*भारतीय मानक*

# पूर्वप्रबलित कंक्रीट पाइप (विशेष सहायकांग सहित) — विशिष्टि

*( दूसरा पुनरीक्षण )*

*Indian Standard*

# PRESTRESSED CONCRETE PIPES (INCLUDING SPECIALS) — SPECIFICATION

*( Second Revision )*

ICS 23.040.50; 91.100.30



**BUREAU OF INDIAN STANDARDS**
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Cement Matrix Products Sectional Committee, CED 53

## FOREWORD

This Indian Standard (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Cement Matrix Products Sectional Committee had been approved by the Civil Engineering Division Council.

This standard was published in 1959 and subsequently revised in 1978 to introduce prestressed concrete cylinder pipes, requirements of fittings, provision of more details on design criteria for the pipes, etc.

This standard lays down the requirements of prestressed concrete pipes primarily used for the conveyance of water and sewerage and specials for use with them. Two types of prestressed concrete pipes are covered by this specification, namely, prestressed concrete cylinder pipes and prestressed concrete non-cylinder pipes.

This second revision incorporates number of modifications, the most significant of them being:

a) modifications in design and other aspects,
b) inclusion of typical worked out examples of design,
c) inclusion of detailed inspection procedure, and
d) increase in range of diameters of pipes.

In the formulation of this standard, assistance has been derived for EN 642 : 1994 Prestressed Concrete Pressure Pipes, Cylinder and Non-Cylinder, European Committee for Standardization (CEN).

The composition of the technical committee responsible for formulation of this standard is given at Annex K.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# PRESTRESSED CONCRETE PIPES (INCLUDING SPECIALS) — SPECIFICATION

*( Second Revision )*

## 1 SCOPE

This standard covers the requirements of prestressed concrete pipes (including specials) with nominal internal diameter in the range of 200 mm to 2 500 mm (*see* Note under Table 1), in which permanent internal stresses are deliberately introduced by tensioned steel to the desired degree to counteract the stresses caused in pipe under service.

## 2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated in Annex A.

## 3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

**3.1 Prestressed Concrete Cylinder Pipe** — A welded sheet steel cylinder with steel socket and spigot rings welded to its ends, lined with concrete suitably compacted and circumferentially prestressed to withstand internal pressure and external design loads and subsequently coated with cement mortar or concrete to protect the steel cylinder and prestressing wires.

**3.2 Prestressed Concrete Non-Cylinder Pipe** — A suitably compacted concrete core longitudinally prestressed with pretensioned high tensile steel wire embedded in the concrete, circumferentially prestressed and coated with cement mortar or concrete to protect the circumferential prestressing wire, to withstand internal pressure and external design loads.

**3.3 Specials** — All items in the pipeline other than straight pipes of standard length, such as bends, air valves and scour valve tees, etc, are classified as specials.

**3.4 Working Pressure** — The maximum sustained internal pressure excluding surge to which each portion of the pipeline may be subjected when installed.

**3.5 Site Test Pressure** — 1.5 times working pressure pertaining to the section or 1.1 times static pressure, whichever is more (surge pressure is to be controlled within 25 percent of pump head in case of pumping main).

**3.6 Factory Test Pressure**

a) Site test pressure + 0.1 N/mm$^2$, for working pressure upto 1 N/mm$^2$, and
b) Site test pressure + 0.2 N/mm$^2$, for working pressure above 1 N/mm$^2$.

**3.7 Surge (Water Hammer) Pressure**

It is a pressure which is produced by a change of velocity of the moving stream and becomes maximum when there is sudden stoppage which may be caused by the closing of a valve or by shutting down a pump station. Surge pressure is to be controlled within 25 percent of pump head.

## 4 MATERIALS

**4.1 Cement**

The cement used in the manufacture of prestressed concrete pipes and specials shall be one of the following:

a) 43 grade ordinary Portland cement conforming to IS 8112.
b) 53 grade ordinary Portland cement conforming to IS 12269.
c) Rapid hardening Portland cement conforming to IS 8041.
d) Portland slag cement conforming to IS 455 with slag not more than 50 percent.
e) Sulphate resisting Portland cement conforming to IS 12330.

NOTE — Sulphate resisting Portland cement shall be used where sulphate is predominant.

**4.2 Aggregates**

The aggregates shall conform to IS 383. The provision of 4 (Grading) of IS 383 shall not apply. Manufacturer shall furnish the grading curve for coarse and fine aggregates which he proposes to use. The variation in fineness modulus during manufacture shall not be more than ±5 percent. Silt content in fine aggregates shall be less than 3 percent. The fineness modulus of the aggregates for coating shall be between 2.6 to 3.2.

**4.3 Water**

Water used for concrete, cement mortar and for curing the pipes shall be free from injurious amounts of oil, acid, strong alkaline scales and vegetable matter and shall be able to make concrete of satisfactory strength requirements.

**4.4 Admixtures**

Admixtures may be used with the approval of the purchaser. However, use of any admixture containing chlorides in any form shall be prohibited. The admixtures shall conform to IS 9103.

**4.5 Steel for Reinforcement**

**4.5.1** *Prestressing Steel*

Prestressing steel wire shall conform to IS 1785 (Part 1) or IS 1785 (Part 2) or IS 6003 or IS 6006. For longitudinal prestressing, wire having tensile strength, less upto 15 percent of ultimate tensile strength, may be used, if required. This is to avoid excessive wear of rollers for threading, or cracking of wire during button heading for end anchors.

**4.5.2** *Untensioned Reinforcement*

Untensioned reinforcement may consist of mild steel conforming to IS 432 (Part 1) or IS 432 (Part 2) or high strength deformed bars conforming to IS 1786 or plain hard drawn steel wire conforming to IS 1785 (Part 1) and IS 1785(Part 2) or welded wire fabric conforming to IS 1566.

**4.6 Steel for Cylinders and Specials**

Steel plates for cylinders and specials shall conform to IS 2062.

**4.7 Rubber Sealing Rings**

**4.7.1** Rubber sealing rings shall comply with IS 5382. The manufacturer of pipe shall examine each sealing ring visually for defects, particularly at the joints.

**4.7.2** Every sealing ring shall be clearly marked. The marking shall indicate the chord diameter, internal diameter of the ring and name of the manufacturer of rubber sealing rings.

**4.7.3** In case of splices, each splice shall be thoroughly visually checked by twisting the ring through 360°. Splices showing visible separation or cracks shall be rejected. Not more than two splices in each ring shall be permitted. All sealing rings shall be protected from direct rays of the sun and stored in dry place.

Following composition of natural rubber is recommended for sealing rings:

| | |
|---|---|
| Natural rubber content as compound | 75.0 percent by mass, *Min* |
| Ash | 6.0 percent by mass, *Max* |
| Total sulphur | 3.0 percent by mass, *Max* |
| Acetone extract | 8.0 percent by mass, *Max* |
| Sulphur in acetone extract | 0.6 percent by mass, *Max* |
| Alcohol potash extract | 1.5 percent by mass, *Max* |
| Filler | Carbon black only |
| Accelerators | As required |

The compounding ingredients listed below shall be added to the composition in the proportions (given based on 100 parts by mass of raw rubber):

| | |
|---|---|
| Waxes (melting point 57° C *Min*) | 0.5 parts by mass, *Min*<br>1.5 parts by mass, *Max* |
| Napthenic process oil | 2.5 parts by mass, *Max* |
| Anti-oxidant | 1.5 parts by mass, *Min* |

**4.8 Bitumen or Other Protective Coating**

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 coating shall not contain any constituents soluble in such water or any ingredient which could impart any taste or odour to the potable water.

## 5 DIMENSIONS AND TOLERANCES

**5.1** Nominal internal diameter of the pipes and minimum core thickness shall be as given in Table 1

**5.2 Length**

Effective length of pipes shall be 2 m to 6 m. However, the preferred effective lengths should be 2, 2.5, 4, 5 and 6 m. For pipes upto and including 300 mm diameter, the effective length shall not be more than 3 m.

**5.3 Tolerance**

**5.3.1** *Length*

Tolerance on length shall be ±1 percent of the specified length.

**5.3.2** *Internal Diameter*

For pipes of length less than 4 m, the tolerance shall be ±5 mm for diameter upto and including 350 mm. For diameter above 350 mm, the tolerance shall be ±10 mm.

For pipes of length 4 m and above, the tolerance shall be as given below:

| *Internal Diameter* | *Tolerances* | |
|---|---|---|
| | In areas within 600 mm of an end of the pipe | Over rest of the pipe |
| | mm | mm |
| Up to 900 mm | ± 6 | ± 9 |
| Over 900 mm and upto 1 600 mm | ± 9 | ± 12 |
| Over 1 600 mm | ± 12 | ± 12 |

**Table 1 Nominal Internal Diameter and Minimum Core Thickness of Pipes**

(*Clause* 5.1)

| Nominal Internal Diameter of Pipe mm | Minimum Core Thickness mm | Nomianl Internal Diameter of Pipe mm | Minimum Core Thickness mm |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| 200 | 35 | 1 300 | 75 |
| 250 | 35 | 1 400 | 75 |
| 300 | 35 | 1 500 | 80 |
| 350 | 35 | 1 600 | 85 |
| 400 | 35 | 1 700 | 90 |
| 450 | 35 | 1 800 | 95 |
| 500 | 35 | 1 900 | 100 |
| 600 | 40 | 2 000 | 105 |
| 700 | 40 | 2 100 | 110 |
| 800 | 45 | 2 200 | 115 |
| 900 | 55 | 2 300 | 120 |
| 1 000 | 60 | 2 400 | 125 |
| 1 100 | 65 | 2 500 | 130 |
| 1 200 | 70 | | |

NOTES

1 Internal diameter of pipes other than those mentioned in this table may be supplied by mutual agreement between the purchaser and the manufacturer. For higher pressure the core thickness have to be increased; in such cases:

a) the diameter will be correspondingly reduced (This is to enable use of same moulds), and

b) multiple layers of circumferential prestressing wire shall be adopted.

2 This standard includes provision upto 2 500 mm diameter pipes. Pipes of diameter beyond 2 500 mm may be supplied in special cases by mutual agreement between purchaser and manufacturer subject to additional precautions taken in design, manufacture, testing and construction of the pipe.

**5.3.3** *Core Thickness*

The core thickness shall not be less than the design thickness by more than 5 percent. The manufacturer shall declare the core thickness and the above tolerance shall be applicable to that core thickness.

## 6 JOINT DIMENSIONS

Joint dimensions with tolerances for socket and spigot diameters shall be furnished by the manufacturer for inspection. The indicative dimensions of socket and spigot are given in Annex B.

## 7 DESIGN

**7.1** Information to be supplied by purchaser is given in Annex C.

**7.2** All pipes shall be designed to withstand the combined effects of internal water pressure and external loads.

**7.3** The design of the prestressed concrete pipes shall cover all such stages, which may induce stresses in any section of the pipe. For investigation of these design stages, the likely extreme conditions of stresses shall be considered in the order of their occurrence, during the process of manufacture, handling, erection and under service.

### 7.4 Design Criteria for Non-Cylinder Pressure Pipes

The pipes shall be designed to meet the requirements given in subsequent clauses.

**7.4.1** *Longitudinal Prestressing Requirements*

The permissible stresses for various load combinations shall be as follows:

| *Description of Loading Combination* | *Permissible Stresses* | |
|---|---|---|
| | Tension $N/mm^2$ | Compression $N/mm^2$ |
| a) Longitudinal prestress (after losses) in barrel | — | Minimum residual compression of 2.5 $N/mm^2$ for upto and including pipe dia 600 mm and 1.0 $N/mm^2$ for dia above 600 mm. |
| b) Longitudinal prestress during circumferential prestressing (temporary) | $0.56 f_p^{0.5}$ | $0.5 f_p$ |
| c) Longitudinal prestress after losses plus beam action | $0.34 f_{ck}^{0.5}$ | $0.5 f_{ck}$ |
| d) Handling | 0.67 $N/mm^2$ | $0.5 f_p$ |
| e) Transport and unloading | $0.56 f_{ck}^{0.5}$ | $0.5 f_{ck}$ |

where

$f_p$ = Characteristic compressive strength of concrete at $p$ days in $N/mm^2$, and

$f_{ck}$ = Characteristic compressive design strength of concrete in $N/mm^2$.

NOTES

1 Longitudinal stresses induced in the core during circumferential prestressing shall be treated as temporary and shall be equal to 0.284 times initial compressive stress induced in core.

2 For longitudinal stress due to beam action, a pipe shall be assumed to span its full length and support a total load per meter in Newtons equal to the self weight, the weight of the water in the pipe and earth load equivalent to 2.2 times the outside diameter of pipe (in mm).

3 For calculation of number of longitudinals for transport and unloading conditions; following bending moment shall be considered for effective length of pipes upto 5 meter and diameter upto 600 mm:

| Dia mm | Bending Moment N mm |
|---|---|
| 200 | $3.04 \times 10^7$ |
| 250 | $3.78 \times 10^7$ |
| 300 | $4.59 \times 10^7$ |
| 350 | $5.45 \times 10^7$ |
| 400 | $6.37 \times 10^7$ |
| 450 | $7.36 \times 10^7$ |
| 500 | $8.44 \times 10^7$ |
| 600 | $11.08 \times 10^7$ |

For pipes having effective length more than 5 m, the bending moment shall be multiplied by a factor $(L/5)^2$, where $L$ is the effective length of pipe. For pipes above 600 mm diameter, no special consideration is necessary. The minimum number of longitudinals for 4 m and 5 m long pipes shall be 12 and 16 respectively.

**7.4.2** Typical calculation for the design of longitudinals for pipe diameter 600 mm and below is given in Annex D.

**7.4.3** *Circumferential Prestressing Requirements*

The permissible stresses for various load combinations shall be as given below:

| *Description of Loading Combination* | *Permissible Stresses* | |
|---|---|---|
| | Tension N/mm² | Compression N/mm² |
| a) Circumferential prestressing condition (Self weight + Initial prestress) | 0 | $0.55 f_p$ |
| b) Site test condition (Site test pressure + Self weight + Weight of water + Earth fill + Final prestress) | $0.13 f_{ck}^{0.67}$ | $0.45 f_{ck}$ |
| c) Factory test condition (Factory test pressure + Self weight + Weight of water + Pre-stress at factory test) | $0.13 f_{ck}^{0.67}$ | $0.45 f_{ck}$ |
| d) Operating condition (Working pressure+ Self weight + Weight of water + Earth fill + final prestress) | 0 | $0.45 f_{ck}$ |
| e) Operating condition + Live load (with impact) | $0.13 f_{ck}^{0.67}$ | $0.45 f_{ck}$ |

where

$f_p$ = Characteristic compressive strength of concrete at $p$ days in N/mm².

$f_{ck}$ = Characteristic compressive design strength of concrete in N/mm².

NOTES

1 The total tensile stress in the core shall be considered as the sum of the hoop stress and flexural stresses, without the application of any reduction factor.

2 When calculating hoop stress, only core thickness should be considered. When calculating ovalization flexural stress, the sum of the core and coating thickness should be considered.

3 For calculating bending moments and thrusts for external loads, Olander's coefficients are to be used. The values for bedding angles from 30° to 180° are given in Annex E.

4 When submitted to factory test, the mortar or concrete coated pipe shall not have cracks in the coating wider than 0.1 mm for more than 300 mm length.

**7.5** Loss of prestress in circumferential and longitudinal wires shall be calculated as per Annex F.

**7.6** Typical design of prestressed concrete pipe, with winding by process of counter weight/break is given in Annex G.

**7.7** Typical design of prestressed concrete pipe with winding by process of die is given in Annex H.

**7.8** Typical design of prestressed concrete pipe for drainage, sewerage and culverts is given in Annex J.

**7.9 Design Criteria for Cylinder Pipes**

The pipes shall be designed to meet the following conditions:

| *Description of Loading Combination* | *Permissible Stresses* | |
|---|---|---|
| | Tension N/mm² | Compression N/mm² |
| a) Circumferential prestressing condition (Self weight + Initial prestress) | 0 | $0.55 f_p$ |
| b) Site test condition (Site test pressure + Self weight + Weight of water + Earth fill + Final prestress) | $0.38 f_{ck}^{0.67}$ | $0.45 f_{ck}$ |

| Description of Loading Combination | Permissible Stresses | |
|---|---|---|
| | Tension N/mm$^2$ | Compression N/mm$^2$ |
| c) Operating condition (Working pressure+ Self weight + Weight of water + Earth fill + Final prestress) | 0 | $0.45 f_{ck}$ |
| d) Operating condition + Live load (with impact) | $0.38 f_{ck}^{0.67}$ | $0.45 f_{ck}$ |

where

$f_p$ = Characteristic compressive strength of concrete at p days in N/mm$^2$.

$f_{ck}$ = Characteristic compressive design strength of concrete in N/mm$^2$.

## 8 MANUFACTURE

### 8.1 Core

**8.1.1** *Moulds*

The moulds and method of manufacture of pipe shall be such that the form and dimensions of the finished pipe conform to the requirements given in **5** and **12** and the surface and edges are clean and true.

**8.1.2** *Concrete Mix*

The proportions of cement, fine aggregate, coarse aggregate and water used in concrete for pipe core shall be determined and controlled as the work proceeds to obtain homogenous, dense, workable, durable concrete of specified strength in the pipe, and minimum defects on the surface of the pipe. The proportions shall be those, that will give the best overall results with the particular materials and the methods of placing used for the work. A minimum of 350 kg/m$^3$ of cement shall be used for concrete. The water cement ratio shall be such, as to ensure that the concrete will meet the strength requirements, but in no case it shall exceed 0.5. The soluble chloride ion content of the concrete or mortar mix, expressed as a percentage of the mass of cement shall not exceed 0.20 percent.

Unless the design calls for higher concrete strength, the minimum compressive strength of concrete shall not be less than 40 N/mm$^2$ at 28 days.

**8.1.3** *Placing of Concrete*

The concrete in the cores may be placed either by the centrifugal method, vertical casting method, or by other approved methods. For centrifugal spinning method, concrete shall be deposited in the mould and the speed of rotation during placing shall be such, that concrete will be evenly distributed. The same is sufficiently compacted at the specified thickness throughout the length of the pipe. After the concrete has been deposited, the rotation shall be continued at an increased speed, for a length of time sufficient to provide the specified strength, sufficient compaction and bond; to permit handling of the mould from the spinning machine, without damage to the pipe core. Excess water and laitance shall be removed from the interior surface of the pipe in an approved manner so that the surface is solid, straight and true.

### 8.2 Curing of Core and Cover Coat

The curing of the concrete core and that of cover coat shall be in two separate operations. The curing for core shall be for a period, till it attains the required strength.

Curing shall be either by steam or by water or by a combination of steam and water, or by use of approved curing compounds. Coating shall be cured for a minimum period of 7 days, if water curing is used. If steam curing is used for coating, after that it should be water cured for at least 3 days.

### 8.3 Pretensioning and Release of Longitudinal Wires

The concrete core shall be longitudinally prestressed, including the socket, by means of high tensile steel wires or strands, which shall be provided with permanent anchorages embedded in the concrete, within the joint portion at each end. The centreline spacing between the longitudinal wires measured along the barrel shall not exceed twice the core thickness or 150 mm, whichever is greater, subject to the provision of **7.4.1**(c).

The clear cover of concrete over all steel reinforcement including the ends of the longitudinal prestressing wires, shall be such that in any finished pipe it is nowhere less than 12 mm.

**8.3.1** The longitudinal wires shall be stressed to the designed tension, taking into account the loss of stress in wire. The tension shall be maintained by positive means till detensioning.

**8.3.2** The tensioned wires shall not be released until the concrete in the core has attained a compressive strength of at least two times the initial longitudinal prestress or 15 N/mm$^2$ whichever is greater.

### 8.4 Circumferential Prestressing

**8.4.1** Circumferential prestressing shall not take place until the concrete in the core has reached a minimum compressive strength of 25 N/mm$^2$, or as per the design requirements whichever is greater.

8.4.2 The initial stress in the wire during circumferential winding shall not be more than 75 percent of the minimum ultimate tensile strength of wire, when counter-weight or break system is used for developing tension. If tension is developed by use of a die, then the initial stress in the wire shall not exceed 65 percent of the ultimate tensile strength of wire.

8.4.3 The initial compressive stress induced in the core concrete shall not exceed 55 percent of the compressive strength of the concrete in the pipe at the time of transfer.

8.4.4 Methods and equipments for wrapping the wire shall be such that wire shall be wound around the core in a helical form at the predetermined design spacing and capable of controlling the tension. Wire splicing shall be capable of withstanding a force equal to the full strength of wire. At the ends of core pipe, the wire shall continue for at least one extra circumferential turn before being anchored.

8.4.5 The clear spacing between the successive turns of the circumferential prestressing wires shall be not less than 6 mm, except at ends or at joints and shall be not more than 50 mm.

8.4.6 *Test Cube Conversion Factors*

The core concrete compressive strength shall be taken on 150 mm × 150 mm cubes. Where the process of manufacture is such that the strength of concrete in the pipe differs from that given by tests on vibrated cubes, the two may be related by suitable conversion factors. If the purchaser requires evidence of these factors, he shall ask for it, before placing the order. The core concrete strength shall be obtained by multiplying the cube strength with the conversion factor and shall be used for design purpose.

**8.5 Cover Coating**

8.5.1 The circumferential prestressing wires on the core pipes shall be protected with a layer of rich cement mortar or concrete or any other approved material which prevents corrosion of wire.

8.5.2 If cement mortar is used for cover coating, it shall be applied by rotary brushes or by other approved methods and shall preferably be applied within 16 hours after the prestressing wire is wound. The cement, sand and water shall be thoroughly mixed, before being fed into the cover coating machine. Minimum cement content in coating mortar shall be 540 kg/m$^3$ and that for concrete 500 kg/m$^3$. Water cement ratio in the mix shall not be less than 0.27, if cement mortar is used for coating. Rebound or droppings not exceeding one fourth of the total mass of mix, may be used but the resulting mix proportions shall not be, leaner than original design mix. Rebound not used within one hour, shall be discarded.

8.5.3 Pneumatic process in which mixing of ingredients is carried out at the nozzle or gun, shall not be permitted.

8.5.4 The compressive strength of the cover coating mortar shall be obtained from cubes having area of face 50 cm$^2$ or the compressive strength of the cover coating concrete shall be obtained from cube having area of face 100 cm$^2$ and shall not be less than 35 N/mm$^2$ at the time of factory testing of pipe.

8.5.5 The mortar coating shall have a minimum cover of 18 mm and concrete coating shall have a minimum cover of 25 mm, over all steel, except at end face and the spigot portion going inside socket, where it will be not less than 15 mm. To achieve adequate bond between core and coat, approved bonding agent shall be applied, at ends of pipe for a width of 100 mm, along the circumference to prevent separation between core and coat, at ends.

Concurrently with the mortar coating, a cement slurry shall be applied on to the core at a rate of not less than 0.5 l/m$^2$ just ahead of the mortar coating. The slurry shall consist of 1.2 kg of cement to per litre of water.

8.5.6 The thickness shall be checked for every pipe as soon as, coating is done.

8.5.7 *Mortar Soundness*

After the mortar coating is cured and prior to transport, the coating on each pipe shall be checked for delamination and hollows by tapping the exterior with a hammer having a head mass of not more than 0.5 kg. Any hollows or drumming areas detected by sounding shall be repaired by approved methods.

8.5.8 All cement coming in contact with each other shall be of same type and composition and shall be from the same cement works.

## 9 ADDITIONAL REQUIREMENTS FOR CYLINDER PIPES

9.1 The prestressed concrete cylinder pipes shall be manufactured to comply with the following additional requirements.

9.1.1 *Steel Socket and Spigot Rings*

Each ring shall be formed by one piece of steel or a number of pieces of steel butt-welded together. The rings shall be expanded beyond their elastic limit so that they are accurately shaped. The portion of the socket and spigot rings which shall be exposed after the pipe is completed shall be smooth to prevent cutting of the rubber gasket during jointing and shall be protected from corrosion by a sprayed zinc coating of minimum thickness of 0.05 mm followed by one coat of bituminous paint. Other suitable protection may be used with the approval of the purchaser.

9.1.2 *Fabrication of Steel Cylinders*

The cylinder shall be accurately shaped to the size required and steel socket and spigot rings welded thereto after being jigged square with the longitudinal axis (except for bevel).

9.1.2.1 *Testing*

Before it is subjected to any further manufacturing process, each steel cylinder, with steel and spigot rings welded on, shall be subjected to water pressure which stresses the steel to at least 140 $N/mm^2$, but not more than 175 $N/mm^2$. While under stress, the assembly especially welds, shall be inspected and any parts showing leakage shall be repaired and the whole assembly retested.

## 10 SPECIALS

### 10.1 Fabrication

The steel for fabricated steel plate specials, is cut, shaped and welded so that the finished special has the required shape and internal dimensions. 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 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 h. If any coloured spots appear before 4 h, weld shall be repaired and retested.

### 10.2 Lining and Coating

Steel plate specials are lined and coated with concrete or cement mortar or other approved materials, as agreed between the manufacturer and the purchaser. The proportion of cement to total aggregate shall not be leaner than 1 : 3 by mass.

### 10.3 Reinforcement

For concrete or cement mortar coating, reinforcement shall be suitably tack welded to the shell. The reinforcement shall be wire rods and spirals or wire mesh or wire fabric.

### 10.4 Jointing Between Special and Pipe

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 3 $kg/cm^2$.

## 11 JOINTS

11.1 Unless specified otherwise, joints between pipes shall be of the spigot and socket type, so manufactured, that when fitted with the correct size rubber sealing ring, the joint shall be self centreing, flexible and water tight. The joint shall be roll-on or confined type. Sockets of the pipes may be projecting or flush with the barrel. Joint design shall be furnished by manufacturer before undertaking manufacture. The rubber ring joint design, shall take into consideration the tolerance for rubber chord, tolerance for socket and spigot diameters, allowable deflection at joint and permanent set in the rubber ring.

11.2 The sealing rings shall be of such size that when jointed, in accordance with the manufacturer's instructions, it shall provide a positive seal within the manufacturer's recommended range of maximum joint deflection. Not more than two splices in each ring shall be permitted.

## 12 WORKMANSHIP AND FINISH

### 12.1 Deviation from the Straightness

When measured by means of a one metre straight edge the deviation from straight per metre length shall not exceed 5 mm.

### 12.2 Finish

Pipe shall be free from local depressions or bulges greater than 5 mm extending over a length, in any direction, greater than twice the thickness of barrel. The external surface of the pipe may be sand faced, when coating of cement mortar is applied.

## 13 TEST

### 13.1 Design Proving and Manufacturing Process Approval Test in Factory

As soon as 4 to 5 pipes are made, these shall be installed and site pressure test shall be conducted, to prove and finalize pipe and joint design and joint dimension tolerances, etc. For one diameter and different pressure, only the test for highest pressure shall be done. For this test no external load shall applied.

### 13.2 Hydrostatic Factory Test

The pipe shall be tested in accordance with IS 3597. The pipe must not show leakage. Damp or wet patches shall be accepted. If the pipe fails to pass the test, it can be cured or repaired to improve its water tightness and then retested. In case the pipe does not stand the rated internal pressure, it shall be accepted for lower pressure, purchaser at his own discretion may accept the pipes for lower pressure to which it withstands, provided all other requirements are conforming to this standard.

Non-pressure pipes for drainage, sewerage and culverts, shall be tested for 0.14 $N/mm^2$.

**13.3 Permeability Test on Coating**

The drop of water level, in the specimens of pipes selected, when tested according to the method described in IS 3597 shall not exceed 2 $cm^3$ at the end of two hours and the final permeability between fourth and fifth hour shall not exceed 0.3 $cm^3$. When a higher result is obtained, the test shall be repeated on twice the number of pipes originally tested and the lot shall be accepted, if all pipes pass the test. Where retest is not satisfactory, all pipes from that lot may be tested individually and only those with satisfactory results shall be accepted. No additional treatment of any type shall be allowed on the pipe before permeability test is done.

The criteria for acceptance is the final permeability. The test shall be done immediately after the hydrostatic factory test. In case this is done later, the pipe shall be kept wet for 48 hours prior to test.

**13.4 Three Edge Bearing Test (for Pipes for Drainage, Sewerage and Culverts)**

Pipes designed for drainage, sewerage and culverts when subjected to three edge bearing test in accordance with IS 3597 shall meet the requirement as given in Table 2.

**13.5 Dimensional Characteristic**

The pipe selected shall be checked for conformity to the dimensional requirements as given below:

a) Socket and spigot diameters of the pipes as given by manufacturer.
b) Dimensional requirements as given in **5**.

**13.6 Repair of Core and Coat**

Pipes not satisfying any of the tests, which may be arising due to occasional imperfection in manufacture or damages during handling, may be treated / repaired and shall be accepted if they satisfy the tests. The curing of the repaired concrete or mortar may be done using curing compound.

## 14 SAMPLING AND CRITERIA FOR ACCEPTANCE

**14.1 Pressure Pipes for Water Supply and Sewerage**

Basic requirement, unless the design proving and manufacturing process test in **13.1** is satisfactorily carried out, no acceptance tests shall be undertaken. This has to be done for every new diameter of pipe and for one pressure.

All the pipes manufactured under relatively similar conditions in respect of raw-materials and processing operation, shall be grouped together to constitute a lot.

Each lot shall be taken separately for sampling and evaluation, for conformity to the requirements of this standard, if the conditions mentioned in **5.1**, **5.2**, **5.3**, **11.1**, **11.2** and **12.2** are satisfied (even after repairs). Scale of sampling shall be as given in Table 3.

**14.2** For non pressure pipes for drainage, sewerage and culvert, only permeability test from Table 3 besides dimensions and three edge load bearing test is necessary.

**Table 2 Three Edge Bearing Test Loads for Pipes for Drainage, Sewerage and Culverts**

(*Clause* 13.4)

| Nominal Internal Dia of Pipe | $Np_2$ Class Load to Produce Maximum 0.25 mm Crack | $Np_3$ Class Load to Produce Maximum 0.25 mm Crack | $Np_4$ Class Load to Produce Maximum 0.25 mm Crack | Nominal Internal Dia of Pipe | $Np_2$ Class Load to Produce Maximum 0.25 mm Crack | $Np_3$ Class Load to Produce Maximum 0.25 mm Crack | $Np_4$ Class Load to Produce Maximum 0.25 mm Crack |
|---|---|---|---|---|---|---|---|
| mm | kN/m | kN/m | kN/m | mm | kN/m | kN/m | kN/m |
| (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| 200 | 11.77 | 14.50 | 24.60 | 1 300 | 28.20 | 62.30 | 96.20 |
| 250 | 12.55 | 15.00 | 25.50 | 1 400 | 29.42 | 67.06 | 104.20 |
| 300 | 13.48 | 15.50 | 26.40 | 1 500 | 30.77 | 71.85 | 111.90 |
| 350 | 14.46 | 16.77 | 29.80 | 1 600 | 32.12 | 76.64 | 119.60 |
| 400 | 15.45 | 19.16 | 33.90 | 1 700 | 33.59 | 81.40 | 127.40 |
| 450 | 16.18 | 21.56 | 36.90 | 1 800 | 35.06 | 86.22 | 135.30 |
| 500 | 17.16 | 23.95 | 40.00 | 1 900 | 36.41 | 91.00 | 135.30 |
| 600 | 18.88 | 28.74 | 46.30 | 2 000 | 37.76 | 95.80 | 135.30 |
| 700 | 20.35 | 33.53 | 52.20 | 2 100 | 38.99 | 100.60 | 138.70 |
| 800 | 21.57 | 38.32 | 59.30 | 2 200 | 40.21 | 105.38 | 142.20 |
| 900 | 22.80 | 43.11 | 66.30 | 2 300 | — | 110.00 | 148.60 |
| 1 000 | 24.27 | 47.90 | 72.60 | 2 400 | — | 114.96 | 155.00 |
| 1 100 | 25.50 | 52.69 | 80.40 | 2 500 | — | 119.70 | 160.80 |
| 1 200 | 26.97 | 57.48 | 88.30 | | | | |

NOTE — Pipes with other three-edge bearing test requirements may be supplied by agreement between purchaser and manufacturer.

**Table 3 Scale of Sampling and Number of Acceptable Defective Tests**

(*Clause* 14.1)

| Number of Pipes in Lot | Hydrostatic Test | | Socket and Spigot Dimension | | Permeability | | Coating Thickness | | Dimensional Test | | Three Edge Bearing Test Drainage, Sewerage, Culvert Pipes | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | * | ** | * | ** | * | ** | * | ** | * | ** | * | ** |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| 20-50 | All | Nil | All | Nil | 3 | Nil | 3 | Nil | 3 | Nil | 2 | Nil |
| 51-100 | All | Nil | All | Nil | 5 | Nil | 5 | Nil | 5 | Nil | 2 | Nil |
| 101-300 | All | Nil | All | Nil | 8 | Nil | 8 | Nil | 8 | Nil | 3 | Nil |
| 301-500 | All | Nil | All | Nil | 13 | Nil | 13 | Nil | 13 | Nil | 4 | Nil |
| 501-1 000 | All | Nil | All | Nil | 26 | 1 | 26 | 1 | 26 | 1 | 5 | Nil |

* Number of samples.

** Number of defectives acceptable.

**14.3** After the lot is accepted, each pipe shall be marked with a colour band at ends. Different colours to be used for different pressure heads.

## 15 PROCEDURE FOR INSPECTION

### 15.1 Dimensional Checks

**15.1.1** *Internal Diameter*

The internal diameter shall be measured at each end of the pipe at approximately 50 mm from the ends and at centre. Two measurements of the internal diameter at 90° to each other shall be made at each end and at the centre.

To accomplish this, 'Go' and 'No Go' gauges of a stiff rod with hardened rounded ends shall be used. The length of gauges and colour shall be given below:

| | *Length* | *Colour* |
|---|---|---|
| Gauges for ends | | |
| 'Go' | 1 mm less than – ve tolerance | Green |
| 'No Go' | 1 mm more than + ve tolerance | Orange |
| Gauges for centre | | |
| 'Go' | 1 mm less than – ve tolerance | Green with white bands |
| 'No Go' | 1 mm more than + ve tolerance | Orange with white bands |

*Example*:

Suppose theoretical diameter of pipe = 1 200 mm and length of pipe 5 m.

| | *Tolerance* | *Length of gauge* |
|---|---|---|
| Ends | ± 9 | 'Go' 1 200 – 8 = 1 192 mm |
| | | 'No Go' 1 200 + 10 = 1 210 mm |
| Centre | ± 12 | 'Go' 1 200 – 11 = 1 189 mm |
| | | 'No Go' 1 200 + 13 = 1 213 mm |

**15.1.2** *Core Thickness*

Measurement of outer circumference of core shall be made at three barrel positions and average outer diameter of core shall be calculated. The inside diameter shall be measured at three barrel positions and average is calculated. The core thickness shall be calculated as follows:

$$\frac{\text{Average outside diameter} - \text{Average inside diameter}}{2}$$

**15.1.3** *Socket and Spigot Diameters*

**15.1.3.1** *Socket diameter (jointing surface)*

The socket diameter shall be checked by measuring the sway by touching the two points $B$ and $B_1$ along the circumference of socket (*see* Fig. 1); $BB_1$ gives the sway.

*Example*:

Suppose the theoretical diameter of socket

$D$ = 1 383 mm

Permissible variation = + 2 mm
–0.5 mm

The maximum diameter = $D_1$ = 1 385 mm

The minimum diameter = $D_2$ = 1 382.5 mm

The sway = $S = 2 \times [h \times (D_1 - h)]^{0.5}$

Assume $h$ = 5 mm (*see* Fig. 1)

Sway $S = 2 \times [5 \times (1385 - 5)]^{0.5}$
$= 2 \times 83$
$= 166$ mm.

$L^2 = (S/2)^2 + (D_1 - h)^2$
$= (166/2)^2 + (1\ 385 - 5)^2$
$= 6\ 889 + 1\ 90\ 4400$

$L$ = 1 382.5 mm

This should not be more than the minimum permissible inside diameter.

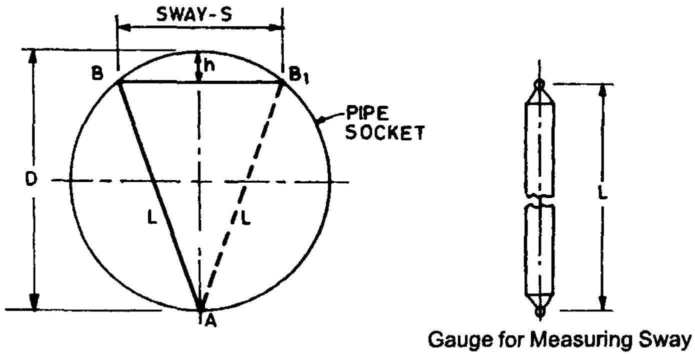



FIG. 1 ARRANGEMENT FOR MEASURING SWAY

Therefore, in this case

| | |
|---|---|
| Length of gauge, *L* | = 1 382.5 mm |
| Maximum permissible sway | = 166 mm. |

**15.1.3.2** *Spigot Diameter*

The gauge as shown in Fig. 2 shall be used.

*Example*:

Suppose the theoretical outside diameter of spigot = 1 200 mm

Permissible variation = ± 1 mm

The maximum diameter = 1 201 mm

The minimum diameter = 1 199 mm.

To enable gauge to pass over the spigot surface, the diameter must be more by 1 mm than the maximum spigot diameter.

The clearance between gauge points = 1 200 + 1 + 1
= 1 202 mm.

For checking spigot, the gauge is held in the position as shown in Fig. 2. Then by keeping point 'X' fixed, other end 'Y' of gauge is moved over the circumference of spigot, where the gap between spigot surface and gauge is maximum, a strip 2.5 mm, thick and 25 mm wide (straight side) (1 201 – 1 199 = 2.0 mm) is inserted. It should not go. Two checks shall be done at 90° to each other.

**15.1.4** *Straightness*

The straightness shall be measured by a one metre long gauge . The deviation from straight line taken between two points one metre apart, along the pipe barrel shall not exceed 5 mm (*see* Fig. 3).

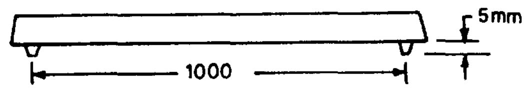



FIG. 3 GAUGE FOR MEASURING STRAIGHTNESS

## 16 MARKING

**16.1** The following information shall be clearly marked on each pipe:

a) Source of identification of the manufacturer,
b) Size and hydrostatic factory test pressure, and
c) Date of manufacture.

**16.2** Each pipe may also be marked with the Standard Mark.

**16.2.1** The use of the Standard Mark is governed by the provisions of *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which a licence for the use of Standard Mark may be granted to manufacturer and producers may be obtained from the Bureau of Indian Standards.

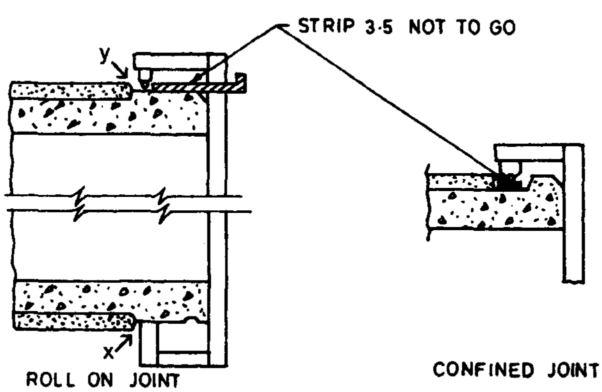



FIG. 2 ARRANGEMENT FOR CHECKING SPIGOT DIAMETER

# ANNEX A

## (*Clause* 2)

## LIST OF REFERRED INDIAN STANDARDS

| *IS No.* | *Title* |
|---|---|
| 432 | Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement |
| (Part 1) : 1982 | Part 1 Mild steel and medium tensile steel bars (*third revision*) |
| (Part 2) : 1982 | Part 2 Hard-drawn steel wire (*third revision*) |
| 455 : 1989 | Specification for Portland slag cement (*fourth revision*) |
| 783 : 1985 | Code of practice for laying of concrete pipes (*first revision*) |
| 1566 : 1982 | Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*) |
| 1785 | Specification for plain hard-drawn steel wire for prestressed concrete |
| (Part 1) : 1983 | Part 1 Cold-drawn stress relieved wire (*second revision*) |
| (Part 2) : 1983 | Part 2 As drawn wire (*first revision*) |
| 1786 : 1985 | Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*) |
| 1916 : 1989 | Specification for steel cylinder pipe with concrete lining and coating (*first revision*) |
| 2062 : 1992 | Steel for general structural purposes (*fourth revision*) |
| 3597 : 1998 | Methods of test for concrete pipes (*second revision*) |
| 3658 : 1999 | Code of practice for liquid permanent flaw detection (*second revision*) |
| 5382 : 1985 | Rubber sealing rings for gas mains, water mains and sewers (*first revision*) |
| 6003 : 1983 | Specification for intended wire for prestressed concrete (*first revision*) |
| 6006 : 1983 | Specification for uncoated stress relieved strand for prestressed concrete (*first revision*) |
| 8041 : 1990 | Specification for rapid hardening Portland cement (*second revision*) |
| 8112 : 1989 | Specification for 43 grade ordinary Portland cement (*first revision*) |
| 9103 : 1999 | Specification for admixtures for concrete (*first revision*) |
| 12269 : 1987 | Specification for 53 grade ordinary Portland cement |

# ANNEX B

(*Clause* 6)

## INDICATIVE DIMENSIONS OF SOCKET AND SPIGOT OF PRESTRESSED CONCRETE PIPE

**B-1** The indicative dimensions of socket and spigot of prestressed concrete pipe are given below (*see also* Fig. 4):

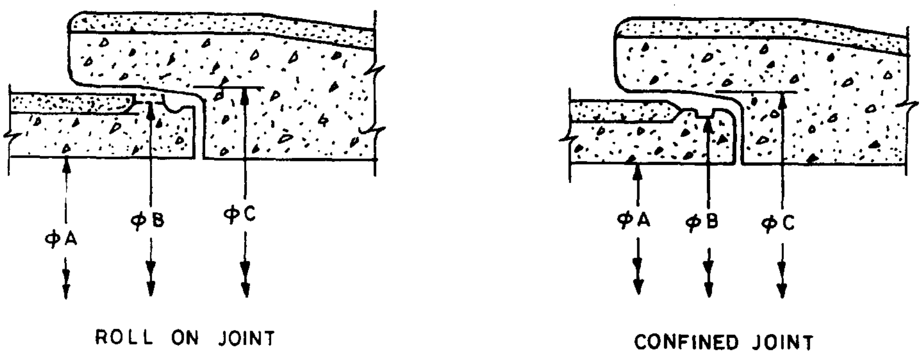



FIG. 4 DETAILS OF JOINTS

| *A* Nominal Dia of Pipe | *Roll On Joint* | | *Confined Joint* | |
|---|---|---|---|---|
| | *C* Internal Dia of Socket | *B* External Dia of Spigot | *C* Internal Dia of Socket | *B* External Dia of Spigot |
| 200 | 308 | 290 | 308 | 290 |
| 250 | 352 | 334 | 352 | 334 |
| 300 | 404 | 386 | 404 | 386 |
| 350 | 456 | 438 | 456 | 438 |
| 400 | 518 | 500 | 518 | 500 |
| 450 | 562 | 544 | 562 | 544 |
| 500 | 612 | 594 | 612 | 594 |
| 600 | 726.5 | 704 | 726.5 | 704 |
| 700 | 826.5 | 804 | 826.5 | 804 |
| 800 | 937.5 | 915 | 937.5 | 915 |
| 900 | 1 058.5 | 1 036 | 1 058.5 | 1 036 |
| 1 000 | 1 165.5 | 1 141 | 1 165.5 | 1 141 |
| 1 100 | 1 270.5 | 1 246 | 1 270.5 | 1 246 |
| 1 200 | 1 381.5 | 1 357 | 1 381.5 | 1 337 |
| 1 300 | 1 496.5 | 1 472 | 1 496.5 | 1 472 |
| 1 400 | 1 595.5 | 1 571 | 1 595.5 | 1 571 |
| 1 500 | 1 706 | 1 678 | 1 706 | 1 678 |
| 1 600 | 1 818 | 1 790 | 1 818 | 1 790 |
| 1 700 | 1 928 | 1 900 | 1 928 | 1 900 |
| 1 800 | 2 036 | 2 008 | 2 036 | 2 008 |
| 1 900 | 2 154 | 2 126 | 2 154 | 2 126 |
| 2 000 | 2 264 | 2 236 | 2 264 | 2 236 |
| 2 100 | 2 374 | 2 346 | 2 374 | 2 346 |
| 2 200 | 2 488 | 2 454.5 | 2 488 | 2 431.5 |
| 2 300 | 2 598 | 2 564.5 | 2 598 | 2 564.5 |
| 2 400 | 2 708 | 2 674.5 | 2 708 | 2 674.5 |
| 2 500 | 2 818 | 2 784.5 | 2 818 | 2 784.5 |

NOTE — All the manufacturers shall try to achieve above dimensions within a period of five years.

# ANNEX C

(*Clause* 7.1)

## INFORMATION TO BE SUPPLIED BY PURCHASER WITH AN ENQUIRY OR ORDER FOR PRESTRESSED CONCRETE PIPES

**C-1** The following information shall be supplied:

a) The type of cement to be used in the core and the cover coat (**4.1**);

b) Whether or not a bituminous or other approved coating is required internally and externally (**4.8**);

c) The maximum working pressure (**3.4**);

d) The maximum site test pressure (**3.5**);

e) Factory test pressure (**3.6**);

f) Pressure in addition to (c) to which the pipe-line will be subjected due to surge (water hammer) (**3.7**), if any; and

g) Following pipe installation details:

1) The maximum and minimum depths of cover over the crown of the pipe.

2) The width of the trench at the crown of the pipe (normally outside diameter of pipe + 600 mm). If the pipes are to be laid above ground in case of partial trench, full details including L-section should be supplied.

3) Whether more than one pipeline is to be laid in the trench and if so, what will be the trench width at the crown of the pipe.

4) Details of the backfill material, that is, sand, gravel, etc.

5) Density of filling material.

6) Type of bedding intended.

7) Anticipated superimposed loading on ground surface.

# ANNEX D

(*Clause* 7.4.2)

## TYPICAL CALCULATION FOR THE DESIGN OF LONGITUDINALS FOR PIPE DIAMETER 600 mm AND BELOW

**D-1** Explanation of various symbols used in subsequent clauses is given in Annex K.

**D-2 DATA**

Diameter of pipe, $D$ = 500 mm
Effective length of pipe = 5 000 mm
Core thickness, $t_c$ = 35 mm
Coat thickness, $t_b$ = 22 mm

Minimum compressive strength of core concrete (spun) at various stages

a) Characteristic compressive design strength, $f_{ck}$ = 40 N/mm²

b) At winding (*see* **8.4.1**), $f_{p2}$ = 25 N/mm²

c) At detensioning longitudinals (*see* **8.3.2**), $f_{p1}$ = 15 N/mm²

Diameter of longitudinal wire = 4 mm

Ultimate tensile strength of wire (*see* **4.5.1**) = 1 715 N/mm²

Initial compressive stress induced in core, $f_{ci}$ = 10.657 5 N/mm² (Assumed)

**D-3 CALCULATION OF STRESS IN LONGITUDINAL DIRECTION**

**D-3.1 Centreline Spacing Between Longitudinal Wires**

Centreline spacing between longitudinal wires shall not exceed twice the core thickness or 150 mm whichever is greater (*see* **8.3**), that is

2 × 35 or 150 mm, that is, 150 mm.

Number of longitudinals considered in design = 16

Centreline spacing between longitudinal wires $= 3.141\,6 \times (D + T_c)/N$ $= 3.141\,6 \times (500 + 35)/16$, $= 105.04 \text{ mm} < 150 \text{ mm}$

Hence, number of longitudinals considered in design is correct.

**D-3.2 Intial Longitudinal Precompression in Core**

Initial stress in longitudinal wire (*see* **8.4.2**), $f_{sil}$

1 715 × 0.75 = 1 286.25 N/mm$^2$

Area of core concrete, $A_c$

3.141 6 × 535 × 35 = 58 826.46 mm$^2$

Longitudinal precompression

$$= \frac{\text{Longitudinal force}}{A_c} = \frac{N \times A_{dl} \times f_{sil}}{A_c}$$

$$\text{Initial precompression}, f_{cil} = \frac{16 \times 12.57 \times 1\,286.25}{58\,826.46}$$

$$= 4.397\,5 \text{ N/mm}^2$$

Concrete strength required at detensioning of longitudinals, $f_{pl}$ (*see* **8.3.2**)

2 × $f_{cil}$ OR 15 N/mm$^2$, whichever is greater,

that is, 2 × 4.397 5 = 8.795 0 or 15 N/mm$^2$, whichever is greater

Adopt $f_{pl}$ = 15 N/mm$^2$

**D-3.3 Loss of Stress in Longitudinal Wires** (*see* **Annex F**)

a) Relaxation of wire
   $0.08 \times f_{sil} = 0.08 \times 1\,286.25 = 102.90$ N/mm$^2$
b) Deformation due to creep
   $2.50 \times f_{cil} = 2.50 \times 4.397\,5 = 10.99$ N/mm$^2$
c) Deformation due to shrinkage
   $0.000\,1 \times E_s = 0.000\,1 \times 20.0 \times 10^4$
   $= 20.00$ N/mm$^2$
d) Yield due to mould shortening, wire stretch due to filling, vibration during spinning, etc

$$= \frac{2 \times E_s}{\text{Effective length of pipe } + 80 \text{ mm}}$$

$$= \frac{2 \times 20 \times 10^4}{5\,000 + 80} = 78.74 \text{ N/mm}^2$$

Total losses = 102.90 + 10.99 + 20.0 + 78.74 = 212.63 N/mm$^2$

**D-3.4 Precompression in Core in Longitudinal Direction**

*At the stage of winding*

Loss of prestress in longitudinal wire at winding = Total losses × 0.9 = 212.63 × 0.9 = 191.37 N/mm$^2$

Stress in longitudinal wire at winding ($f_{slw}$) = 1 286.25 – 191.37$f_{slw}$ = 1 094.88 N/mm$^2$

$$\text{Precompression at winding}, f_{clw} = \frac{16 \times 12.57 \times 1\,094.88}{58\,826.46}$$

$$f_{clw} = 3.742\,2 \text{ N/mm}^2$$

*At site test*

Stress in longitudinal wire after losses, $f_{sl}$ = 1 286.25 – 212.63 = 1 073.62 N/mm$^2$

$$\text{Final precompression}, f_{cl} = \frac{16 \times 12.57 \times 1\,073.62}{58\,826.46}$$

$$f_{cl} = 3.670\,5 \text{ N/mm}^2$$

**D-3.5 Longitudinal Stress Due to Circumferential Winding**

Maximum local longitudinal tensile stress during winding

= 0.284 × 10.657 5 = 3.026 7 N/mm$^2$

**D-3.6 Stress Due to Beam Action**

Self weight of pipe $W_s$ = 2 295.62 N/m
Weight of water $W_w$ = 1 963.50 N/m

Earth load to be considered (*see* **7.4.1**)

$2.2 \times (D + 2 \times T_c + 2 \times T_b)$ = 1 350.80 N/m
= 2.2 × 614

Total load $W = W_s + W_w$ + 1 350.80 = 5 609.92 N/m

Modulus of circular section of pipe ($Z_1$)

$$\frac{3.141\,6}{32} \times \frac{614^4 - 500^4}{614} = 12\,731\,728 \text{ mm}^3$$

Bending moment (BM)

$$\frac{WL^2}{8} = \frac{5\,609.92 \times 5 \times 5 \times 1\,000}{8} = 17\,531\,000 \text{ Nmm}$$

$$\text{Stress due to beam action} = \frac{BM}{Z_1} = 1.376\,9 \text{ N/mm}^2$$

**D-3.7 Stress Due to Self Weight of Core**

Self weight of core ($W_c$) = 1 411.84 N/m

Modulus of circular section of core ($Z_2$)

$$\frac{3.141\,6}{32} \times \frac{570^4 - 500^4}{570} = 7\,416\,520 \text{ mm}^3$$

B.M. due to mass of core (*BM*)

$$\frac{1\,411.84 \times 5 \times 5 \times 1\,000}{8} = 4\,411\,985 \text{ Nmm}$$

$$\text{Stress due to self weight of core} = \frac{BM}{Z_2} = \pm 0.594\,9 \text{ N/mm}^2$$

**D-3.8 Stress Due to Transport and Handling**

Bending moment = $8.44 \times 10^7$ (*see* Note 3 under **7.4.1**)

Modulus of circular section of pipe ($Z_1$)

$$\frac{3.1416}{32} \times \frac{614^4 - 500^4}{614} = 12\,731\,728\ \text{mm}^3$$

Stress due to transport and handling =

$$\frac{\text{Bending Moment}}{Z_1} = \frac{8.44 \times 10^7}{12\,731\,728} = \pm 6.6291\ \text{N/mm}^2$$

**D-3.9 Summary of Stresses in Longitudinal Direction**

| *Stresses due to* | *Compressive* N/mm² | *Tensile* N/mm² |
|---|---|---|
| Maximum local longitudinal tensile stress due to bending during winding | — | –3.026 7 |
| Beam action | + 1.376 9 | –1.376 9 |
| Self weight of core | + 0.594 9 | –0.594 9 |
| Transport and unloading | + 6.629 1 | –6.629 1 |
| Initial precompression | + 4.397 5 | — |
| Precompression at winding | + 3.743 2 | — |
| Final precompression | + 3.670 5 | — |

**D-3.10 Load Combination of Longitudinal Stresses Under Different Condition** (*see* **7.4.1**)

*Actual against Permissible*

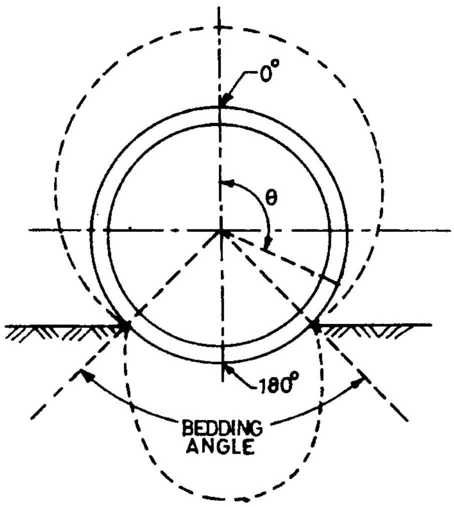
| *Loading Combination* | *Longitudinal Stresses,* N/mm² | | | |
|---|---|---|---|---|
| | Tensile | | Compressive | |
| | Actual | Permissible | Actual | Permissible |
| a) Longitudinal prestress in barrel (after losses) | — | — | +3.6705 | Minimum residual compressive stress +2.5 |
| b) Longitudinal prestress during winding | – (3.026 7 + 0.594 9) + 3.743 2 = +0.121 6 | $0.56 \times (f_{p2})^{0.5}$ 0.56 × $(25)^{0.5}$ = –2.800 0 | (0.594 9 + 3.743 2) = + 4.338 1 | $0.5 \times (f_{p2})^{0.5} \times 25$ = 12.500 0 |
| | **+0.121 6 < –2.800 0** | | **+4.338 1 < 12.500 0** | |
| c) Longitudinal prestress after losses plus beam action | (–1.376 9 + 3.670 5) = +2.293 6 | $0.34 \times (f_{ck})^{0.5}$ 0.34 × $(40)^{0.5}$ = –2.150 3 | (1.376 9 + 3.670 5) = + 5.047 4 | $0.5 \times (f_{ck})^{0.5} \times 40$ = 20.0 |
| | **+2.293 6 < – 2.150 3** | | **+5.047 4 < 20.0** | |
| d) Handling before winding | (–0.594 9 + 3.743 2) = +3.148 3 | – 0.67 | (0.594 9 + 3.743 2) = + 4.338 1 | $0.5 \times (f_{p1})^{0.5} \times 15$ = 7.5 |
| | **+3.148 3 < – 0.67** | | **+ 4.338 1 < 7.5** | |
| e) Transport and unloading | –6.629 1 + 3.670 5 = –2.958 6 | $0.56 \times (f_{ck})^{0.5}$ 0.56 × $(40)^{0.5}$ = –3.541 7 | +6.629 1 + 3.670 5 = +10.299 6 | $0.5 \times (f_{ck})^{0.5} \times 40$ = 20 |
| | **–2.958 6 < – 3.541 7** | | **+10.299 6 < 20.0** | |

# ANNEX E

(*Clause* 7.4.3)

## THRUST AND MOMENT COEFFICIENTS

**E-1** The coefficients at control sections for bedding angles from 30° to 180° developed by use of Olander's Equations are as given below:




| *Bedding Angle* | *Location of Control Section, θ* | *Thrust Coefficients, $C_t$* | | | *Moment Coefficient, $C_m$* | | |
|---|---|---|---|---|---|---|---|
| | | Pipe $C_{tp}$ | Water $C_{tw}$ | Earth $C_{te}$ | Pipe $C_{tp}$ | Water $C_{tw}$ | Earth $C_{te}$ |
| | 0° | –0.078 | –0.237 | +0.487 | +0.079 | +0.079 | +0.062 |
| 30° | 104° | +0.302 | –0.058 | +0.633 | +0.100 | +0.100 | +0.085 |
| | 180° | +0.125 | –0.352 | +0.376 | +0.194 | +0.194 | +0.173 |
| | 0° | –0.071 | –0.230 | +0.425 | +0.076 | +0.076 | +0.065 |
| 60° | 104° | +0.302 | –0.059 | +0.576 | +0.096 | +0.096 | +0.086 |
| | 180° | +0.168 | –0.310 | +0.345 | +0.155 | +0.155 | +0.145 |
| | 0° | –0.061 | –0.220 | +0.382 | +0.070 | +0.070 | +0.069 |
| 90° | 104° | +0.295 | –0.062 | +0.539 | +0.088 | +0.088 | +0.089 |
| | 180° | +0.207 | –0.270 | +0.326 | +0.121 | +0.121 | +0.125 |
| | 0° | –0.046 | –0.205 | +0.351 | +0.063 | +0.063 | +0.073 |
| 120° | 100° | +0.282 | –0.065 | +0.516 | +0.077 | +0.077 | +0.091 |
| | 180° | +0.245 | –0.233 | +0.316 | +0.091 | +0.091 | +0.109 |
| | 0° | –0.026 | –0.185 | +0.331 | +0.054 | +0.054 | +0.079 |
| 150° | 96° | +0.267 | –0.067 | +0.504 | +0.063 | +0.063 | +0.094 |
| | 180° | +0.282 | –0.196 | +0.313 | +0.065 | +0.065 | +0.097 |
| | 0° | –0.000 | –0.159 | +0.318 | +0.044 | +0.044 | +0.087 |
| 180° | 90° | +0.250 | –0.068 | +0.500 | +0.047 | +0.047 | +0.095 |
| | 180° | +0.318 | –0.159 | +0.318 | +0.044 | +0.044 | +0.087 |

# ANNEX F

(*Clauses* 7.5, G-3 *and* J-4.2.2.1)

## LOSS OF PRESTRESS

**F-1** Explanation of various symbols used in subsequent clause is given in Annex K.

**F-2 CALCULATION FOR LOSS OF PRESTRESS**

| *Sl No.* | | *Longitudinal (Pre Tensioning)* | *Circumferential (Post Tensioning)* |
|---|---|---|---|
| 1. | Elastic deformation | — | $3.2 f_{ci}$ |
| 2. | Relaxation of wire | $0.16 f_{si\ long}$ | $0.16 f_{si}$ |
| 3. | Deformation due to creep | $2.5 f_{si\ long}$ | $2.5 f_{si}$ |
| 4. | Deformation due to shrinkage | $0.000\,1\ E_s$ | $0.000\,1\ E_s$ |
| 5. | Yield due to mould shortening (wire stretch due to filling, vibrations during spinning, etc, slippage = 2 mm) | $\frac{2\ E_s}{L + 80}$ | |

where

$f_{ci\ long}$ = Initial stress in core in longitudinal direction in N/mm².

$f_{ci}$ = Initial stress in core in circumferential direction in N/mm².

$f_{si\ long}$ = Initial stress in core in circumferential wire in N/mm².

$E_s$ = Modulus of elasticity of high tensile wire.
= $2.00 \times 10^5$ N/mm² (for stress relieved), and
= $1.93 \times 10^5$ N/mm² (for as drawn).

$L$ = Effective length of pipe in mm + 80 mm.

NOTE — Loss of stress in high tensile wire at factory test pressure will be 90 percent of the total losses.

# ANNEX G

(*Clauses* 7.6, H-3.3 *and* J-5)

## TYPICAL DESIGN OF PRESTRESSED CONCRETE PIPE OF DIA 1 200 mm — WINDING BY PROCESS OF COUNTER WEIGHT/BREAK

**G-1** Explanation of various symbols used in subsequent clauses is given in Annex K.

**G-2 DATA**

| | |
|---|---|
| Diameter of pipe, $D$ | = 1 200 mm |
| Effective length of pipe, $L$ | = 5.0 m |
| Working pressure, $P_w$ (*see* **3.4**) | = 0.700 N/mm² |
| Site test pressure, $P_s$ | = 1.050 N/mm² |
| Factory test pressure, $P_t$ | = 1.150 N/mm² |
| Height of fill, $H$ | = 1.00 m |
| Density of fill material, $K_e$ | = 15 700 N/m³ |
| Live load | Class AA (IRC) |

**G-3 ASSUMPTIONS**

| | |
|---|---|
| Density of core concrete, $K_c$ | = 24 000 N/m³ |
| Density of coating, $K_b$ | = 21 600 N/m³ |
| Density of water, $K_w$ | = 10 000 N/m³ |
| Process for winding | Counter Weight/ Break |
| Core thickness, $T_c$ | = 70 mm |
| Coat thickness, $T_b$ | = 22 mm |
| Width of trench ($D + 2T_c + 2T_b + 600$), $B_t$ | = 1.984 m |
| Diameter of circumferential wire, $d_s$ | = 4 mm |
| Diameter of longitudinal wire, $d_c$ | = 4 mm |
| Number of longitudinals, $N$ | = 28 |
| Ultimate tensile strength of circumferential wire (*see* **4.5.1**) | = 1 715 N/mm² |
| Ultimate tensile strength of longitudinal wire (*see* **4.5.1**) | = 1 715 N/mm² |
| Area of circumferential wire, $A_s$ | = 0.623mm²/mm |
| Modulus of elasticity of steel, $E_s$ | = $20 \times 10^4$ N/mm² |

Modulus of elasticity of concrete, $E_c$ = $4\times10^4$ N/mm²

Modular ratio, $n$ = 5

Minimum compressive strength of core concrete (spun) at various stages

a) Characteristic compressive design strength, $f_{ck}$ = 40 N/mm²

b) At winding, $f_{p2}$ (*see* **8.4.1**) = 25 N/mm²

c) At detensioning longitudinals $f_{p1}$ (*see* **8.3.2**) = 15 N/mm²

## G-4 CALCULATION OF PRESTRESS IN CORE IN CIRCUMFERENTIAL DIRECTION

**G-4.1 Spacing of Circumferential Wire**

Allowable clear spacing (*see* **8.4.5**)

Maximum clear spacing of wire = 50 mm

Minimum clear spacing of wire = 6 mm

Area of spiral considered in design ($A_s$) = 0.623 N/mm²

Number of turns per meter length $= 0.623\times\dfrac{1\,000}{0.785\,4}\times(4)^2$

= 49.57

Centre to centre spacing of spiral wire $=\dfrac{1\,000}{49.57}$

= 20.17 mm

Clear spacing of spiral wire is 20.17 – 4 = 16.17 mm

16.17 mm is in between 50 mm and 6 mm.

Hence, the area of spiral ($A_s$) considered is correct.

Initial stress in wire during winding ($f_{si}$) (*see* **8.4.2**)

0.75 × 1 715 = 1 286.25N/mm²

**G-4.2 Initial Compressive Stress Induced in Core ($f_{ci}$)**

$$= 1\,286.25\times\frac{0.623}{70} = 11.447\,6 \text{ N/mm}^2$$

**G-4.3 Loss of Stress in Wire (*see* Annex E)**

a) Elastic deformation

$3.2\times f_{ci} = 3.2\times11.447\,6$ = 36.63 N/mm²

b) Relaxation of wire

$0.08\times f_{si} = 0.08\times1\,286.25$ = 102.90 N/mm²

c) Deformation due to creep

2.5 × 11.447 6 = 28.62 N/mm²

d) Deformation due to shrinkage

$0.000\,1\times E_s = 0.000\,1\times20\times10^4$ = 20.00 N/mm²

Total losses

36.63 + 102.90 + 28.62 + 20.00 = 188.15 N/mm²

Losses at factory test

0.9 × Total loss

0.9 × 188.15 = 169.34 N/mm²

Stress in wire at factory test, ($f_{sf}$)

= 1 286.25 – 169.34 = 1 116.91 N/mm²

Stress in wire at site test ($f_s$)

= 1 286.25 – 188.15 = 1 098.10 N/mm²

**G-4.4 Compressive Stress Induced in Core at Factory Test**

$$f_{cf} = 1\,116.91\times\frac{0.623}{70} \quad f_{cf} = +\,9.940\,5 \text{ N/mm}^2$$

**G-4.4.1** *Compressive Stress in Core at Site Test*

$$f_{ct} = 1\,098.10\times\frac{0.623}{70} \quad f_{ct} = +\,9.773\,1 \text{ N/mm}^2$$

**G-4.5 Section Constant**

a) Outside diameter of core (*ODC*)

ODC = $D + 2\times T_c$ = 1 340 mm

b) Outside diameter of pipe (*ODP*)

ODP = $D + 2\times T_c + 2\times T_b$ = 1 384 mm

c) Mean radius of pipe ($r$)

$$r = \frac{D+T_c+T_b}{2} = 646 \text{ mm}$$

d) Modulus of section for circumferential stress ($Z$)

$Z = {}^1/_6\times(T_c+T_b)^2\times1\,000$ = 1 410 667 mm³/m

e) Sectional area ($A$)

$A = (T_c + T_b)\times1\,000$ = 92 000 mm²

f) Modulus of circular section of core ($Z_2$)

$$\frac{3.141\,6}{32}\times\frac{\text{ODP}^4-\text{D}^4}{\text{ODC}} = 84\,297\,111 \text{ mm}^3$$

g) Modulus of circular section of pipe ($Z_1$)

$$\frac{3.141\,6}{32}\times\frac{\text{ODP}^4-\text{D}^4}{\text{ODP}} = 113\,168\,797 \text{ mm}^3$$

**G-4.6 Self Weight of Pipe ($W_s$)**

a) Self weight of core ($W_c$)

$W_c = 3.141\,6\times(D+T_c)\times T_c\times K_c$

= 3.141 6 × (1.200 + 0.070) × 0.070 × 24 000

= 6 702.92 N/m

b) Self weight of coat ($W_b$)

$W_b = 3.141\,6\times(D+2\times T_c+T_b)\times T_b\times K_b$

= 3.141 6 × (1.200 + 2 × 0.070 + 0.022) × 0.022 × 21 600

= 2 033.31 N/m

c) Self weight of pipe ($W_s$)

$W_s = W_c + W_b = 8\ 736.23$ N/m.

**G-4.7 Weight of Water ($W_w$)**

$W_w = (3.141\ 6/4) \times D^2 \times K_w$

$= 0.7\ 85\ 4 \times (1.200)^2 \times 10\ 000 = 11\ 309.76$ N/m

**G-4.8 Weight Of Earth Fill ($W_e$)** (*see* Fig. 4 of IS 783)

$\frac{H}{B_t} = \frac{1.00}{1.984} = 0.5040$

$C_t = 0.472\ 3$

$W_e = (C_t \times K_e \times B_t^2)$

$= 0.472\ 3 \times 15\ 700 \times (1.984)^2$

$W_e = 29\ 187.77$ N/m

**G-4.9 Live Load ($W_l$)** (*see* **10.1**)

$W_l = C_p \times P/l \times O$

where

$P$ = Axle load = 61 300 N

$O$ = Impact factor = 1.0

$l$ = $1.15\,H + 2\,ODP + S = 3.918$

Assuming $S = 0$

the value of $C_p = 0.664$ is obtained from Fig. 3 of IS 783, using the values,

for ratio $\frac{l}{2H} = \frac{3.918}{2 \times 1} = 1.959$, and

$\frac{D}{2H} = \frac{1.384}{2 \times 1} = 0.692$

$W_l = \frac{0.664 \times 613\ 001}{3.918}$ $W_l = 10\ 388.80$ N/m

**G-4.10 Calculations of Stresses Due to External Loads**

Circumferential stresses due to external load Olander's (coefficient for 90° bedding angle).

| *External Load* | *At Bottom* | |
|---|---|---|
| | Moment ($M_b$) | Thrust ($H_b$) |
| Self weight | $+ 0.121\ W_s r$ | $+ 0.207\ W_s$ |
| Water weight | $+ 0.121\ W_w r$ | $- 0.270\ W_w$ |
| Earth fill | $+ 0.125\ W_e r$ | $+ 0.326\ W_e$ |
| Live load | $+ 0.125\ W_l r$ | $+ 0.326\ W_l$ |

+ Moment causes tension inside pipe at bottom.

Only stresses at bottom are calculated as those are more severe.

**G-4.10.1** *Stress Due to Self Weight of Pipe*

Moment ($M$) $= 0.121 \times 8\ 736.23 \times 646.0$
$= 682\ 876.20$ Nmm

Thrust ($T$) $= 0.207 \times 8\ 736.23$
$= 1\ 808.40$ N/m

Stress due to moment:

$\frac{M}{Z} = \frac{682\,876.20}{1\,410\,667} = 0.484\ 1$ N/mm$^2$

Stress due to thrust:

$\frac{T}{A} = \frac{1\,808.40}{92\,000} = 0.019\ 7$ N/mm$^2$

Net tensile stress:

$= (-0.484\ 1) + (+0.019\ 7)$

$= -0.464\ 4$ N/mm$^2$

Net compressive stress:

$= (+0.484\ 1) + (+0.019\ 7) = +0.503\ 8$ N/mm$^2$

**G-4.10.2** *Stress Due to Weight of Water*

Moment ($M$) $= 0.121 \times 11\ 309.76 \times 646.0$
$= 884\ 038.70$ Nmm

Thrust ($T$) $= 0.270 \times 11\ 309.8$
$= 3\ 053.64$ N/m

Stress due to moment:

$\frac{M}{Z} = \frac{884\,038.70}{1\,410\,667} = 0.626\ 7$ N/mm$^2$

Stress due to thrust:

$\frac{T}{A} = \frac{3\,053.64}{92\,000} = 0.033\ 2$ N/mm$^2$

Net tensile stress:

$= (-0.626\ 7) + (-0.033\ 2) = -0.659\ 9$ N/mm$^2$

Net compressive stress:

$= (+0.626\ 7) + (-0.033\ 2) = +0.593\ 5$ N/mm$^2$

**G-4.10.3** *Stress Due to Weight of Earth Fill*

Moment ($M$) $= 0.125 \times 29\ 187.77 \times 646.0$
$= 2\ 356\ 912.40$ Nmm

Thrust ($T$) $= 0.326 \times 29\ 187.77$
$= 9\ 515.21$ N/m

Stress due to moment:

$\frac{M}{Z} = \frac{2\,356\,912.40}{1\,410\,667} = 1.670\ 8$ N/mm$^2$

Stress due to thrust:

$\frac{T}{A} = \frac{9\,515.67}{92\,000} = 0.103\ 4$ N/mm$^2$

Net tensile stress:

$= (-1.670\ 8) + (+0.103\ 4) = -1.567\ 4$ N/mm$^2$

Net compressive stress:

$= (+1.670\ 8) + (+0.103\ 4) = +1.774\ 2$ N/mm$^2$

**G-4.10.4** *Stress Due to Live Load*

Moment ($M$) $= 0.125 \times 10\ 388.8 \times 646.0$
$= 838\ 895.60$ Nmm

Thrust ($T$) = 0.326 × 10 388.8
= 3 386.75 N/m

Stress due to moment:

$$\frac{M}{Z} = \frac{838\,895.60}{1\,410\,667} = 0.594\,7 \text{ N/mm}^2$$

Stress due to thrust:

$$\frac{T}{A} = \frac{3\,886.75}{92\,000} = 0.036\,8 \text{ N/mm}^2$$

Net tensile stress:

= (–0.594 7) + (+0.036 8) = –0.557 9 N/mm$^2$

Net compressive stress :

= (+0.594 7) + (+0.036 8) = +0.631 5 N/mm$^2$

**G-4.11 Calculation of Stresses in Pipe Core Due to Internal Pressure**

a) At factory test

$$f_{wf} = \frac{-P_t \times D}{2 \times \left[T_c + (n \times A_s)\right]}$$

$$= \frac{-1.150 \times 1\,200}{2 \times \left[70 + (5 \times 0.623)\right]}$$

$f_{wf}$ = – 9.437 2 N/mm$^2$

b) At site test

$$f_{ws} = \frac{-P_s \times D}{2 \times \left[T_c + (n \times A_s)\right]}$$

$$= \frac{-1.150 \times 1\,200}{2 \times \left[70 + (5 \times 0.623)\right]}$$

$f_{ws}$ = –8.616 6 N/mm$^2$

c) At working pressure

$$f_{ww} = \frac{-P_w \times D}{2 \times \left[T_c + (n \times A_s)\right]}$$

$$= \frac{-0.700 \times 1\,200}{2 \times \left[70 + (5 \times 0.623)\right]}$$

$f_{ww}$ = –5.744 4 N/mm$^2$

**G-4.12 Summary of Circumferential Stresses**

| *Stresses Due To* | *Tensile* N/mm$^2$ | *Compressive* N/mm$^2$ |
|---|---|---|
| a) *External Loads* | | |
| Self weight of pipe | – 0.464 4 | + 0.503 8 |
| Weight of water | – 0.659 9 | + 0.593 5 |
| Weight of earth fill | – 1.567 4 | + 1.774 2 |
| Live load | – 0.557 9 | + 0.631 5 |
| b) *Internal Pressure* | | |
| Site test pressure | – 8.616 6 | — |
| Working pressure | – 5.744 4 | — |
| Factory test pressure | – 9.437 2 | — |
| c) *Compressvie Stress in Core Due to Circumferential Winding* | | |
| Initial compressive stress | — | +11.447 6 |
| Prestress at factory test | — | + 9.940 5 |
| Prestress at site test | — | + 9.773 1 |

## G-5 CIRCUMFERENTIAL PRESTRESS REQUIREMENTS (*see* 7.4.3)

| *Loading Combination* | *Circumferential Stresses in* N/mm$^2$ | | | |
|---|---|---|---|---|
| | Tensile | | Compressive | |
| | Actual | Permissible | Actual | Permissible |
| a) *Circumferential pre-stressing condition* Self weight + Initial prestress | — | — | (0.503 8 + 11.447 6) = 11.951 4 | 0.55 × $f_{p2}$ 0.55 × 25 = 13.750 0 |
| | | | **+ 11.951 4 <** | **13.750 0** |
| b) *Site test condition* (Self weight + Weight of water + Earth fill load + Site test press Final prestress) | – (0.464 4 + 0.659 9 + 1.567 4 + 8.616 6) + 9.773 1 = –135.5 2 | 0.13 $(f_{ck})^{0.67}$ = 0.13 × $(40)^{0.67}$ = –1.54 | (0.503 8 + 0.593 5 + 1.774 2 + 9.773 1) = +12.644 6 | 0.45 × $f_{ck}$ = 0.45 × 40 = 18.0 |
| | **– 1.535 2 <** | **–1.54** | **+ 12.644 6 <** | **18.0** |

| *Loading Combination* | *Circumferential Stresses in* N/mm² | | | | | |
|---|---|---|---|---|---|---|
| | Tensile | | | Compressive | | |
| | Actual | | Permissible | Actual | | Permissible |
| c) *Factory test condition*<br>(Self weight +<br>Weight of water +<br>Factory test<br>pressure +<br>Prestress at factory<br>test) | –(0.464 4 +<br>0.659 9 +<br>9.437 2) +<br>9.940 5<br>= –0.6210<br>**– 0.621 0** | **<** | 0.13 $(fck)^{0.67}$<br>0.13 × $(40)^{0.67}$<br>= –1.54<br>**–1.54** | (0.503 8 +<br>0.593 5 +<br>9.940 5)<br>= + 11.037 8<br>**+11.037 8** | **<** | 0.45 × $f_{ck}$<br>= 0.45 × 40<br>= 18.0<br>**18.0** |
| d) *Operating condition*<br>(Self weight +<br>Weight of water +<br>Earth fill load +<br>Working pressure<br>final prestress) | –(0.464 4 +<br>0.659 9 +<br>1.567 4 +<br>5.744 4) +<br>9.773 1<br>= +1.337 0<br>**+ 1.337 0** | **<** | 0.00<br>**0.00** | (0.503 8 +<br>0.593 5 +<br>1.774 2 +<br>9.731)<br>= +12.644 6<br>**+12.644 6** | **<** | 0.45 × $f_{ck}$<br>= 0.45 × 40<br>=18.0<br>**18.0** |
| e) *Live load condition*<br>[Operating<br>condition live load<br>(with impact)] | (+1.337 0) +<br>(–0.557 9)<br>= +0.779 1<br>**+0.779 1** | **<** | 0.13 $(f_{ck})^{0.67}$<br>0.13 × $(40)^{0.67}$<br>= –1.54<br>**–1.54** | (+12.644 6) +<br>(+0.631 5)<br>= +13.276 1<br>**+13.276 1** | **<** | 0.45 × $f_{ck}$<br>= 0.45 × 40<br>= 18.0<br>**18.0** |

($f_{ck}$ = 40 N/mm², $f_{p2}$ = 25 N/mm²), – ve is tensile, + ve is compressive

**G-6 CALCULATION OF STRESS IN LONGITUDINAL DIRECTION**

**G-6.1 Centreline Spacing Between Longitudinal Wires** (*see* **8.3**)

Centreline spacing between longitudinal wires shall not exceed twice the core thickness or 150 mm whichever is greater, that is

2 × 70 or 150 mm 150 mm

Number of longitudinals considered in design = 28

Centreline spacing between longitudinal wires $= \dfrac{3.146 \times (D + T_c)}{N}$

$$= \frac{3.141\,6 \times (1\,200 + 70)}{28}, \text{ that is } 142.49 \text{ mm}$$

142.49 mm < 150 mm

Hence, number of longitudinals considered in design is correct.

**G-6.2 Initial Longitudinal Precompression in Core** (*see* **8.4.2**)

Initial stress in longitudinal wire ($f_{sil}$)

1 715.0 × 0.75 = 1 286.25 N/mm²

Area of core concrete ($A_c$)

3.141 6 × 1 270 × 70 = 279 288.24 mm²

Longitudinal precompression

$$= \frac{\text{Longitudinal precompression}}{A_c} = \frac{N \times A_{dl} \times f_{sil}}{A_c}$$

$$\text{Initial precompression } (f_{cil}) = \frac{28 \times 12.57 \times 1\,286.25}{279\,288.24}$$

= 1.620 9 N/mm²

Concrete strength required at detensioning of longitudinals ($f_{p1}$) (*see* **8.3.2**)

2 × $f_{cil}$ or 15 N/mm², whichever is greater

that is 2 × 1.620 9 = 3.24 or 15 N/mm², whichever is greater.

Adopt $f_{p1}$ = 15 N/mm²

**G-6.3 Loss of Stress in Longitudinal Wires** (*see* **Annex F**)

a) Relaxation of wire

0.08 × $f_{sil}$ = 0.08 × 1 286.25 = 102.9 N/mm²

b) Deformation due to creep

$= 2.50 \times f_{cil} = 2.50 \times 1.620\,9 = 4.05$ N/mm²

c) Deformation due to shrinkage

$= 0.000\,1 \times E_s$

$= 0.000\,1 \times 20.0 \times 10^4$

$= 20.00$ N/mm²

d) Yield due to mould shortening (Wire stretch due to filling, vibration during spinning, etc)

$$= \frac{2 \times E_s}{\text{Effective length of pipe} + 80 \text{ mm}}$$

$$= \frac{2 \times 20 \times 10}{5\,000 + 80} = 78.74 \text{ N/mm}^2$$

Total losses = 102.9 + 4.05 + 20.0 + 78.74

= 205.69 N/mm²

**G-6.4 Precompression in Core in Longitudinal Direction**

*At the stage of winding*

Loss of prestress in longitudinal wire at winding = Total loss × 0.9 = 205.69 × 0.9 = 185.12 N/mm²

Stress in longitudinal wire at winding ($f_{slw}$) = 1 286.25 −185.12 = 1 101.13 N/mm²

Precompression at winding ($f_{clw}$) $= \dfrac{28 \times 12.57 \times 1\,101.13}{2\,798\,288.24}$ = 1.387 6 N/mm²

*At site test*

Stress in longitudinal wire after losses ($f_{sl}$) = 1 286.25 − 205.69 = 1 080.56 N/mm²

Final Precompression ($f_{cl}$) $= \dfrac{28 \times 12.57 \times 1\,080.56}{2\,798\,288.24}$ = 1.361 7 N/mm²

**G-6.5 Longitudinal Stress Due to Circumferential Winding**

Maximum local longitudinal tensile stress during winding (*see* Note 1 under **7.4.1**)

= 0.284 × 11.447 6 = 3.251 1 N/mm²

**G-6.6 Stress Due to Beam Action**

Self weight of pipe $W_s$ = 8 736.23 N/m

Weight of water $W_w$ = 11 309.76 N/m

Earth load to be considered (*see* Note 2 under **7.4.1**)

$$= 2.2 \times OPD = 2.2 \times \frac{1\,384}{1\,000}$$

= 3.044 8 KN/m = 3 044.80 N/m

Total load, $W$ = 8 736.23 + 11 309.76 + 3 044.80 = 23 090.79 N/m

Bending moment ($BM$)

$$= \frac{WL^2}{8} = 23\,090.79 \times 5 \times 5 \times \frac{1\,000}{8} = 72\,158\,719 \text{ Nm}$$

Modulus of circular section of pipe ($Z_1$) = 113 168 797 mm³

$$\text{Stress due to beam action} = \frac{BM}{Z_1} = 0.637\,6 \text{ N/mm}^2$$

**G-6.7 Stress Due to Self Weight of Core**

Self weight of core ($W_c$) = 6 702.92 N/m

Bending moment due to mass of core ($BM$)

$$6\,702.92 \times 5 \times 5 \times \frac{1\,000}{8} = 20\,946\,625 \text{ Nmm}$$

Modulus of circular section of core ($Z_2$) = 84 297 111 mm³

Stress due to self weight of core $= \dfrac{BM}{Z_2} = +0.248\,5$ N/mm²

**G-6.8 Summary of Stresses in Longitudinal Direction**

| *Stresses Due To* | *Tensile* N/mm² | *Compressive* N/mm² |
|---|---|---|
| Maximum local longitudinal tensile stress due to bending during winding | — | 3.251 1 |
| Beam action | + 0.637 6 | −0.637 6 |
| Self weight of core | + 0.248 5 | −0.248 5 |
| Initial precompression | + 1.620 9 | — |
| Precompression at winding | + 1.387 6 | — |
| Final precompression | + 1.361 7 | — |

**G-6.9 Load Combination of Longitudinal Stresses Under Different Condition** (*see* **7.4.1**)

Actual against permissible

| *Loading Combination* | *Longitudinal Stresses*, N/mm$^2$ | | | | | |
|---|---|---|---|---|---|---|
| | Tensile | | | Compressive | | |
| | Actual | | Permissible | Actual | | Permissible |
| a) Longitudinal prestress in barrel, (after losses) | — | | — | **+1.361 7** | > | Minimum residual compressive stress **+1.0** |
| b) Longitudinal prestress during winding | – (3.251 1 + 0.248 5) + 1.387 6 = –2.112 0 | | $0.56 \times (f_{p2})^{0.5}$ $0.56 \times 25^{0.5}$ = –2.800 0 | (0.248 5 + 1.387 6) = +1.636 1 | | $0.5 \times f_{p2}$ $0.5 \times 25$ = 12.500 0 |
| | **–2.112 0** | < | **–2.800 0** | **+1.636 1** | < | **12.500 0** |
| c) Longitudinal prestress after losses plus beam action | (–0.637 6 + 1.361 7) = 0.724 1 | | $0.34 \times (f_{ck})^{0.5}$ $0.34 \times (40)^{0.5}$ = –2.150 3 | (0.637 6 + 1.3617) = +1.361 7 | | $0.5 \times f_{ck}$ $0.5 \times 40$ = 20.0 |
| | **0.724 1** | < | **–2.150 3** | **+1.361 7** | < | **20.0** |
| d) Handling before winding | (–0.248 5) + (+1.387 6) = +1.139 1 | | – 0.67 | (0.248 5 + 1.387 6) = +1.636 1 | | $0.5 \times f_{p1}$ $0.5 \times 15$ = 7.50 |
| | **+1.139 1** | < | **–0.67** | **+1.636 1** | < | **7.50** |

As the diameter of pipe is above 600 mm checking for load combination of transport and unloading is not necessary.

# ANNEX H

(*Clause* 7.7)

## TYPICAL DESIGN OF PRESTRESSED CONCRETE PIPE OF DIAMETER 1200 mm — WINDING BY PROCESS OF DIE

**H-1** Explanation of various symbols used in subsequent clauses is given in Annex J.

**H-2 DATA**

Remaining data is same as considered in Annex G, except area of circumferential wire ($A_s$) being different.

Ultimate tensile strength of circumferential wire = 1 715 N/mm$^2$

Initial stress in wire during winding ($f_{si}$) (*see* **8.3.2**)

$0.65 \times 1715 f_{si}$ = 1 114.75 N/mm$^2$

Initial stress in wire during winding ($f_{si}$) in Annex G.

$0.75 \times 1\,715 f_{si}$ = 1 286.25 N/mm$^2$

Area of circumferential wire ($A_s$) in Annex G.

$$A_s = 0.623 \text{ mm}^2/\text{mm}$$

Area of circumferential wire ($A_s$) to be considered if the process for winding is die

$$A_s = 0.623 \times \frac{1\,286.25}{1114.75} = 0.718\,8 \text{mm}^2/\text{mm}$$

**H-3 CALCULATION OF PRESTRESS IN CORE IN CIRCUMFERENTIAL DIRECTION**

**H-3.1 Spacing of Circumferential Wire**

As the process for winding is die, 4.00 mm diameter of spiral wire is reduced to 3.45 mm to get the required tension.

Allowable clear spacing (*see* **8.4.5**)

Maximum clear spacing of wire = 50 mm
Minimum clear spacing of wire = 6 mm
Area of spiral considered in design ($A_s$) = 0.718 8 mm²/mm
Number of turns per meter length

$$= 0.718\,8 \times \frac{1\,000}{0.785\,4} \times (3.45)^2 = 6.89$$

$$\text{Centre to centre spacing of spiral wire} = \frac{1\,000}{76.89} = 13.00\text{mm}$$

Clear spacing of spiral wire = 13 – 3.45 = 9.55 mm

9.55 mm is in between 50 mm and 6 mm.

Hence, the area of spiral ($A_s$) considered is correct.

**H-3.2 Initial Compressive Stress Induced in Core ($f_{ci}$)**

$$f_{ci} = 1\,114.75 \times \frac{0.718\,8}{70} = 11.446\,8 \text{ N/mm}^2$$

**H-3.3** For futher design, the procedure as given in Annex G shall be adopted.

# ANNEX J

(*Clause* 7.8)

## DESIGN OF PRESTRESSED CONCRETE PIPES FOR DRAINAGE, SEWERAGE AND CULVERT

**J-1** Explanation of various symbols used in subsequent clauses is given in Annex K.

**J-2 DATA**

Diameter of pipe, $D$ = 1 000 mm
Core thickness of pipe, $t_c$ = 60 mm
Coat thickness of pipe, $t_b$ = 22 mm
Three edge bearing load, $P$ = 72.6 kN/m = 72 600 N/m
Flexural strength of spun concrete = 6.87 N/mm²

**J-3 ASSUMPTIONS**

Process of winding : Counter weight/Break
Diameter of circumferential wire, $d_s$ = 4 mm
Ultimate tensile strength of circumferential wire = 1 715 N/mm²
Area of circumferential wire, $A_s$ = 0.240 mm²/mm

**J-4 DESIGN**

**J-4.1 Calculation of Final Prestress Required**

Calculation of moment at bottom = $M$

$M = 0.159 \times P \times D_m$

Where, $D_m$ = Mean diameter of pipe $= D + t_c + t_b$
= 1 000 + 60 + 22 = 1 082 mm

$M = 0.159 \times 72\,600 \times 1\,082$
= 12 489 959 Nmm

Calculation of section modulus of pipe, $Z$

$$Z = \frac{1}{6} \times b \times d^2$$

$$d = t_c + t_b = 60 + 22 = 82 \text{ mm}$$

$$Z = \frac{1}{6} \times 1\,000 \times 82 = 112\,066.7 \text{ mm}^3$$

$$\text{Stress} = \frac{M}{Z} = \frac{12\,489\,959}{112\,066.7} = 11.14 \text{ N/mm}^2$$

Final prestress required = (Stress due to three edge bearing load) – (Flexural strength of concrete)

$f_{ct} = 11.14 - 6.87 = 4.27$ N/mm²

**J-4.2 Design of Circumferential Prestressing**

**J-4.2.1** *Spacing of Circumferential Wire* (*see* **8.4.5**)

Allowable clear spacing
Maximum clear spacing of wire = 50 mm
Minimum clear spacing of wire = 6 mm
Area of spiral considered in design ($A_s$) = 0.240 mm²/mm
Number of turns per meter length

$$= 0.240 \times \frac{1\,000}{19.09} \times (4)^2 = 19.09$$

$$\text{Centre to centre spacing of spiral wire} = \frac{1\,000}{19.09} = 52.38 \text{ mm}$$

Clear spacing of spiral wire = 52.38 – 4 = 48.38 mm

48.38 mm is in between 50 mm and 6 mm

Hence, the Area of spiral ($A_s$) considered is correct.

**J-4.2.2** *Calculation of Prestress in Core in Circumferential Direction*

Initial Stress in wire during winding ($f_{si}$)
(*see* **8.3.2**)

$f_{si} = 0.75 \times 1\,715 = 1\,286.25$ N/mm$^2$

Initial Compressive stress induced in core ($f_{ci}$)

$$f_{ci} = 1\,286.25 \times \frac{0.240}{60} = 5.145\,0 \text{ N/mm}^2$$

**J-4.2.2.1** *Loss of stress in wire* (*see* Annex F)

a) Elastic deformation
$3.2 \times f_{ci} = 3.2 \times 5.145\,0 = 16.46$ N/mm$^2$

b) Relaxation of wire
$0.08 \times f_{si} = 0.08 \times 1\,286.25 = 102.90$ N/mm$^2$

c) Deformation due to creep
$2.5 \times 5.145\,0 = 12.86$ N/mm$^2$

d) Deformation due to creep and shrinkage
$0.000\,1 \times E_s = 0.000\,1 \times 20 \times 10^4$
$= 20.00$ N/mm$^2$

Total losses

$16.46 + 102.90 + 12.86 + 20.00 = 152.22$ N/mm$^2$

Losses at factory test

$0.9 \times$ Total loss $\quad 0.9 \times 152.22$
$= 137.00$ N/mm$^2$

Stress in wire at factory test ($f_{sf}$)

$f_{sf} = 1\,286.25 - 137.00 = 1\,149.25$ N/mm$^2$

Stress in wire at Site test ($f_s$)

$f_s = 1\,286.25 - 152.22 = 1\,134.03$ N/mm$^2$

Compressive stress in core at site test

$$f_{ct} = 1\,134.03 \times \frac{0.240}{60} = +4.536\,1 \text{ N/mm}^2$$

As final prestress (4.536 1) is more than final prestress required (4.270 0), the design is safe.

**J-5** For design of longitudinal prestressing, the procedure as given in **D-1** is to be adopted.

# ANNEX K

(*Clauses* D-1, F-1, G-1 H-1 *and* J-1)

## SYMBOLS USED IN THE DESIGN

$A$ = Crossectional area of pipe, mm$^2$
$A_c$ = Crossectional area of core, mm$^2$
$A_{dl}$ = Crossectional area of longitudinal wire, mm$^2$
$A_s$ = Area of circumferential wire, mm$^2$/mm
$B_t$ = Trench width, m
$C_t$ = Coefficient from Fig. 4 of IS 783
$D$ = Internal diameter of pipe, mm
$d_l$ = Diameter of longitudinal wire, mm
$d_s$ = Diameter of circumferential wire, mm
$E_c$ = Modulus of elasticity of concrete, N/mm$^2$
$E_s$ = Modulus of elasticity of wire, N/mm$^2$
$f_{cf}$ = Compressive stress in core concrete at factory test, N/mm$^2$
$f_{ci}$ = Initial compressive stress induced in core, N/mm$^2$
$f_{cil}$ = Initial precompression in core, N/mm$^2$
$f_{cl}$ = Final precompression in core, N/mm$^2$
$f_{clw}$ = Precompression at winding, N/mm$^2$
$f_{ct}$ = Compressive stress in core concrete at site test, N/mm$^2$
$f_{ck}$ = Characteristic compressive strength of concrete, N/mm$^2$
$f_{p1}$ = Compressive strength of concrete at detensioning of longitudinals, N/mm$^2$
$f_{p2}$ = Compressive strength of concrete at winding, N/mm$^2$
$f_s$ = Final stress in circumferential wire after losses, N/mm$^2$
$f_{sf}$ = Stress in circumferential wire at factory test, N/mm$^2$
$f_{si}$ = Initial stress in circumferential wire during winding, N/mm$^2$
$f_{sil}$ = Initial stress in longitudinal wire at longitudinal prestressing, N/mm$^2$
$f_{sl}$ = Final stress in longitudinal wire after losses, N/mm$^2$
$f_{slw}$ = Stress in longitudinal wire at winding, N/mm$^2$
$f_{ws}$ = Stress in core pipe at site test due to internal pressure, N/mm$^2$
$f_{ww}$ = Stress in core pipe in operating condition due to internal pressure, N/mm$^2$

$H$ = Height of earth fill, m
$K_b$ = Density of coat concrete, N/mm$^3$
$K_c$ = Density of core concrete, N/mm$^3$
$K_e$ = Density of filling material, N/mm$^3$
$K_w$ = Density of water, N/mm$^3$
$L$ = Effective length of pipe, m
$n$ = Modular ratio
$N$ = Number of longitudinals
$ODC$ = Out side diameter of core, mm
$ODP$ = Out side diameter of pipe, mm
$P$ = Axle load = 61 300 N (AA Class)
$P_s$ = Site test pressure, N/mm$^2$
$P_{st}$ = Maximum static pressure, N/mm$^2$
$P_t$ = Factory test pressure, N/mm$^2$
$P_w$ = Working pressure, N/mm$^2$
$r$ = Mean radius of pipe wall, mm
$T_b$ = Coat thickness, mm
$T_c$ = Core thickness, mm
$W_b$ = Self weight of coat, N/m
$W_c$ = Self weight of core, N/m
$W_e$ = Weight of earth fill, N/mm$^2$
$W_l$ = Live load, N/m
$W_s$ = Self weight of pipe (Core + Coat), N/m
$W_w$ = Weight of water, N/m
$Z$ = Modulus of section for circumferential stress, mm$^3$/m
$Z_1$ = Modulus of circular section of pipe, mm$^3$/m
$Z_2$ = Modulus of circular section of core, mm$^3$/m

## ANNEX L

*(Foreword)*

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*(Continued on page 27)*

(*Continued from page* 26)

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# AMENDMENT NO. 1 MARCH 2003
# TO
# IS 784 : 2001 PRESTRESSED CONCRETE PIPES (INCLUDING SPECIALS) — SPECIFICATION

*( Second Revision )*

( *Page* 8, *clause* **13.3**) — Substitute the following for the existing:

'**13.3 Permeability Test on Coating**

The permeability test when conducted in accordance with the method described in IS 3597 shall meet the requirement of final permeability. The final permeability shall not exceed 0.3 $cm^3$.'

NOTE — It is recommended that initial absorption should not exceed 2.0 $cm^3$ and the difference in any two readings during initial absorption should not be more than 0.8 $cm^3$.

( CED 53 )

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