IS 15155 (2002): Bar/Wire Wrapped Steel Cylinder Pipes With Mortar lining and Coating (Including Specials) -- [CED 53: Cement Matrix Products]

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Indian Standard

BAR/WIRE WRAPPED STEEL CYLINDER PIPES WITH MORTAR LINING AND COATING (INCLUDING SPECIALS) — SPECIFICATION

ICS 23.040.10

BUREAU OF INDIAN STANDARDS
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Price Group 8

Cement Matrix Products Sectional Committee, CED 53

FOREWORD

This Indian Standard 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.

The manufacture and use of bar/wire wrapped steel cylinder pipes with mortar lining and coating has started in the country. These pipes have to be designed for the internal pressure, external loads and bedding conditions as specified by the purchaser. Typical applications of these pipes include cross country transmission mains, distribution feeder mains, sewer pumping mains, water intake and discharge lines and plant piping. This standard has, therefore, been formulated to provide necessary guidance to the manufacturers and users of these pipes.

In the preparation of this standard, assistance has been drawn from the following publications :

AWWA Manual M9 'Concrete pressure pipe'; American Water Works Association.

EN641:1994 'Reinforced concrete pressure pipes, cylinder type, including joints and fittings'; European Committee for Standardization

The composition of the Committee responsible for formulation of this standard is given at Annex D.

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

BAR/WIRE WRAPPED STEEL CYLINDER PIPES WITH MORTAR LINING AND COATING (INCLUDING SPECIALS) — SPECIFICATION

1 SCOPE

This standard covers the requirements of bar/wire wrapped steel cylinder pipes with mortar lining and coating with nominal internal diameter in the range of 250 mm to 1 600 mm (*see* Note under Table 1).

2 REFERENCES

The Indian 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 editions of the standards indicated in Annex A.

3 TERMINOLOGY

3.0 For the purpose of this standard, the definitions given in **3.1** to **3.6** shall apply.

3.1 Bar/Wire Wrapped Steel Cylinder Pipe

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

3.2 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.

3.3 Working Pressure

The maximum sustained internal pressure excluding surge to which each portion of the pipe line may be subjected when installed.

3.4 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).

3.5 Factory Test Pressure

a) Site test pressure plus 0.1 N/mm^2, for working pressure up to 1 N/mm^2, and

b) Site test pressure plus 0.2 N/mm^2, for working pressure above 1 N/mm^2

3.6 Surge (Water Hammer) Pressure

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 bar/wire wrapped steel cylinder 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 not more than 50 percent slag;

e) Supersulphated cement conforming to IS 6909;

f) Portland pozzolana cement conforming to IS 1489 (Part 1) or IS 1489 (Part 2); and

g) 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 requirements of **4** (Grading) of IS 383 shall not apply. Manufacturer shall furnish the grading curve for 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 cement mortar preparation and for curing the pipes shall conform to the requirements given in **5.4** of IS 456.

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 admixture shall conform to IS 9103.

4.5 Reinforcement

Reinforcement bar/wire shall conform to IS 432 (Part 1) or IS 432 (Part 2).

4.6 Steel for Cylinders, Joint Rings and Specials

Steel plates for cylinders, joint rings 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 and internal diameter of the ring and the 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* 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 lining 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 Dimensions

5.1.1 *Internal Diameter, Wall Thickness and Lining Thickness*

Nominal internal diameter of the pipes, minimum wall thickness (*see* Fig. 1) and minimum thickness of cement mortar lining shall be as given in Table 1.

5.1.2 *Coating Thickness*

The cement mortar coating shall provide a minimum cover of 19 mm over the bar/wire reinforcement or 25 mm over the cylinder, whichever is greater.

5.1.3 *Length of Pipe*

Effective length of pipes shall be 4 m to 8 m. The manufacturer shall declare the length of pipe for any given design and the tolerance shall be applicable to that.

5.2 Tolerances

5.2.1 *Internal Diameter*

The tolerances applicable to the internal diameter shall be as given in Table 2.

5.2.2 *Wall Thickness*

The wall thickness shall not be less than the design thickness by more than 5 percent or 5 mm whichever is greater. The manufacturer shall declare the wall thickness for any given design and the above tolerance shall be applicable to that wall thickness.

5.2.3 *Length of Pipe*

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

Table 1 Nominal Internal Diameter, Minimum Wall Thickness (t_{Min}) and Minimum Thickness of the Cement Mortar Lining ($t_{i\ Min}$)

(*Clauses* 1, 5.1.1 *and* 7.5)

All dimensions in millimetres.

Nominal Internal Diameter of Pipe (1)	t_{Min} (2)	$t_{i\ Min}$ (3)	Minimum Cylinder Thickness (4)	Minimum Thickness of Joint Rings (5)
250	40	15	1.6	5.0
300	40	15	1.6	5.0
400	40	15	1.6	5.0
500	45	20	1.6	5.0
600	45	20	2.0	5.0
700	45	20	2.0	5.0
800	45	20	2.0	5.0
900	45	20	2.5	5.0
1 000	45	20	2.5	7.0
1 100	50	22	4.0	7.0
1 200	50	22	4.0	7.0
1 300	50	22	4.0	8.0
1 400	50	22	4.0	8.0
1 500	50	22	4.0	8.0
1 600	50	22	4.0	8.0

NOTE — Pipes with internal diameters other than those mentioned in this table and pipes for working pressure higher than 28 kg/cm^2 can be supplied by mutual agreement between the purchaser and the manufacturer.

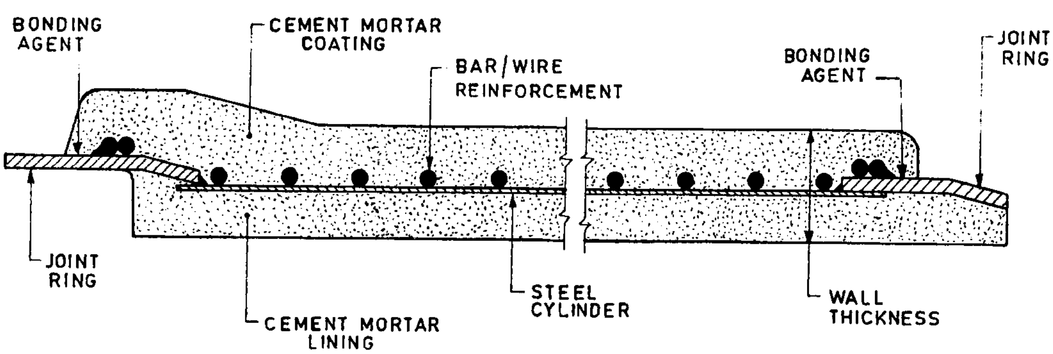

FIG. 1 TYPICAL LONGITUDINAL SECTION OF BAR/WIRE WRAPPED STEEL CYLINDER PIPE

Table 2 Tolerances on Internal Diameter

(*Clause* 5.2.1)

Internal Diameter	Tolerances: In Areas Within 600 mm of an end of the Pipe (mm)	Tolerances: Over Rest of the Pipe (mm)
Up to 900 mm	± 6	± 9
Over 900 mm and Up to 1 600 mm	± 9	± 12

5.2.4 *Circumference of the Joint Rings*

The tolerance on the circumference of the joint rings shall be as given:

Tolerance on circumference, in mm

	Socket Ring	*Spigot Ring*
All Diameters	+8.5, −1.5	−1.5 −8.5

5.2.5 *Out-of-roundness of Socket and Spigot Rings*

The tolerances on the out-of-roundness of the internal surface of the socket ring and the outer surface of the spigot shall be as stated below:

Tolerance for out-of-roundness, in mm

DN/ID	*Socket Ring*	*Spigot Ring*
Up to 1 600	+7, −3	−3 , −7

6 JOINT DIMENSIONS

Joint dimensions with tolerances for socket and spigot diameters shall be furnished by the manufacturer for inspection.

7 DESIGN

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

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

7.3 Design Criteria

7.3.1 The reinforcement of the pipe shall consist of a welded steel cylinder and bar/wire is directly wrapped under low tension. The average circumferential stress in the steel cylinder and bar/wire reinforcement of the pipe shall be as given below:

a) At factory test pressure, stress shall not exceed 187 N/mm^2 nor 75 percent of the minimum yield strength of the steel used in the cylinder.

b) At site test pressure, stress shall not exceed 165 N/mm^2 nor 66 percent of the minimum yield strength of the steel used in the cylinder.

c) At working pressure, stress shall not exceed 125 N/mm^2 nor 50 percent of the minimum yield strength of the steel used in the cylinder.

The yield strength considered shall be the lower value of the steel cylinder and the bar/wire.

7.3.2 The structural properties of the pipe, together with the bedding and backfill, shall be designed to limit the deflection of pipe to not more than $D^2/(1.02 \times 10^5)$ mm, D is the nominal inside diameter of the pipe measured in millimetres.

7.4 The area of bar/wire reinforcement shall not be greater than 60 percent of the total area of circumferential reinforcement. The area of bar/wire reinforcement in square millimetres per linear metre of pipe, shall not be less than 83 percent of the inside diameter of the pipe, in mm, nor 487 mm^2/m linear. The bar/wire shall not be less than 5.0 mm in diameter. The design clear spacing between bars/wires shall not be less than the diameter of the bar/wire used and the centre to centre bar/wire spacing shall not exceed 50 mm.

7.5 The minimum nominal cylinder thickness shall be as shown in Table 1.

7.6 Typical design of bar/wire wrapped steel cylinder pipe with mortar lining and coating is given in Annex C.

8 MANUFACTURE

8.1 Fabrication of Steel Cylinders

The steel cylinders shall be formed either by spiral welding or circumferential or longitudinal welding, and the steel socket and spigot joint rings/steel end rings shall be welded to the ends before testing. Representative weld samples shall be made at the beginning of each production run, when either the pipe diameter or cylinder thickness is changed. A representative weld sample test shall consist of three reduced section tension specimens and three bend test specimens.

8.2 Cement Mortar Lining

8.2.1 *Mortar*

Before the steel cylinder is wound with bar/wire reinforcement, a cement mortar lining shall be centrifugally cast within the cylinder to provide a dense, hard, smooth lining of the thickness specified in **5.1.1**. Minimum cement content in cement mortar lining shall be 540 kg/m^3. Water-cement ratio in the mix shall not be less than 0.42. The water soluble chloride ion content of the cement mortar lining mix, expressed as a percentage of the mass of cement, shall not exceed 0.20 percent. The minimum 28-days compressive strength of cement mortar shall be 35 N/mm^2 and at the time of wrapping of bar/wire shall be 10 N/mm^2.

8.2.2 *Mortar Preparation and Lining*

The cement, aggregate and water shall be batched by weighing. The material shall be mixed thoroughly. Immediately before applying the cement mortar lining, all loose mill scale, excessive rust, oil, grease and other foreign substance shall be removed from all steel surfaces to which the lining is to be applied. End gauge rings shall be attached securely to the pipe ends to control the lining thickness, prevent mortar leakage, hold back the lining in the socket ring, and stiffen and hold the pipe ends round. The end gauge rings shall remain in place until the end of the primary cure unless other measures at least equally effective are taken to stiffen and hold the pipe ends round. Immediately on completion of the lining operation, the pipe shall be moved for curing. Care shall be exercised at all times during handling to prevent damage to the lining.

8.2.3 *Curing Before Placing Bar/Wire Reinforcement*

Lining shall be cured either by steam or by water or by a combination of steam and water, or by use of approved curing compounds. The curing of lining shall be done for a period, till it attains the required strength.

8.2.4 *Test Cube Conversion Factors*

The cement mortar strength shall be taken on 100 mm × 100 mm cubes. As the lining is done by centrifugal process the strength of the mortar in the pipe differs from that given by test on vibrated cubes. These 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 mortar strength shall be obtained by multiplying with the factors and shall be used for design purpose.

8.3 Reinforcement Bar/Wire Wrapping

After the lining has been cured, circumferential reinforcing bar/wire shall be wound helically around the cylinder under a tensile stress of between 50 and 70 MPa. Methods and equipments for wrapping the bar/wire shall be such that bar/wire shall be wound around the cylinder in a helical form at the predetermined design spacing and capable of controlling the tension. As the circumferential bar/wire reinforcement is wound, a cement slurry shall be applied to the cylinder just ahead of the bar/wire at a rate of not less than 0.5 l/m^2. The slurry shall consist of 1.2 kg of cement to 1 l of water.

8.4 Cement Mortar Coating

After the lined cylinder has been wrapped with reinforcement bar/wire, the steel cylinder and reinforcement bar/wire shall be protected with a layer of rich cement mortar.

Cement mortar coating shall be applied by rotary brushes or by other approved methods and shall preferably be applied within 16 h after the bar/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. Water-cement ratio in the mix shall not be less than 0.27. 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 1 h, shall be discarded. The minimum 28-days compressive strength of cement mortar shall be 35 N/mm^2. Pneumatic process in which mixing of ingredients is carried out at the nozzle or gun, shall not be permitted.

The cement mortar coating shall have a minimum thickness as per **5.1.2** 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 steel and cement mortar coating at ends.

Concurrently with the cement mortar coating a cement slurry shall be applied on to the core at a rate of not less than 0.45 l/m^2 just ahead of the cement mortar coating. The slurry shall consist of 1.5 kg of cement to 1 l of water.

The thickness shall be checked for every pipe as soon as, coating is done and to be corrected, if required.

The cement mortar coating shall be cured either by steam or by water or by a combination of steam and water, or by use of approved curing compounds. If water curing is used for coating, it shall be kept moist for a period of at least 7 days.

After the cement 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 weight of not more than 0.5 kg. Any hollows or drumming areas detected by sounding shall be repaired by approved methods.

9 SPECIALS

9.1 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 7322.

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.

9.2 Reinforcement

For cement mortar coating, reinforcement shall be suitably tack welded to the shell. The reinforcement shall be spirals, wire mesh or wire fabric which shall conform to IS 1566. The reinforcement shall be a minimum 3 percent by mass of the quantity of the steel cylinder.

10 WORKMANSHIP AND FINISH

10.1 Deviation from the Straightness

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

10.2 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.

11 TESTS

11.1 Hydrostatic Test for Steel Cylinder of Pipe

Each steel cylinder, with joint rings welded to its ends, shall be tested by the manufacturer to a hydrostatic pressure not less than that determined by the following formula:

$$P = \frac{2St_y}{D_{yi}}$$

where

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

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

t_y = Cylinder thickness in mm; and

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

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

11.2 Pipe Test at Factory

The finished pipe shall be subjected to factory pressure test. The pipe shall be tested in accordance with IS 3597.

One in 50 pipes shall be subjected to an internal hydrostatic test. Should a pipe fail the test, then a further two pipes from the same batch of 50 shall be tested. If both pipes pass then the batch shall be accepted. If one or both pipes fail then (the batch shall be rejected or) each pipe in the batch shall be tested for individual approval.

The pipe shall be tested for a period of 3 min. During the test the pipe shall be absolutely water-tight and show no leaks, weeping or defects considered detrimental to the pipe's performance. No crack in the external surface shall be wider than 0.5 mm on a length exceeding 300 mm using a feeler gauge.

11.3 Permeability Test on Coating

The drop of water level, in the specimens of pipes selected; when tested according to 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 hours 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 re-test 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 taken.

The criteria for acceptance is the final permeability. The measurement to be taken immediately after factory test. In case this is taken later, then the pipe has to be kept wet for 48 h prior to test.

11.4 Repair of Lining and Coating

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 mortar may be done using curing compound.

12 SAMPLING AND CRITERIA FOR ACCEPTANCE

12.1 Pressure Pipes for Water Supply and Sewerage

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 evaluation, for conformity to the requirements of this standard. Scale of sampling is as given in Table 3.

12.2 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.

13 PROCEDURE FOR INSPECTION

13.1 Dimensional Checks

13.1.1 *Internal Diameter*

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

To accomplish this, 'Go' and 'No Go' gauges of the stiff rod with hardened rounded ends are used. The

Table 3 Scale of Sampling and Number of Acceptable Defectives

(*Clause* 12.1)

No. of Pipes in Lot	Joint Rings Dimensions		Hydrostatic Testing of Cylinder		Coating Thickness		Hydrostatic Test of Pipe at Factory		Dimensional Test [1)]		Permeability Test	
	*	**	*	**	*	**	*	**	*	**	*	**
Up to 50	All	Nil	All	Nil	3	Nil	1	Nil	3	Nil	3	Nil
51 - 100	All	Nil	All	Nil	5	Nil	1	Nil	5	Nil	5	Nil
101 - 300	All	Nil	All	Nil	8	Nil	2	Nil	8	Nil	8	Nil
300 - 500	All	Nil	All	Nil	13	Nil	2	Nil	13	Nil	13	Nil
500 - 1 000	All	Nil	All	Nil	26	1	4	Nil	26	1	26	1

[1)] Includes socket and spigot dimensions for pipes with rubber ring joints.
* Number of samples.
** Number of defectives acceptable.

length of gauges and colour are 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 is 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

13.1.2 *Wall Thickness*

Measurement of outside circumference of the pipe shall be made at three positions and average outside diameter of the pipe shall be calculated. The inside diameter shall be measured at three positions and average shall be calculated. The wall thickness shall be calculated as follows:

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

At the spigot section of the pipe the shape of the steel joint ring may require thickness of the lining to be less than that specified. The internal diameter shall be maintained within the tolerance specified.

13.1.3 *Internal Barrel Length*

The length shall be measured on four longitudinals at 90° intervals. The average reading shall be internal barrel length.

13.1.4 *Socket and Spigot Diameters*

The inside circumference of the socket ring and outside circumference of the spigot ring shall be checked by the measurement.

13.1.5 *Straightness*

The straightness shall be measured by a 1 m long gauge. The deviation from straight line taken between two points 1 m apart, along the pipe barrel shall not exceed 5 mm (*see* Fig. 2).

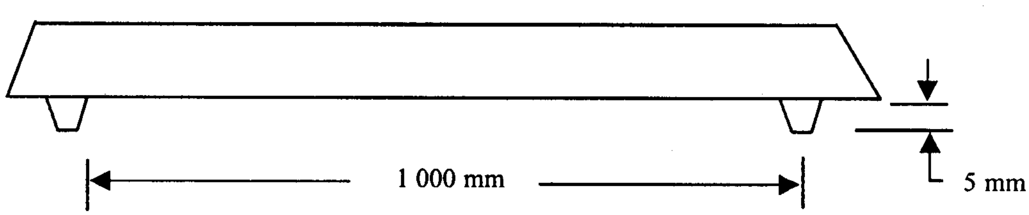

FIG. 2 GAUGE FOR MEASURING STRAIGHTNESS

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
383 : 1970	Specification for coarse and fine aggregates from natural sources for concrete (*second revision*)
432	Specification for mild steel and medium tensile steel bar/wires hard-drawn steel wire for concrete reinforcement:
(Part 1) : 1982	Mild steel and medium tensile steel bar/wires (*third revision*)
(Part 2) : 1982	Hard-drawn steel wire (*third revision*)
455 : 1989	Specification for Portland slag cement (*fourth revision*)
456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
1489	Specification for Portland pozzolana cement:
(Part 1) : 1991	Fly ash based (*third revision*)
(Part 2) : 1991	Calcined clay based (*third revision*)
1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second 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 penetrant flaw detection (*second revision*)
5382 : 1985	Rubber sealing rings for gas mains, water mains and sewers (*first revision*)
6909 : 1990	Specification for supersulphated cement
7322 : 1985	Specification for specials for steel cylinder reinforced concrete pipes (*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
12330 : 1988	Specification for sulphate resisting Portland cement

ANNEX B

(*Clause* 7.1)

INFORMATION TO BE SUPPLIED BY PURCHASER WITH AN ENQUIRY OR ORDER FOR BAR/WIRE WRAPPED STEEL CYLINDER PIPES

The following information shall be supplied:

a) The type of cement to be used for the lining 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 (**3.3**);

d) The maximum site test pressure (**3.4**);

e) Factory test pressure (**3.5**);

f) Pressure in addition to (c) to which the pipeline will be subjected due to surge (water hammer), if any;

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 out side diameter of pipe + 600 mm). If the pipes are to laid above ground/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, and

7) Anticipated superimposed loading on ground surface,

h) Soil investigation and soil data.

ANNEX C

(*Clause* 7.6)

TYPICAL DESIGN OF 1 000 mm DIAMETER BAR/WIRE WRAPPED STEEL CYLINDER PIPE

C-1 Explanation of various symbols used in subsequent clauses is given at **C-4**.

C-2 DATA

Dia of pipe, D	=	1 000 mm
Working pressure, P_w	=	0.784 6 N/mm^2
Height of fill, H	=	1.0 m
Density of fill material, K_c	=	1765 kg/m^3
Live load	=	Class AA (I.R.C.)
Modulus of soil reaction, $\acute{E}$	=	4.80 N/mm^2
Bedding angle	=	90°
Bedding coefficient, K_b	=	0.096
Deflection lag factor, D_l (for pressure pipe)	=	1.0

C-3 DESIGN

Site test pressure ($P_w \times 1.5$) P_s	=	1.176 9 N/mm^2
Factory test pressure ($P_s \times 1.2$) P_f	=	1.412 3 N/mm^2
Lining thickness, t_l	=	20 mm
Cylinder thickness, t_y	=	2.5 mm
Coating thickness, t_c	=	26 mm
Bar/wire diameter, d_b	=	6 mm
Internal diameter of steel cylinder D_{yi}	=	$(D + 2t_l) = 1\,000 + 2 \times 20$
	=	1 040 mm
Outside diameter of cylinder, D_{yo}	=	1 045 mm

Wall thickness, t	=	$t_i + t_y + t_c = 20 + 2.5 + 26 = 48.50$ mm > 45 mm
Outside diameter of Pipe, B_c	=	$D + 2 \times t = 1000 + 2 \times 48.5 = 1097.00$ mm = 1.097 m
Trench width, B_t	=	$B_c + 0.6 = 1.097 + 0.6 = 1.697$ m
Yield strength of steel cylinder, f_{sce}	=	250 N/mm²
Yield strength of bar/wire, f_b	=	315 N/mm²
Modulus of elasticity of steel, E_s	=	196 145 N/mm²
Modulus of elasticity of concrete, E_c	=	27 460 N/mm²
Modulus ratio (E_s/E_c), n	=	7.142 9

C-3.1 Calculation of Total Steel Area (A_{st})

a) *Required total steel area considering factory test pressure*

$$A_{st} = \frac{P_f \times D_{yi}}{2 \times f_{sf}}$$

for factory test pressure P_f, $f_{st} \leq 0.75 \times f_{sce}$ or 187 N/mm²

that is $f_{sf} \leq 0.75 \times 250$ or 187 N/mm²

Average circumferential stress in steel cylinder for site test pressure, f_{st} = 187 N/mm²

$$A_{st} = \frac{1.412\ 3 \times 1\ 040}{2 \times 187} = 3.927 \text{ mm}^2/\text{mm} = 3\ 927 \text{ mm}^2/\text{m} \qquad \ldots\ldots (1)$$

b) *Required total steel area considering site test pressure*

$$A_{st} = \frac{P_s \times D_{yi}}{2 \times f_{st}}$$

for site test pressure P_s, $f_{st} \leq 0.66 \times f_{sce}$ or 165 N/mm²

that is $f_{ss} \leq 0.66 \times 250$ or 165 N/mm²

Average circumferential stress in steel cylinder for site test pressure, f_{ss} = 165 N/mm²

$$A_{st} = \frac{1.176\ 9 \times 1\ 040}{2 \times 165} = 3.709\ 0 \text{ mm}^2/\text{mm} = 3\ 709 \text{ mm}^2/\text{m} \qquad \ldots\ldots (2)$$

c) *Required total steel area considering working pressure*

$$A_{st} = \frac{P_w \times D_{yi}}{2 \times f_s}$$

for working pressure P_w, $f_s \leq 0.5 \times f_{sce}$ or 125 N/mm²

that is, $f_{sw} \leq 0.5 \times 250$ or 125 N/mm²

Average circumferential stress in steel cylinder for working pressure, f_{sw} = 125 N/mm²

$$A_{st} = \frac{0.784\ 6 \times 1\ 040}{2 \times 125} = 3.264 \text{ mm}^2/\text{mm} = 3\ 264 \text{ mm}^2/\text{m} \qquad \ldots\ldots (3)$$

Total steel area, A_{st} = Greater of (1), (2) and (3) = 392 7.00 mm²/m say, 3 930 mm²/m

C-3.2 Cylinder Steel Area, A_y

$A_y = t_y \times 1\ 000 = 2.5 \times 1\ 000 = 2\ 500$ mm²/m

C-3.3 Area of Bar/Wire Reinforcement (A_b)

Total steel area (A_{st}) = Cylinder steel area (A_y) + Area of bar/wire reinforcement (A_b)

$A_b = A_{st} - A_y = 3\ 930 - 2\ 500 = 1\ 430\ mm^2/m$ ...... (4)

As per **7.4,** minimum area of bar/wire reinforcement

$A_b = 0.83 \times D$ or 487 mm^2/m,

that is, $A_b = 0.83 \times 1\ 000 = 830\ mm^2/m$ ...... (5)

or

$A_b = 487\ mm^2/m$ ...... (6)

Provide area of bar/wire reinforcement greater of (4), (5) and (6).

Therefore, provide $A_b = 1430\ mm^2/m$

C-3.3.1 *Centre to Centre Spacing for Bar/Wire Reinforcement*

Bar/wire diameter, $d_b = 6$ mm

Cross-sectional area of bar/wire, $A_{db} = \pi/4 \times d_b^2 = 0.785\ 4 \times 6^2 = 28.27\ mm^2$

$$\text{Centre to centre spacing} = \frac{1\ 000 \times A_{db}}{A_b}$$

$$= \frac{1\ 000 \times 28.27}{1\ 430} = 19.77 \text{ mm}$$

As per **7.4**, centre to centre bar/wire spacing shall not exceed 50 mm.

Since, 19.77 < 50 , spacing for 6 mm diameter bar/wire is acceptable.

C-3.4 Calculation of Stress in Steel Considering Total Steel Area Provided

Actual total steel area, A_{st}

$A_{st} = A_y + A_b = 2\ 500 + 1\ 430 = 3\ 930\ mm^2/m$

$= 3.930\ mm^2/mm$

As per **7.3.1** stress in steel shall not exceed :

- 187 N/mm^2 or 75 percent of the yield strength of steel when the pipe is subjected to the factory test pressure.
- 165 N/mm^2 or 66 percent of the yield strength of steel when the pipe is subjected to the site test pressure.
- 125 N/mm^2 or 50 percent of the yield strength of steel when the pipe is subjected to the working pressure.

Calculation of stress in steel (F_a)

$F_a = P \times D_{yi} / 2 \times A_{st}$

a) *For factory test pressure,* $P = 1.412\ 3\ N/mm^2$

$F_a = 14.40 \times 104/2 \times 0.395\ 0 = 186.87\ N/mm^2$

Yield strength of steel cylinder, $f_{sce} = 250\ N/mm^2$

(As the yield strength of steel cylinder is less than yield strength of bar/wire, it is considered.)

Allowable stress in steel $\leq 0.75 \times 250$ or 187 N/mm^2

Therefore, allowable stress in steel = 187 N/mm^2

As the actual stress in steel (186.87) is less than allowable stress in steel (187), satisfies the criteria.

b) *For site test pressure,* P = 1.176 9 N/mm^2

F_a = 1.176 9 × 1 040/2 × 3.93 = 155.72 N/mm^2

Yield strength of steel cylinder, f_{sce} = 250 N/mm^2

(As the Yield strength of steel cylinder is less than Yield strength of bar/wire, it is considered.)

Allowable stress in steel ≤ 0.66 × 250 or 165 N/mm^2

Therefore, allowable stress in steel = 165 N/mm^2

As the actual stress in steel (155.72) is less than allowable stress in steel (165), satisfies the criteria.

c) *For working pressure,* P_w = 0.784 6 N/mm^2

F_a = 0.784 6 × 1 040/2 × 3.93 = 103.81 N/mm^2

Yield strength of steel cylinder, f_{sce} = 250.00 N/mm^2

(As the Yield strength of steel cylinder is less than Yield strength of bar/wire, it is considered)

Allowable stress in steel ≤ 0.5 × 250 or 125 N/mm^2

Therefore allowable stress in steel = 125 N/mm^2

As the actual stress in steel (103.81) is less than allowable stress in steel (125), satisfies the criteria.

C-3.5 Calculation of Hydrostatic Test Pressure of Cylinder

As per **11.1**, each steel cylinder, with joint rings welded to its ends, shall be tested by the manufacturer to a hydrostatic pressure not less than that determined by the following formula:

$$P = \frac{2St_y}{D_{yi}}$$

where

P = Minimum hydrostatic test pressure in N/mm^2,
S = Stress in pipe wall during hydrostatic test in N/mm^2,
= 0.75 × 250 = 187.50 N/mm^2,
t_y = Cylinder thickness in mm = 2.5 mm,
D_{yi} = Inside diameter of steel cylinder (in mm) = 1 040 mm.

Therefore, hydrostatic test pressure for steel cylinder,

$$P = \frac{2 \times 187.50 \times 2.5}{1\ 040}$$
$$= 0.901\ 4 \text{ N/mm}^2$$

C-3.6 Check for Horizontal Deflection of Pipe

C-3.6.1 *Calculation of Allowable Deflection of Pipe*

As per **7.3.2**, allowable deflection of pipe should not be more than $D^2/(1.02 \times 10^5)$.

$$\text{Allowable deflection} = \frac{1\ 000^2}{(1.02 \times 10^5)} = 9.80\text{mm}$$

C-3.6.2 *Calculation of Actual Deflection of Pipe*

Actual horizontal deflection of pipe is calculated by using the Spangler formula for deflection

$$\Delta_x = \frac{D_l \times K_b \times W \times r_m^3}{E_l + 0.061\ 4 \times \acute{E} \times r_m^3}$$

where

Δ_X = Increase of diameter at the springline,
D_l = Deflection lag factor,
K_b = Bedding coefficient,
W = Vertical load on pipe,
E_I = Flexural rigidity of pipe wall (computed wall stiffness),
$\acute{E}$ = Modulus of soil reaction, and
r_m = Pipe mean radius.

The computed wall stiffness should be one-fourth of the value derived from the composite wall section of pipe.

C-3.6.2.1 *Calculation of vertical load on top of pipe due to backfill (W)*

C-3.6.2.1.1 *Weight of earth fill (W_e)* (see *Fig. 4 of IS 783)*

H/B_t = 1.0/1.697 = 0.589
C_t = 0.542
$W_e = C_t \times K_e \times Bt^2$
$= 0.542 \times 17\,650 \times 1.697^2 = 27\,550$ N/m

C-3.6.2.1.2 *Live load (W_l)* (see *Fig. 3 of IS 783)*

$$W_l = \frac{C_p \times P \times a}{l}$$

where

P = Axle load = 6 250 kg = 61 295 N
a = Impact factor = 1.0,
l = Length of the pipe carrying concentrated load = 3.344 m
C_p = 0.576, and

$$W_e = \frac{0.576 \times 61\,295 \times 1.0}{3.344}$$

= 10 558 N/m, say 10 560 N/m

Total vertical load , W

$W = W_e + W_l = 27\,550 + 10\,560 = 38\,110$ N/m = 38.11 N/mm

C-3.6.2.2 *Calculation of flexural rigidity of pipe wall (EI)*

To determine $\overline{I_x}$ longitudinal cross-section is transformed into an equivalent cement mortar section by multiplying steel area by the modular ratio *n*.

First moment *AY* and moment of Inertia $\overline{I_x}$ are taken about X-axis. Moment of inertia of steel cylinder and bar/ wire reinforcement about their own centres of gravity are ignored . The section properties determined are,

$\overline{Y}$ = distance from X-axis to the section center of gravity in mm.

$\overline{I_x}$ = moment of inertia of the transformed section about it's centre of gravity parallel to the X-axis in mm^4/m.

The general solution in tabular format is as follows.

Component	A	Y	AY	I_x
Total Section	$1000\,t$	$0.5\,t$	$500\,t^2$	$333.33\,t^3$
Steel Cylinder	$(n-1)\,A_y$	$t_i + 0.5\ t_y = Y_y$	$(n-1)\,A_y\,Y_y$	$(n-1)\,A_y\,Y_y^2$
Steel Bar/Wire	$(n-1)\,A_b$	$t_l + t_y + 0.5\,d_b = Y_b$	$(n-1)\,A_b\,Y_b$	$(n-1)A_b\,Y_b^2$
	ΣA		ΣAY	ΣI_x
	$\bar{Y} = \Sigma A_Y/\Sigma A$		$\bar{I}_x = I_x - \bar{Y}^2 \times \Sigma A$	

Component	A	Y	AY	I_x
Total Section	48 500.00	24.25	1 176 125.00	38 027 661.39
Steel Cylinder	15 357.25	21.25	326 341.56	6 934 758.20
Steel Bar/Wire	8 784.35	25.50	224 000.93	5 712 021.64
	72 641.60		1 726 467.49	50 674 441.23

Y = Distance from X-axis to the Section centre of gravity = $\dfrac{1\ 726469.49}{72\ 641.60} = 23.77$ mm

$\bar{I}_x$ = Moment of inertia of the transformed Section about it's centre of gravity parallel to X-axis. = $50\ 674\ 441.23 - \{(23.77)^2 \times 72\ 641.60\}$
9 631 000.15 mm^4/m
9 631.00 mm^4/mm

The wall stiffness E_I is calculated using the modulus of elasticity of mortar and I as $0.25 \times \bar{I}_x$.

$$E_I = E_c \times (0.25 \times I_x)$$
$$27\ 460 \times (0.25 \times 9\ 631.00)$$
$$= 66\ 116\ 815 \text{ N mm}^2\text{/mm}$$

C-3.6.2.3 *Calculation of pipe mean radius* ($\boldsymbol{r_m}$)

$$r_m = 0.5 \times (D + t)$$
$$= 0.5 \times (1\ 000 + 48.50)$$
$$= 524.25 \text{ mm}$$

Actual horizontal deflection of pipe is

$$\Delta_X = \frac{D_l \times K_b \times W \times r_m^{\ 3}}{E_l + 0.061\ 4 \times \acute{E} \times r_m^{\ 3}}$$

$$\Delta_X = \frac{1 \times 0.096 \times 3.886 \times 524.25^3}{6\ 743\ 041 + 0.061\ 4 \times 0.49 \times 524.25^3}$$

$$\Delta_X = \frac{53\ 751\ 346}{11\ 077\ 948}$$

$$\Delta_X = 4.85 \text{ mm}$$

Actual horizontal deflection of pipe (4.85 mm) is less than allowable deflection of pipe (9.80 mm). Hence the design is safe for horizontal deflection.

C-4 SYMBOL USED IN THE DESIGN

a = Impact factor
A_b = Area of bar/wire reinforcement, mm²/m
A_{db} = Cross-sectional area of bar/wire, mm²
A_y = Cylinder steel area, mm²/m
A_{st} = Total steel area, mm²/m
B_c = Outside diameter of pipe, mm
B_t = Trench width, mm
C_p = Coefficient used in the calculation of vertical load on a pipe due to concentrated superimposed load
C_t = Coefficient used in the calculation of vertical load on a pipe due to fill material when the pipe is installed in trench conditions
D = Diameter of pipe, mm
d_b = Bar/wire diameter, mm
D_l = Deflection lag factor
D_{yi} = Internal diameter of steel cylinder, mm
D = Outside diameter of steel cylinder, mm
$\acute{E}$ = Modulus of soil reaction, N/mm²
E_s = Modulus of elasticity of steel, N/mm²
E_c = Modulus of elasticity of concrete, N/mm²
E_l = Flexural rigidity of pipe wall (computed wall stiffness), N.mm² /mm
f_b = Yield strength of bar/wire, N/mm²
f_s = Average circumferential stress in steel cylinder, N/mm²
f_{sce} = Yield strength of steel cylinder, N/mm²
f_{ss} = Allowable average circumferential stress in steel cylinder for site test pressure, N/mm²
f_{st} = Allowable average circumferential stress in steel cylinder for factory test pressure, N/mm²
f_{sw} = Allowable average circumferential stress in steel cylinder for working pressure, N/mm²
F_a = Calculation of stress is steel, kg/cm²
F_i = Flexural rigidity of pipe wall (computed wall stiffness)
H = Height of fill, m
I_x = Moment of inertia of the transformed section about it's centre of gravity parallel to the X-axis, mm⁴ /m
K_b = Bedding coefficient
K_e = Density of fill material, kg/m³
m = Length of pipe assumed to carry concentrated load, m
n = Modular ratio
p = Axle load, N
P = Minimum hydrostatic test pressure, N/mm²
P_w = Working pressure, N/mm²
P_s = Site test pressure, N/mm²
P_f = Factory test pressure, N/mm²
r_m = Pipe mean radius, mm
S = Stress in pipe wall during hydrostatic test, N/mm²
t_i = Lining thickness, mm
t_y = Cylinder thickness, mm
t_c = Coating thickness, mm
t = Wall thickness, mm
W = Total vertical load of pipe, N/mm
W_e = Weight of Earth fill, N/m
W_l = Live load, N/m
Δ_X = Increase of diameter at the springline, mm
Y = Distance from X-axis to the section centre of gravity, mm

ANNEX D

(Foreword)

COMMITTEE COMPOSITION

Cement Matrix Products Sectional Committee, CED 53

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