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Indian Standard

CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

PART II REINFORCED CONCRETE STRUCTURES

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard

CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

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Indian Standard

CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

PART II REINFORCED CONCRETE STRUCTURES

0. FOREWORD

0.1 This Indian Standard (Part II) was adopted by the Indian Standards Institution on 19 November 1965, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The need for a code covering the design and construction of reinforced concrete and prestressed concrete structures for the storage of liquids has been long felt in this country. So far, such structures have been designed to varying standards adapted from the recommendations of the Institution of Civil Engineers and of the Portland Cement Association with the result that the resultant structures do not possess a uniform guaranteed margin of safety and dependability. Moreover, the design and construction methods in reinforced concrete and prestressed concrete are influenced by the prevailing construction practices, the physical properties of the material and the climatic conditions. The need was, therefore, felt to lay down uniform requirements of structures for the storage of liquids. In order to fulfil this need, formulation of this Indian Standard code of practice for the storage of liquids (IS : 3370) was undertaken. This part [IS : 3370 (Part II)-1965] deals with reinforced concrete structures. Three other parts of the code are the following:

Part I General requirements

Part III Prestressed concrete structures

Part IV Design tables

0.3 Although the provisions of this code cover mainly structures for the storage of liquids, the general provisions of this code may also be applied, with such modifications as found necessary, to suit the special conditions in the design of reinforced concrete and prestressed concrete structures for the conveyance of liquids such as aqueducts and superpassages.

0.4 While the common methods of design and construction have been covered in this code, design of structures of special forms or in unusual circumstances should be left to the judgement of the engineer and in such cases special systems of design and construction may be permitted on production of satisfactory evidence regarding their adequacy and safety by analysis or test or by both.

0.5 In this standard it has been assumed that the design of liquid retaining structures, whether of plain, reinforced or prestressed concrete, is entrusted to a qualified engineer and that the execution of the work is carried out under the direction of an experienced supervisor.

0.6 All requirement of IS : 456-1964* and IS : 1343-1960†, in so far as they apply, shall be deemed to form part of this code except where otherwise laid down in this code.

0.7 The Sectional Committee responsible for the preparation of this standard has taken into consideration the views of engineers and technologists and has related the standard to the practices followed in the country in this field. Due weightage has also been given to the need for international co-ordination among the standards prevailing in different countries of the world. These considerations led the Sectional Committee to derive assistance from published materials of the following organizations:

British Standards Institution,

Institution of Civil Engineers, London, and

Portland Cement Association, Chicago, USA.

0.8 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‡. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard (Part II) lays down the requirements applicable specifically to reinforced concrete structures for the storage of liquids, mainly water. These requirements are in addition to the general requirements laid down in IS : 3370 (Part I)-1965§.

*Code of practice for plain and reinforced concrete (*second revision*).

†Code of practice for prestressed concrete.

‡Rules for rounding off numerical values (*revised*).

§Code of practice for concrete structures for the storage of liquids: Part I General requirements.

1.2 This code does not cover the requirements for reinforced and prestressed concrete structures for storage of hot liquids and liquids of low viscosity and high penetrating power like petrol, diesel oil, etc. Special problems of shrinkage arising in the storage of non-aqueous liquid and the measures necessary where chemical attack is possible, are also not dealt with. The recommendations, however, may generally be applicable to the storage at normal temperatures of aqueous liquids and solutions which have no detrimental action on concrete and steel or where sufficient precautions are taken to ensure protection of concrete and steel from damage due to action of such liquids as in the case of sewage.

2. GENERAL REQUIREMENTS

2.1 Design and construction of reinforced concrete liquid retaining structures shall comply with the requirements of IS : 3370 (Part I)-1965*.

3. DESIGN

3.1 General — Provisions shall be made for conditions of stresses that may occur in accordance with principles of mechanics, recognized methods of design and sound engineering practice. In particular, adequate consideration shall be given to the effects of monolithic construction in the assessment of bending moment and shear.

3.1.1 Before taking up the detailed design, the designer should satisfy himself on the correct estimation of loads and on the adequate statical equilibrium of the structure, particularly in regard to safety against overturning of overhanging members; in the latter case the general arrangement should be such that statical equilibrium should be satisfied even when the overturning moment is doubled.

3.2 Basis of Design

3.2.1 General basis of design shall be in line with the recommendations of IS : 456-1964† except where otherwise specified in this code. The parts of the structure neither in contact with the liquid on any face nor enclosing the space above the liquid, as in case of staging of a water tower, shall be designed in accordance with the requirements of IS : 456-1964†.

3.2.2 Design of members other than those excluded by **3.2.1** shall be based on consideration of adequate resistance to cracking as well as adequate strength. Calculation of stresses shall be based on the following

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*Code of practice for concrete structures for the storage of liquids: Part I General requirements.

†Code of practice for plain and reinforced concrete (*second revision*).

assumptions in addition to the general assumptions given in IS : 456-1964*:

a) In calculations for both flexure and direct tension (or combination of both) relating to resistance to cracking, the concrete is capable of sustaining limited tensile stress, the whole section of concrete including the cover, together with the reinforcement being taken into account.

b) The total shear stress given by the following equation shall not exceed the value given in **3.3.1** whatever the reinforcement provided:

$$\text{Total shear stress} = \frac{Q}{b\ jd}$$

where

Q = total shear,

b = breadth, and

jd = lever arm.

c) In strength calculations the concrete has no tensile strength.

3.2.3 *Plain Concrete Structures* — Plain concrete members of reinforced concrete liquid retaining structures may be designed against structural failure by allowing tension in plain concrete as per the permissible limits for tension in bending specified in IS : 456-1964*. This will automatically take care of failure due to cracking. However, nominal reinforcement in accordance with the requirements of IS : 456-1964* shall be provided for plain concrete structural members.

3.3 Permissible Stresses in Concrete

3.3.1 *For Resistance to Cracking* — For calculations relating to the resistance of members to cracking, the permissible stresses in tension (direct and due to bending) and shear shall conform to the values specified in Table 1. The permissible tensile stresses due to bending apply to the face of the member in contact with the liquid. In members less than 225 mm thick and in contact with the liquid on one side, these permissible stresses in bending apply also to the face remote from the liquid.

3.3.2 *For Strength Calculations* — In strength calculations, the permissible concrete stresses shall be in accordance with **8** of IS : 456-1964*. Where the calculated shear stress in concrete alone exceeds the permissible value, reinforcement acting in conjunction with diagonal compression in the concrete shall be provided to take the whole of the shear.

*Code of practice for plain and reinforced concrete (*second revision*).

TABLE 1 PERMISSIBLE CONCRETE STRESSES IN CALCULATIONS RELATING TO RESISTANCE TO CRACKING

(*Clause* 3.3.1)

Grade of Concrete	Permissible Stresses kg/cm²		Shear = ($Q/b\,jd$)
	Direct Tension	Tension Due to Bending	
M 150	11	15	15
M 200	12	17	17
M 250	13	18	19
M 300	15	20	22
M 350	16	22	25
M 400	17	24	27

3.4 Permissible Stresses in Steel

3.4.1 *For Resistance to Cracking* — When steel and concrete are assumed to act together for checking the tensile stress in concrete for avoidance of cracks, the tensile stress in the steel will be limited by the requirement that the permissible tensile stress in the concrete is not exceeded; so the tensile stress in steel shall be equal to the product of modular ratio of steel and concrete, and the corresponding allowable tensile stress in concrete.

3.4.2 *For Strength Calculations* — For strength calculations, the permissible stresses in steel reinforcement shall be as given in Table 2.

3.5 Stresses Due to Drying Shrinkage or Temperature Change — Stresses due to drying shrinkage or temperature change may be ignored provided that:

a) the permissible stresses specified in **3.3** and **3.4** are not otherwise exceeded.

b) adequate precautions are taken to avoid cracking of concrete during the construction period and until the reservoir is put into use.

c) the recommendations of this code [*see* IS : 3370 (Part I)-1965*] as regards the provisions of joints and for suitable sliding layer beneath the reservoir are complied with, or the reservoir is to be used only for the storage of water or aqueous liquids at or near ambient temperature and the circumstances are such that the concrete will never dry out.

*Code of practice for concrete structures for the storage of liquids: Part I General requirements.

TABLE 2 PERMISSIBLE STRESSES IN STEEL REINFORCEMENT FOR STRENGTH CALCULATIONS

(*Clause* 3.4.2)

SL No.	TYPE OF STRESS IN STEEL REINFORCEMENT	PERMISSIBLE STRESSES IN kg/cm²	
		Plain Round Mild Steel Bars Conforming to Grade 1 of IS : 432 (Part I)-1966*	High Yield Strength Deformed Bars Conforming to IS : 1786-1966† or IS : 1139-1966‡
(1)	(2)	(3)	(4)
i)	Tensile stress in members under direct tension	1 150	1 500
ii)	Tensile stress in members in bending:		
	a) On liquid retaining face of members	1 150	1 500
	b) On face away from liquid for members less than 225 mm	1 150	1 500
	c) On face away from liquid for members 225 mm or more in thickness	1 250	1 900
iii)	Tensile stress in shear reinforcement:		
	a) For members less than 225 mm thickness	1 150	1 500
	b) For members 225 mm or more in thickness	1 250	1 750
iv)	Compressive stress in columns subjected to direct load	1 250	1 750

NOTE — Stress limitations for liquid retaining faces shall also apply to the following:

a) Other faces within 225 mm of the liquid retaining face.

b) Outside or external faces of structures away from the liquid but placed in water logged soils up to the level of the highest subsoil water level.

*Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part I Mild steel and medium tensile steel bars (*second revision*).

†Specification for cold twisted steel bars for concrete reinforcement (*revised*).

‡Specification for hot rolled mild steel, medium tensile steel and high yield strength steel deformed bars for concrete reinforcement (*revised*).

3.5.1 Shrinkage stresses may, however, be required to be calculated in special cases, when a shrinkage coefficient of 300×10^{-6} may be assumed.

3.5.2 When the shrinkage stresses are allowed, the permissible stresses, tensile stresses in concrete (direct and bending) as given in Table 1 may be increased by 33⅓ percent.

3.5.3 Where reservoirs are protected with an internal impermeable lining, consideration should be given to the possibility of concrete eventually drying out. Unless it is established on the basis of tests or experience that the lining has adequate crack bridging properties, allowance for the increased effect of drying shrinkage should be made in the design.

4. FLOORS

4.1 Provisions of Movement Joints — Movement joints shall be provided in accordance with **8** of IS : 3370 (Part I)-1965*.

4.2 Floors of Tanks Resting on Ground — If the tank is resting directly over ground, floor may be constructed of concrete with a nominal percentage of reinforcement (smaller than the minimum specified in **7**) provided it is certain that the ground will carry the load without appreciable subsidence in any part and that the concrete floor is cast in panels with sides not more than 4·5 metres with contraction or expansion joints between. In such cases a screed or concrete layer not less than 75 mm thick shall first be placed on the ground and covered with a sliding layer of bitumen paper or other suitable material to destroy the bond between the screed and floor concrete.

In normal circumstances the screed layer shall be of grade not weaker than M 100 specified in IS : 456-1964†, where injurious soils or aggressive water are expected, the screed layer shall be of grade not weaker than M 150 specified in IS : 456-1964† and if necessary a sulphate resisting or other special cement should be used.

4.3 Floors of Tanks Resting on Supports — If the tank is supported on walls or other similar supports, the floor slab shall be designed as floors in buildings for bending moments due to water load and self weight. The worst conditions of loadings may not be those given in **9.3** of IS : 456-1964†, since water level extends over all spans in normal construction except in the case of multi-cell tanks, these will have to be determined by the designer in each particular case.

4.3.1 When the floor is rigidly connected to the walls (as is generally the case) the bending moments at the junction between the walls and floor shall be taken into account in the design of floor together with any direct forces transferred to the floor from the walls or from the floor to the wall due to the suspension of the floor from the wall.

*Code of practice for concrete structures for the storage of liquids: Part I General requirements.

†Code of practice for plain and reinforced concrete (*second revision*).

If the walls are non-monolithic with the floor slab, such as in cases where movement joints have been provided between the floor slabs and walls, the floor shall be designed only for the vertical loads on the floor.

4.3.2 In continuous T-beams or L-beams with ribs on the side remote from the liquid, the tension in concrete on the liquid side at the face of the supports shall not exceed the permissible stresses for controlling cracks in concrete. The width of the slab given in **9.2.2** of IS : 456-1964* shall be made the basis for calculation of the resistance to cracking of T-beam, L-beam sections at supports.

4.3.3 The floor slab may be suitably tied to the walls by reinforcement bars properly embedded in both the slab and the walls. In such cases no separate beam (curved or straight) is necessary under the wall, provided the wall of the tank itself is designed to act as a beam over the supports under it.

4.3.4 Sometimes it may be economical to provide the floors of circular tanks in the shape of dome. In such cases the dome shall be designed for the vertical load of the liquid over it and the ratio of its rise to its diameter shall be so adjusted that the stresses in the dome are, as far as possible, wholly compressive. The dome shall be supported at its bottom on the ring beam which shall be designed for resultant circumferential tension in addition to vertical loads.

5. WALLS

5.1 Provision of Joints

5.1.1 *Sliding Joints at the Base of the Wall* — Where it is desired to allow the walls to expand or contract separately from the floor, or to prevent moments at the base of the wall owing to fixity to the floor, sliding joints may be employed.

5.1.1.1 Considerations affecting the spacing of vertical movement joints are discussed in **8** of IS : 3370 (Part I)-1965†. While the majority of these joints may be of the partial or complete contraction type, sufficient joints of the expansion type should be provided to satisfy the requirements of **8** of IS : 3370 (Part I)-1965†.

5.2 Pressure on Walls

5.2.1 In liquid retaining structures with fixed or floating covers, the gas pressure developed above liquid surface shall be added to the liquid pressure.

*Code of practice for plain and reinforced concrete (*second revision*).

†Code of practice for concrete structures for the storage of liquids: Part I General requirements.

5.2.2 When the wall of liquid retaining structure is built in ground or has earth embanked against it, the effect of earth pressure shall be taken into account as discussed in **4** of IS : 3370 (Part I)-1965*.

5.3 Walls of Tanks Rectangular or Polygonal in Plan — While designing the walls of rectangular or polygonal concrete tanks, the following points should be borne in mind:

a) In plane walls, the liquid pressure is resisted by both vertical and horizontal bending moments. An estimate should be made of the proportion of the pressure resisted by bending moments in the vertical and horizontal planes. The direct horizontal tension caused by the direct pull due to water pressure on end walls should be added to that resulting from horizontal bending moment. On liquid retaining faces, the tensile stresses due to the combination of direct horizontal tension and bending action shall satisfy the following condition:

$$\frac{t'}{t} + \frac{\sigma_{ct}'}{\sigma_{ct}} \leqslant 1$$

where

t' = Calculated direct tensile stress in concrete,

t = Permissible direct tensile stress in concrete (*see* Table 1),

σ_{ct}' = Calculated tensile stress due to bending in concrete, and

σ_{ct} = Permissible tensile stress due to bending in concrete (*see* Table 1).

b) At the vertical edges where the walls of a reservoir are rigidly joined, horizontal reinforcement and haunch bars should be provided to resist the horizontal bending moments, even if the walls are designed to withstand the whole load as vertical beams or cantilever without lateral supports.

c) In the case of rectangular or polygonal tanks, the side walls act as two way slabs, whereby the wall is continued or restrained in the horizontal direction, fixed or hinged at the bottom and hinged or free at the top. The walls thus act as thin plates subject to triangular loading and with boundary conditions varying between full restraint and free edge. The analysis of moment and forces may be made on the basis of any recognized method. However, moment coefficients, for boundary conditions of wall panels for some common cases are given in IS : 3370 (Part IV)-1967† of this code for general guidance.

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*Code of practice for concrete structures for the storage of liquids: Part I General requirements.

†Code of practice for concrete structures for the storage of liquids: Part IV Design tables.

5.4 Walls of Cylindrical Tanks — While designing walls of cylindrical tanks, the following points should be borne in mind:

a) Walls of cylindrical tanks are either cast monolithically with the base or are set in grooves and key ways (movement joints). In either case deformation of the wall under the influence of liquid pressure is restricted at and above the base. Consequently, only part of the triangular hydrostatic load will be carried by ring tension and part of the load at the bottom will be supported by cantilever action.

b) It is difficult to restrict rotation or settlement of the base slab and it is advisable to provide vertical reinforcement as if the walls were fully fixed at the base, in addition to the reinforcement required to resist horizontal ring tension for hinged at base conditions of walls, unless the appropriate amount of fixity at the base is established by analysis with due consideration to the dimensions of the base slab, the type of joint between the wall and slab and, where applicable, the type of soil supporting the base slab.

5.4.1 Coefficients for ring tension and vertical moments for different conditions of the walls for some common cases are given in IS : 3370 (Part IV)-1967* for general guidance.

6. ROOFS

6.1 Provision of Movement Joints — To avoid the possibility of sympathetic cracking, it is important to ensure that movement joints in the roof correspond with those in walls if roof and walls are monolithic. If, however, provision is made by means of a sliding joint for movement between the roof and the wall, correspondence of joints is not so important.

6.2 Loading — Fixed covers of liquid retaining structures should be designed for gravity loads, such as the weight of roof slab, earth cover, if any, live loads, and mechanical equipment. They should also be designed for upward load if the liquid retaining structure is subjected to internal gas pressure.

6.2.1 A superficial load sufficient to ensure safety with the unequal intensity of loading which occurs during the placing of the earth cover should be allowed for in designing roofs. The engineer should specify a loading under these temporary conditions, which should not be exceeded. In designing the roof, allowance should be made for the temporary condition of some spans loaded and other spans unloaded, even though in the final state the load may be small and evenly distributed.

*Code of practice for concrete structures for the storage of liquids: Part IV Design tables.

6.3 Water-Tightness — In case of tanks intended for the storage of water for domestic purposes, the roof must be made water-tight. This may be achieved by limiting the stresses as for the rest of the tank or by the use of the covering of waterproof membrane or by providing slopes to ensure adequate drainage.

6.4 Protection Against Corrosion — Protective measures shall be provided to the underside of the roof to prevent it from corrosion due to condensation.

7. DETAILING

7.1 Minimum Reinforcement

7.1.1 The minimum reinforcement in walls, floors and roofs in each of two directions at right angles shall have an area of 0·3 percent of the concrete section in that direction for sections up to 100 mm thick. For sections of thickness greater than 100 mm and less than 450 mm the minimum reinforcement in each of the two directions shall be linearly reduced from 0·3 percent for 100 mm thick section to 0·2 percent for 450 mm thick section. For sections of thickness greater than 450 mm, minimum reinforcement in each of the two directions shall be kept at 0·2 percent. In concrete sections of thickness 225 mm or greater, two layers of reinforcing steel shall be placed one near each face of the section to make up the minimum reinforcement specified in this clause.

7.1.1.1 The minimum reinforcement specified in **7.1.1** may be decreased by 20 percent in case of high yield strength deformed bars conforming to IS : 1786-1966* or IS : 1139-1966†.

7.1.2 In special circumstances (*see* **4.2**) floor slabs may be constructed with percentage of reinforcement less than that specified above. In no case the percentage of reinforcement in any member shall be less than that specified in IS : 456-1964‡.

7.2 Minimum Cover to Reinforcement

7.2.1 For liquid faces of parts of members either in contact with the liquid or enclosing the space above the liquid (such as inner faces of roof slab), the minimum cover to all reinforcement should be 25 mm or the diameter of the main bar, whichever is greater. In the presence of sea water and soils and water of corrosive character the cover should be increased by 12 mm but this additional cover shall not be taken into account for design calculations.

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*Specification for cold twisted steel bars for concrete reinforcement (*revised*).

†Specification for hot rolled mild steel, medium tensile steel and high yield strength steel deformed bars for concrete reinforcement (*revised*).

‡Code of practice for plain and reinforced concrete (*second revision*).

7.2.2 For faces away from the liquid and for parts of the structure neither in contact with the liquid on any face nor enclosing the space above the liquid, the cover shall conform to the requirements of IS : 456-1964*.

7.3 Size of Bars, Distance Between Bars, Laps and Bends — Subject to the requirements of **7.3.1** and **7.3.2**, details regarding reinforcement such as size of bars, distance between bars, laps and bends in bars, and fixing of bars shall comply with the provisions of IS : 456-1964* and IS : 2502-1963†.

7.3.1 *Bends in Bars* — In bends in reinforcing bars, the local stresses on concrete may be increased to three times the value permitted in **3.3.2** for concrete in direct compression.

7.3.2 *Laps in Bars* — Bars should be lapped only when such practice is unavoidable. Where laps are used they should be designed in accordance with the relevant requirements of IS : 456-1964*.

*Code of practice for plain and reinforced concrete (*second revision*).
†Code of practice for bending and fixing of bars for concrete reinforcement.

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AMENDMENT NO. 2 AUGUST 1981

TO

IS:3370(Part 2)-1965 CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

PART 2 REINFORCED CONCRETE STRUCTURES

Alteration

(*Page 3, clause 0.3*) - Substitute the following for the existing clause:

'0.3 Although the provisions of this code cover mainly structures for the storage of liquids, the general requirements given in Part 1 of this code may generally apply to the design of reinforced concrete and prestressed concrete structures for the conveyance of liquids, such as aqueducts and superpassages; the other requirements given in the code may also be applied with appropriate modifications.'

(BDC 2)