

- (c) Sum of the maximum sustained operating pressure and the maximum surge pressure.
- (d) Sum of the maximum pipeline static pressure and the maximum surge pressure, subject to a maximum equal to the work test pressure for any pipe fittings incorporated. //

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 atleast four hours. 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 atleast 24 hours. The test pressure shall be gradually raised at the rate of 1 kg/cm²/min. 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.

The hydrostatic test pressure at works and at field after installation and the working pressure for different classes of pipes are given in Appendix. 6.4. //

The allowable leakage during the maintenance stage of pipes carefully laid and well tested during construction, however should not exceed;

$$qL = \frac{ND\sqrt{P}}{115} \quad (6.11)$$

Where,

- qL = Allowable leakage in cm³/hour
- N = No of joints in the length of pipe line
- D = Diameter in mm
- P = The average test pressure during the leakage test in kg/cm²

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.

The above is applicable to spigot and socket Cast Iron pipes and A.C. pressure pipes, whereas, twice this figure may be taken for steel and prestressed concrete pipes.

6.4.4.3 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 the 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.

6.5 STEEL PIPES

6.5.1 GENERAL

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). The thickness of steel used is often controlled by the need to make the pipe stiff enough to keep its circular shape during storage, transportation and laying as also to prevent excessive deflection under the load of trench back filling. 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, 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. 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. 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.

6.5.2 PROTECTION AGAINST CORROSION

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 under ground pipeline may be in cement-sand guiniting or hot applied coal-tar asphaltic enamel reinforced with fibreglass fabric yarn.

6.5.3 LAYING AND JOINTING

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. When these pipes are used in the construction of tube wells, the socketed ends after positioning without any jointing material are welded and lowered down. Lining and out-coating is done by different methods to protect steel pipes. 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 jointed 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. For laying of welded steel pipe I.S. 5822-1986 may be referred to.

For more details on different types of steel pipes used, reference may be made to the ISI codes indicated in Appendix 'C'.

For hydraulic testing of steel pipelines, the procedure described for cast iron spun pipes and ductile iron pipes may be followed.

6.6 DUCTILE IRON PIPES

6.6.1 GENERAL

Ductile Iron is made by a metallurgical process which involves the addition of magnesium into molten iron of low sulfur content. The magnesium causes the graphite in the iron to precipitate in the form of microscopic (6.25 micron) spheres rather than the flakes found in ordinary cast iron. The spheroidal graphite in iron improves the properties of ductile iron. It possesses properties of high mechanical strength, excellent impact resistance and good casting qualities of grey cast iron. Ductile iron pipes are normally prepared using the centrifugal cast process. The ductile iron pipes are usually provided with cement mortar lining at the factory by centrifugal process to ensure a uniform thickness through out its length. Cement mortar lining is superior to bituminous lining as the former provides a smooth surface and prevents tuberculation by creating a high pH at the pipe wall and ultimately by providing a physical and chemical barrier to the water.

The Indian standard IS 8329-1994 provides specifications for the centrifugally cast ductile iron pipes (Similar to ISO:2531-1998 and EN:545-1994). These pipes are available in the range of 80 mm to 1000 mm diameter; in lengths of 5.5 to 6 m. These pipes are being manufactured in the country with ISO 9002 accreditation.

Ductile iron 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 ductile iron 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. These pipes are approximately 30% lighter than conventional cast iron pipes.

Ductile iron pipes are lined with cement mortar in the factory by centrifugal process and unlined ductile iron pipes are also available. For more details reference may be made to IS 8329 - 1994 for Ductile Iron Pipes.

6.6.2 DUCTILE IRON FITTINGS

The ductile iron fittings are manufactured conforming to IS 9523-1980 for Ductile Iron fittings.

6.6.3 JOINTS

The joints for ductile iron pipes are suitable for use of rubber gaskets conforming to IS 5383.

6.6.4 LAYING AND JOINTING

Reference may be made to para 6.4.2 (laying and jointing of cast iron pipes).

6.6.5 TESTING OF DUCTILE IRON PIPELINES

The Ductile Iron pipelines are tested as per para 6.4.4 (testing of the pipeline) The test pressures shall be as per IS 8329 - 1994.

6.7 ASBESTOS CEMENT PIPES

6.7.1 GENERAL

Asbestos cement pipes are made of a mixture of asbestos paste and cement 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 over come by screwing the ferrules through malleable iron saddles fixed at the point of service connections as is the general practice. 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.

The available safety against bursting under pressure and against failure in longitudinal bending, though less than that for spun iron pipes, is nevertheless adequate and increases as the pipe ages. In most cases, good bedding of the pipes and the use of flexible joints are of greater importance in preventing failure by bending, than the strength of pipe itself. Flexible joints are used at regular intervals to provide for repairing of pipes, if necessary.

AC pipes are manufactured from classes 5 to 25 and nominal diameters of 80mm to 600mm with the test pressure of 5 to 25 Kg/cm².

AC pipe can meet the general requirements of water supply undertakings for rising main as well as distribution main. It is classified as class 5, 10, 15, 20 and 25, which have test pressures 5, 10, 15, 20 and 25 Kg/cm² respectively. Working pressures shall not be greater

than 50% of test pressure for pumping mains and 67% for gravity mains.

For further details, refer to IS 1592-1989.

6.7.2 HANDLING

Utmost care must be taken while loading, transportation, unloading, stacking and retransporting to the site to avoid damage to the pipes.

6.7.2.1 Laying And Jointing

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 atleast 1.25 meter is provided on the top of the pipe.

The AC pipes to be laid are stacked along the trenches on the side or opposite to the spoils. Each pipe should be examined for any defects such as cracks, chipped ends, crusting of the sides etc. The defective pipes should be removed forthwith from the site as otherwise they are likely to be mixed up with the good pipes. 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.

6.7.3 PIPE JOINTS

There are two types of joints for AC pipes.

- ◆ Cast iron detachable joint, (CID)and
- ◆ AC coupling joint.

(a) 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.

(b) A.C. 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 close 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 may be followed for laying A.C. pipes.

6.7.4 PRESSURE TESTING

The procedure for the test 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 or for filling the line 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 test pressures will be generally as specified in 6.7.1 and Appendix 6.4. The water will then be emptied through scour valves and defects observed in the test will be rectified.

6.8 CONCRETE PIPES

6.8.1 GENERAL

Reinforced concrete pipes used in water supplies are classified as P1, P2 and P3 with test pressures of 2.0, 4.0, and 6.0 Kg/cm² 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. 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.

6.8.2 LAYING AND JOINTING

The concrete pipes should be carefully loaded, transported and unloaded avoiding impact. The use of inclined planes or chain pulley block is recommended. 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 15 cm on either side.

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 $1/4$ the internal diameter of pipe with the range of 10-30cm. It shall extend upto the sides of the pipe atleast to a distance of $1/4$ 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 300mm 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 150mm layers upto 900mm above the top of the pipe.

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)

For more details of jointing procedure, reference may be made to I.S. 783-1985.

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 a 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.

6.8.3 PRESSURE TEST

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 in 6.4.4.2. and maintained at this pressure during the period of test with the permissible allowance indicated therein. For further details, reference may be made to I.S. 458-1971.

6.9 PRESTRESSED CONCRETE PIPES

6.9.1 GENERAL

While RCC pipes can cater to the needs where pressures are upto 6.0 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 binding 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 prestressing wire is protected against corrosion by a surround of cementitious cover coat giving atleast 25mm 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 P.S.C. pipes are in use today:

- (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.

Recommended specifications for above pipe are covered by Indian and foreign codes IS: 784- 1978 AWWA C-301 EN-639 and EN-642.

- (a) Steel Cylinder Prestressed Concrete Pipes are used in America and Europe Confirming to AWWA C-301 and in Europe EN - 642.

Prestressed Concrete Cylinder pipe has the following two general types of construction : (1) a steel cylinder lined with a concrete core or (2) 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 pipe is hydrostatically tested to ensure water-tightness. A concrete core with a minimum thickness of one-sixteenth times the pipe diameter 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 ranges between 150,000 and 189,000 psi (1034 and 1303 Mpa) depending on the wire size and class. 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 : AWWA C-301 covers prestressed concrete cylinder pipe 16 in. (410 mm) in inside diameter and larger. Lined cylinder pipe is commonly available in inside diameters ranging from 16 to 48 in. (410 to 1,220 mm). Sizes upto 60 in. are available from some manufacturers. Embedded cylinder pipe has been manufactured larger than 250 in. (6,350 mm) in diameter and is commonly available in inside diameters of 48 in. (1,220 mm) and larger. Lengths are generally 16 - 24 ft (4.9-7.3 m), although longer units can be furnished.

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 impermeability. 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 jointed 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 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.

It is worth while 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 but this is a costly item.

6.9.2 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. Refer to IS 784 -1978, for laying of PSC pipes.

6.9.3 PRESSURE TESTING

Testing of PSC pipe is the same as given in the para 6.4.4.2.

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 (para 15.5.3 pages 28 & 29).

6.9.4 BAR WRAPPED STEEL CYLINDER CONCRETE PRESSURE PIPES

6.9.4.1 General

Bar Wrapped Steel Cylinder Concrete Pressure Pipes (confirming to AWWA C 303 and EN639 & EN 641) are reported to be manufactured in India. No Indian Standard is presently available for these pipes. Bar Wrapped Steel Cylinder Concrete Pressure Pipes are available in diameters of 250 mm to 1500 mm and higher diameter pipes can be designed for working pressures upto 25 kgs per sq. cm.. Standard lengths are generally 5 to 6m. Longer length pipes can also be custom made.

6.9.4.2 Manufacture

Manufacture of Bar Wrapped Steel Cylinder Concrete Pressure Pipes 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. The lining varies from 12mm to 25 mm. 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.

6.9.4.3 Joints

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 clients 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 AWWA C-303 provides for use of elastomeric sealing ring (rubber joint), and EN 641 provides both elastomeric sealing ring and steel end rings welded together on site. At present the pipes available in India use steel end rings welded at site.

6.10 PLASTIC PIPES

6.10.1 GENERAL

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.

6.10.2 PVC PIPES

The chief advantages of PVC pipes are

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

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 buried 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 specially AC. Thermal conductivity of PVC is very low compared to metals. Consequently water transported in these pipes remain at a more uniform temperature.

Rigid PVC pipes weigh only $1/5^{\text{th}}$ 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/cm² as per IS 4985 - 1988.

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.

6.10.3 PRECAUTIONS IN HANDLING AND STORAGE

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. On no account should pipes be dragged along the ground. Pipes should be given adequate support at all times. These pipes should not be stacked in large piles, specially under warm temperature conditions, as the bottom pipes may be 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 I.

6.10.4 LAYING AND JOINTING PROCEDURE

6.10.4.1 Trench Preparation

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.

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.

6.10.4.2 Laying And Jointing

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.

If trucks, lorries, or other heavy traffic will pass across the pipeline, concrete tiles 600 x 600mm of suitable thickness and reinforcement should be laid about 2m above the pipe to distribute the load. If the pipeline crosses a river, the pipe should be buried at least 2m below bed level to protect the pipe.

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 are not recommended. Jointing of PVC pipes can be made in following ways:

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

For further details on laying & jointing of PVC pipes, reference can be made to IS 4985 – 1988, IS 7634 – Part 1-3.

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.

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°. 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°) 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.

6.10.4.3 Pre-Fabricated Connections

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. By proper sizing of the two ends of a connector, it is possible to achieve reduction (or expansion) of pipe size across the connector.

6.10.4.4 Standard Threaded Connections

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.

6.10.5 PRESSURE TESTING

The 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 in 6.4.4.2.

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 Km.

6.11 POLYETHYLENE PIPES

Rigid PVC and high-density polyethylene pipes have been used for water distribution systems mostly ranging from 15 -150mm dia and occasionally upto 350mm.

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 - 1987 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 are coilable, easily be bent in installation, eliminating the use of specials like bends, elbows etc., there by reducing fitting and installation costs. HDPE pipes are easy to carry and install. They are lighter in weight and can be carried to heights as on hills. They can withstand movement of heavy traffic. This would not cause damage to the pipes because of their flexural strength. HDPE has excellent free flowing properties. They have non-adherent surface which reject (not attract) any foreign materials which would impede the flow. HDPE pipes are anti-corrosive, have smooth inner surface so that there is less friction and pressure loss is comparatively less.

HDPE pipes can be jointed by welding.

For further details of PVC and HDPE pipes refer to:

IS 7834 - 1975 Parts 1-8

IS 8008 - 1976 Parts 1-7

IS 7634 - 1975 Parts 1-3

IS 3076 - 1985

IS 4984 - 1987

6.11.1 MEDIUM DENSITY POLYETHYLENE (MDPE) PIPES

The medium density Polyethylene Pipes (MDPE) are now being manufactured in India conforming to ISO specifications (ISO 4427 and BS 6730 - 1986) for carrying potable water. However no BIS is available for these pipes. The MDPE pipes are being used for consumer connection pipes as an alternative to GI pipes. The Polyethylene material used for making the MDPE pipes conforms to PE 80 grade and the MDPE pipes when used for conveying potable water 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.

The Polyethylene material conforms to PE 80 grade. The 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 as per ISO 4427. The pipes are 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.

6.12 GLASS FIBRE REINFORCED PLASTIC PIPES (G.R.P. PIPES)

Glass fibre Reinforced Plastic (GRP) pipes are now being manufactured in India conforming to IS 12709. The diameter range is from 350 mm to 2400 mm. The pressure class is 3,6,9,12 & 15 kgs/sq. cm. The field test pressures are 4.5,9,13.5,18,22.5 kgs/sq cm. The factory test pressures are 6,12,18,24 & 30 kgs/sq cm. Depending on the type of installation, overburden above the crown of the pipe and the soil conditions, four types of stiffness class pipes are available. Standard lengths are 6 & 12 metres, however custom made

lengths can also be made. The specials are made out of the same pipe material i.e. Glass fibre Reinforced Plastic (GRP).

The pipes are jointed as per the techniques; Double bell coupling (GRP) for GRP to GRP; Flange Joint (GRP) for GRP to valves, CI pipes or flanged pipes.

Mechanical Coupling (Steel) for GRP to GRP / steel pipe and Butt - strap joint (GRP) for GRP to GRP.

GRP pipes are corrosion resistant, have smooth surface and high strength to weight ratio. It is lighter in weight compared to metallic and concrete pipes. Longer lengths and hence minimum joints enable faster installation.

G.R.P. pipes are widely used in other countries where corrosion resistant pipes are required at reasonable costs. GRP can be used as a lining material for conventional pipes, which are subject to corrosion. These pipes can resist external and internal corrosion whether the corrosion mechanism is galvanic or chemical in nature.

6.12.1 PIPE INSTALLATION

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.

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-proof. Joint types are normally adhesive bonded, however reinforced overlay and

mechanical types such as flanged, threaded, compressed couplings or commercial/proprietary joints are available.

6.13 STRENGTH OF PIPES

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.

A pipe must withstand the highest internal pressure it is likely to be subjected, the general provisions for which have been discussed in section 6.4.4, while surging or water hammer is discussed in 6.17.

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 and lengths of span increase, the problem becomes more complex and the ends must be supported in saddles or restrained by ring girders. For pipes of more than 900mm in dia the ring girder method will probably provide the most economical design. Structural design of buried pipes is discussed in detail in the companion volume "Manual on Sewerage and Sewage Treatment".

The temperature of the water in a transmission main varies during the year. If the water is

derived from underground sources the variation is relatively small, but if it is obtained from surface sources and is filtered through slow sand filters, the variation may be as much as 20°C during the year. Furthermore, the temperature changes may take place fairly quickly and for these and other reasons, 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 about four years or so, the ground normally consolidates sufficiently around the pipe so that the stress is transferred to the ground. Valves require to be bridged by steel or reinforced concrete blocks so that the valve bodies are not stressed, as this could affect their water tightness.

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 jointed pipelines.

6.13.1 STRUCTURAL REQUIREMENTS

Structurally, closed conduits must resist a number of different forces singly or in combination.

- (a) Internal pressure equal to the full head of water to which the conduit can be subjected (see Appendix 6.4).
- (b) Unbalanced pressures at bends, contractions, and closures which have been discussed in 6.16. 18.
- (c) Water hammer or increased internal pressure caused by sudden reduction in the velocity of the water; by the rapid closing of a gate or shut down of a pump, for example, which has been discussed in 6.17.
- (d) External loads in the form of backfill, traffic, and their own weight between external supports (piers or hangers). A reference may be made to the Manual on Sewerage and Sewage Treatment.
- (e) Temperature induced expansion and contraction, which is discussed in 6.13.2.

Internal pressure, including water hammer, creates transverse stress or hoop tension. Bends and closures at dead ends or gates produce unbalanced pressures and longitudinal stress. When conduits are not permitted to change length, variations in temperature likewise create longitudinal stress. External loads and foundation reactions (manner of support), including the weight of the full conduit, and atmospheric pressure (when the conduit is under vacuum) produce flexural stress.

6.13.2 TEMPERATURE INDUCED EXPANSION AND CONTRACTION

When the conduits are not permitted to change length due to variations in temperature, longitudinal stresses are created in the conduits, which is calculated as shown below:

- (i) Change in pipe length with temperature

$$\Delta = C \theta L \quad (6.12)$$

Where θ = change in temperature and C = coefficient of expansion of conduit per Degree Centigrade and is equal to 11.9×10^{-6} for steel, 8.5×10^{-6} for Cast Iron, and 10×10^{-6} for concrete, L = length of pipe.

- (ii) Resulting longitudinal stress, $S = C \theta E$ (6.13)

for pipeline with fixed ends, and E = Young's Modulus of Elasticity, 2,10,000 N/m² for steel, 1,00,000 N/m² for cast iron, and 1400 - 40,000 N/m² for concrete.

- (iii) Resulting longitudinal force $P = \pi (d+t) t s$ (6.14)

6.13.3 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 semicircular 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) Horse shoe 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.

6.13.4 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 and other aspects as detailed in 6.13.2. When freezing is anticipated, 1.5m cover is recommended as discussed in 10.12.

6.14 ECONOMICAL SIZE OF CONVEYING MAIN

6.14.1 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 is therefore of importance.

The available fall from the source to the town and the ground profile in between should generally help to decide if a free flow conduit is feasible. 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 to help decisions. 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,
 - (ii) Staff for operation of the pump sets,
 - (iii) Cost of repairs and renewals of the pump sets,
 - (iv) Cost of miscellaneous consumable stores, and
 - (v) Cost of replacement of the pumpsets installed to meet the immediate requirements, by new sets at an intermediate stage of design period. The full design period or the repayment period may be 30 years or more while the