffirmed Year : 2020	Tunnel support
20	IS 9668: 1990 Reaffirmed Year : 2020	Code of practice for provision and maintenance of watersupply for fire fighting
21	IS 10221: 2018 Reaffirmed Year : 2021	Code of practice for coating and wrapping of undergroundsteel pipelines.
22	IS 12183: 1987 Reaffirmed Year : 2019	Code of practice for plumbing in multi-storeyed buildings Part 1 Water Supply.
DUCTILE IRON PIPES		
1.	IS 8329: 2000 Reaffirmed Year : 2020	Centrifugally cast(spun) ductile iron pressure pipes for water, gas and sewage − specification

2.	IS 9523: 2000 Reaffirmed Year : 2020	Ductile iron fittings for pressure pipes for water, gas and sewage − specification
3.	IS 5382: 2018	Rubber sealing rings for gas mains, water mains and sewers
4.	IS 638 : 1979 Reaffirmed Year : 2018	Specification for Sheet Rubber Jointing and Rubber Insertion Jointing
5.	IS 12288:1987 Reaffirmed Year : 2017	Code of practice for use and laying of Ductile Iron pipes
6.	ISO 2531: 2009	Ductile iron pipes, fittings, accessories and their joints for water applications
7.	ISO 10802: 2020	Ductile iron pipelines − Hydrostatic testing after installation
8.	ISO 10803: 2011	Design method for ductile iron pipes
9.	ISO 10804: 2018	Restrained joint systems for Ductile Iron pipelines – Design rules and type testing
10.	ISO 21051: 2020	Construction and installation of Ductile Iron pipeline system
11.	ISO 21053: 2019	Life cycle analysis and recycling of ductile iron pipes for water applications
12.	AWWA M-41: 2009	Ductile − Iron pipe and fittings (guideline code for design, manufacturing, testing, jointing, laying &installation etc.)
13.	BSEN 545: 2010	Ductile iron pipes, fittings, accessories and their joints for water pipelines − Requirements and test methods
14	IS:2405 (Part II)-1980 Reaffirmed Year : 2018	Industrial Sieves - Part II : Perforated Plates
CAST IRON PIPES		
1	IS 1536: 1976 Reaffirmed Year : 2016	Centrifugally cast (spun) iron pressure pipes for water, gasand sewage (second revision)
2	IS 1537: 1976 Reaffirmed Year : 2020	Vertically cast iron pressure pipes for water, gas and sewage (first revision)
3	IS 1538 (Parts 1 to 24)	Cast Iron fittings for pressure pipes for water, gas and sewage (second revision)
(i)	Part 1: 1993 Reaffirmed Year : 2018	General requirements
(ii)	Part 2: 1993 Reaffirmed Year : 2018	Specific requirements for sockets and spigots of pipes
(iii)	Part 3: 1993 Reaffirmed Year : 2018	Specific requirements for sockets and fittings
(iv)	Part 4: 1993 Reaffirmed Year : 2018	Specific requirements for flanges of pipes and fittings
(v)	Part 5: 1993 Reaffirmed Year : 2018	Specific requirements for raised flanges
(vi)	Part 6: 1993 Reaffirmed Year : 2018	Specific requirements for standard flange drilling of flanged pipes and fittings
(vii)	Part 7: 1993 Reaffirmed Year : 2018	Specific requirements for flanged sockets
(viii)	Part 8: 1993 Reaffirmed Year : 2018	Specific requirements for flanged spigots
(ix)	Part 9: 1993 Reaffirmed Year : 2018	Specific requirements for double socket bends
(x)	Part 10: 1993 Reaffirmed Year : 2018	Specific requirements for double socket bends
(xi)	Part 11: 1993 Reaffirmed Year : 2018	Specific requirements for TEEs and sockets

(xii)	Part 12: 1993 Reaffirmed Year : 2018	Specific requirements for double sockets tee with flanged branch
(xiii)	Part 13: 1993 Reaffirmed Year : 2018	Specific requirements for crosses, all sockets
(xiv)	Part 14: 1993 Reaffirmed Year : 2018	Specific requirements for double socket tapers (third revision)
(xv)	Part 15: 1993 Reaffirmed Year : 2018	Specific requirements for caps
(xvi)	Part 16: 1993 Reaffirmed Year : 2018	Specific requirements for plugs
(xvii)	Part 17: 1993 Reaffirmed Year : 2018	Specific requirements for bell mouth pieces
(xviii)	Part 18: 1993 Reaffirmed Year : 2018	Specific requirements for double flanged bends
(xix)	Part 19: 1993 Reaffirmed Year : 2018	Specific requirements for all flanged tees
(xx)	Part 20: 1993 Reaffirmed Year : 2018	Specific requirements for all flanged crosses
(xxi)	Part 21: 1993 Reaffirmed Year : 2018	Specific requirements for double flanged taper
(xxii)	Part 22: 1993 Reaffirmed Year : 2018	Specific requirements for split puddle or body flanges
(xxiii)	Part 23: 1993 Reaffirmed Year : 2018	Specific requirements for blank flanges
(xxiv)	Part 24: 1993 Reaffirmed Year : 2018	Specific requirements for all flanged radial tees (second revision)
28	IS 1879: 1975 Pipe Part 1 to 10 Reaffirmed Year : 2014	Malleable cast iron pipe fittings (first revision)
29	IS 3114: 1985 Reaffirmed Year : 2019	Code of practice for laying of cast iron pipes (third revision)
30	IS 782: 1994 Reaffirmed Year : 2017	Caulking lead (third revision)
31	IS 7181: 1986 Reaffirmed Year : 2019	Horizontally cast iron double flanged pipes for water, gas and sewage (first revision)
32	IS 8329: 2000 Reaffirmed Year : 2020	Centrifugally cast (spun) ductile iron pressure pipes for water, gas and sewage
33	IS 11606: 1986 Reaffirmed Year : 2014	Methods of sampling cast iron pipes and fittings
34	IS 11906: 1986 Reaffirmed Year : 2017	Recommendations for cement mortar lining cast iron, mild steel and ductile iron pipes and fittings for transportation of water.
35	IS 12288: 1987 Reaffirmed Year : 2017	Code of practice for laying of ductile iron pipes
36	IS 5382-2018	Rubber Seals — Joint Rings for Water Supply, Drainage and Sewerage Pipelines
37	IS 2405 (Part 2): 1980 Reaffirmed Year: 2018	Specifications for Industrial Sieves (Perforated Plates)
CONCRETE PIPES		
1	IS 458: 2021	Concrete pipes (with and without reinforcements) (second revision)
2	IS 784: 2019	Pre-stressed concrete pipes (including fittings) (first revision)

3	IS 3658:1999, Reaffirmed 2020	Code of Practice for Liquid Penetrant flaw detection
4	AWWA C301	Prestressed Concrete Pressure Pipe, Steel-Cylinder Type
5	EN 639:1995	Common Requirements for Concrete Pressure Pipes including Joints and Fittings
6	EN 642:1995	Prestressed Concrete Pressure Pipes, Cylinder and Non-cylinder, including Joints, Fittings and Specific Requirement for Prestressing Steel for Pipes
7	IS 1916: 2018	Steel cylinder reinforced concrete pipes
8	IS 3597: 1998 Reaffirmed Year : 2018	Methods of test for concrete pipes (first revision)
9	IS 783: 1985 Reaffirmed Year : 2022	Code of practice for laying of concrete pipes (first revision)
10	IS 4350: 1967 Reaffirmed Year : 2022	Concrete porous pipes for under drainage
11	AWWA C300	Reinforced Concrete Pressure Pipe, Steel-Cylinder Type
12	AWWA C302	Reinforced Concrete Pressure Pipe, Non cylinder Type
BAR/WIRE WRAPPED STEEL CYLINDER PIPES WITH MORTAR LINING AND COATING		
1	IS 15155: 2020	Bar/Wire Wrapped Steel Cylinder Pipes with Mortar LiningAnd Coating(Including Specials) — Specification
2	AWWA C 303	Concrete Pressure Pipe, Bar-Wrapped, Steel-Cylinder Type
ASBESTOS CEMENT PIPES		
1	IS 1592: 2003 Reaffirmed Year : 2018	Asbestos cement pressure pipes (second revision)
2	IS 6530: 1972 Reaffirmed Year : 2022	Code of practice for laying of asbestos cement pressurepipes
3	IS 5531: 2014 Reaffirmed Year : 2020	Cast iron specials for asbestos cement pressure pipes forwater, gas and sewage
4	IS 9627: 1980 Reaffirmed Year : 2020	Asbestos cement pressure pipes (light duty)
MILD STEEL TUBES AND PIPES		
1	IS 1239	Mild steel tubes, tubular and other wrought steel fittings.
2	IS 1239 (Part 1): 2004 Reaffirmed Year : 2019	Mild Steel tubes
3	IS 1239 (Part 2): 2004 Reaffirmed Year : 2021	Mild Steel tubular and other wrought steelpipe fittings (third revision)
4	IS 3589: 2001 Reaffirmed Year : 2022	Steel Pipes for Water and Sewage (168.3 to 2540 mm Outside Diameter)
5	IS 4270: 2001 Reaffirmed Year : 2022	Steel tubes used for water wells (first revision)
6	IS 5504: 1997 Reaffirmed Year : 2018	Spiral welded pipes.
7	IS 5822: 1994 Reaffirmed Year : 2019	Code of practice for laying of welded steel pipes for watersupply (first revision)
8	IS 4711: 2008 Reaffirmed Year : 2018	Method for sampling of steel pipes, tubes and fittings(firstrevision)
9	IS 6286: 1971 Reaffirmed Year : 2018	Seamless and welded steel pipes for subzero temperatureservices.
10	IS 6631: 1972 Reaffirmed Year : 2014	Steel pipes for hydraulic purposes

11	IS 11722: 1986 Reaffirmed Year : 2018	Thin welded flexible quick coupling pipes
12	IS 3600 (Part 1): 1985	Method of Testing Fusion Welded Joints and Weld Metal in Steel - Part 1 Destructive Tests on Welds in Metallic Materials-Tensile Test on Cruciform and Lapped Joints
13	AWWA C200	Steel Water Pipe - In. (1500 mm) and Larger
14	AWWA C203	Coal-Tar Protective Coatings and Linings for Steel WaterPipe
15	AWWA C205	Cement-Mortar Protective Lining and Coating for Steel Water Pipe - 4 In. (100 mm) and Larger - Shop Applied
16	AWWA C206	Field Welding of Steel Water Pipe
17	AWWA C209	Tape Coatings for Steel Water Pipe and Fittings
18	AWWA C210	Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings
19	AWWA C213	Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings
20	AWWA C214	Tape Coatings for Steel Water Pipe
21	AWWA C215	Extruded Polyolefin Coatings for the Exterior of Steel Water Pipelines
22	AWWA C216	Heat-Shrinkable Cross-Linked Polyolefin Coatings for Steel Water Pipe and Fittings
23	AWWA C218	Liquid Coating for Aboveground Steel Water Pipelines and Fittings
24	AWWA C222	Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings
25	AWWA C225	Fused Polyolefin Coating System for the Exterior of Steel Water Pipelines
26	AWWA C229	Fusion-Bonded Polyethylene Coatings for Steel Water Pipe and Fittings
GALVANIZED IRON PIPES		
1	IS 1239-1 (2004) Reaffirmed Year : 2014	Steel Tubes, Tubulars and Other Wrought Steel Fittings - Specifications, Part 1: Steel Tubes
2	IS 1239-2 (2011) Reaffirmed Year : 2021	Mild steel tubes, tubulars and other wrought steel fittings: Part 2. Mild steel socket, tubulars and other wrought steel pipe fittings
3	IS 4736: 1986 Reaffirmed Year : 2021	Hot dip zinc coatings on mild steel tubes
4	IS 554: 1999 Reaffirmed Year : 2019	Pipe Threads Where Pressure-Tight Joints are Made on the Threads - Dimensions, Tolerances and Designation (Fourth Revision)
5	IS 4736: 1986 Reaffirmed Year : 2021	Hot-dip Zinc Coatings on Mild Steel Tubes
6	IS 2629: 1986 Reaffirmed Year : 2021	Recommended Practice for Hot-Dip Galvanizing of Iron and Steel
PLASTIC PIPES		
1	IS 4984: 2016 Reaffirmed Year: 2021	Polyethylene Pipes for Water Supply - Specification (Fifth Revision)
2	IS 4985: 2000 Reaffirmed Year: 2015	Unplasticized PVC pipes for potable water supplies
3	IS 12818: 2010 Reaffirmed Year : 2021	Unplasticized Polyvinyl Chloride (pvc-u)screen And Casing Pipes For Bore/tubewell
4	IS 7634 (Part 1): 1975 Reaffirmed Year : 2017	Code of practice for plastic pipes work for potable water supplies: Part 1 Choice of materials and general

		recommendations
5	IS 7634 (Part 1): 1975 Reaffirmed Year : 2017	Choice of materials and general recommendation
6	IS 7634 (Part 2): 1975 Reaffirmed Year : 2017	Laying and jointing polyethylene (PE) pipes.
7	IS 7634 (Part 3): 1975	Laying and jointing of unplasticized PVC pipes.
8	IS 7834 (Part 1-8): 1987 Reaffirmed Year : 2018	Injection molded PVC fittings with solvent cement joints for water supplies.
9	IS 8008 (Part 1-7): 2003 Reaffirmed Year : 2018	Injection moulded HDPE fittings for potable water supplies
10	IS 8360 (Part 1-3): 1977 Reaffirmed Year : 2017	Fabricated high density polyethylene (HDPE) fittings for potable water supplies
11	AWWA C 906	Polyethylene (PE) Pressure Pipe and Fittings, 4 In. Through 65 In (100 mm Through 1,650 mm) for Waterworks (HDPE)
12	ISO 4427-1 : 2007	Plastics piping systems – Polyethylene (PE) pipes & fittingsfor water supply (MDPE)
13	BS 6730-1986	Specification for black polyethylene pipes up to nominal size 63 for above ground use for cold potable water
14	IS 10124 (Part 1-13): 2009 Reaffirmed Year : 2014	Fabricated PVC fittings for potable water supplies
15	IS 12231: 1987 Reaffirmed Year : 2018	UPVC pipes for use in suction and delivery of agriculture pump.
16	AWWA C 605	Underground Installation of Polyvinyl Chloride (PVC) and Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe and Fittings
17	AWWA C 900	Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 In. - 60 In. (100 mm - 1,5000 mm)
18	IS16647 : 2017	Oriented Unplasticized Polyvinyl Chloride (PVC-O) pipes for Water Supply - Specification
19	IS16422: 2016 Reaffirmed Year : 2022	Pipes and joints made of Oriented Unplasticized Polyvinyl Chloride (PVC-O)
20	AWWA C 605	Underground Installation of Polyvinyl Chloride (PVC) and Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe and Fittings
21	IS 12709: 1994 Reaffirmed Year : 2014	Specification for glass fiber reinforced plastic (GRP) pipes for water supply and sewerage.
22	IS 13916: 1994 Reaffirmed year: 2014	Installation of Glass Fibre Reinforced Plastic(GRP) Piping System Code of Practice
23	AWWA M-45	Fiberglass Pipe Design
24	AWWA C 950	Fiberglass Pressure Pipe
25	IS 12235 (Part 1-19): 2004 Reaffirmed year: 2019	Thermoplastics Pipes and Fittings - Methods of Test

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