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Indian Standard

CODE OF PRACTICE FOR
CONCRETE STRUCTURES FOR
THE STORAGE OF LIQUIDS

PART III PRESTRESSED CONCRETE STRUCTURES

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Indian Standard

CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

PART III PRESTRESSED CONCRETE STRUCTURES

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Indian Standard
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PART III PRESTRESSED CONCRETE STRUCTURES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 20 October 1967, 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 engineers, designers and builders in this country have been adapting mainly the recommendations of the Institution of Civil Engineers, London, and more recently some of the recommendations of the Portland Cement Association. The conditions in this country, however, differ in many ways from those prevailing in UK and USA; for instance, climatic and weather conditions are subjected generally to larger variations, materials for concrete differ considerably in their physical properties and the prevailing practices in construction have special influence on the methods of use of reinforced and prestressed concrete. The need was, therefore, felt to give due consideration to these factors in the practices followed in the country with a view to fully satisfying the functional requirements of structures for the storage of liquids. In order to fulfil this need, formulation of 'Indian Standard code of practice for concrete structures for the storage of liquids' was undertaken which is being issued in parts. This part [IS : 3370 (Part III)-1967] deals with prestressed concrete structures. The other parts of the code are the following:

- Part I General requirements
- Part II Reinforced concrete structures
- Part IV Design tables

0.3 Although the provisions of this standard 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 super-passages.

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0.4 While the common methods of design and construction have been covered in this code, design of structures of special forms or under unusual circumstances should be left to the judgment 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 both.

0.5 In this standard it has been assumed that the design of prestressed concrete liquid retaining structures 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 requirements 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 between 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
- Portland Cement Association, Chicago, USA
- Institution of Civil Engineers, London.

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.

1. SCOPE

1.1 This standard (Part III) lays down the requirements applicable specifically to the prestressed 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 liquids 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 prestressed 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 all conditions of stresses that may occur in accordance with the principles of mechanics; recognised 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 moments 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 : 1343-1960† except where otherwise specified in this code. The members other than those specified in **3.2.2** shall be designed in accordance with the requirements of IS : 1343-1960†.

3.2.2 The design of members in contact with the liquid on any face or enclosing the space above the liquid shall be based on consideration of adequate resistance to cracking as well as adequate strength, and the following basic requirements should also be satisfied:

- a) The computed stresses in the concrete and in the steel shall not exceed the permissible stresses given in **3.3** and **3.4**, during transfer, handling and construction, and under working loads.

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

†Code of practice for prestressed concrete.

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- b) Cracking of the liquid retaining face should be entirely avoided. The liquid retaining face should be checked against cracking with a load factor [that is the ratio of the total (dead + live) load at cracking to the total (dead + live) working load] of 1.2.
- c) In estimating the resistance to cracking, the stresses in any cross-section should be calculated as for a homogeneous material, making allowance for all losses in steel tension.
- d) The ultimate load at failure (dead + live) should not be less than twice the working (dead + live) load.
- e) Where found necessary provision should be made by suitable joints or otherwise to allow for elastic distortions of the structure during the process of prestressing.

3.2.3 For cylindrical tanks, additional requirements as specified in 7.1 should also be satisfied.

3.3 Permissible Stresses in Concrete

3.3.1 The permissible stresses in the concrete due to prestressing operations and working loads, and the modulus of elasticity of concrete shall be as specified in IS : 1343-1960*.

3.3.2 For estimation of resistance to cracking, the limiting tensile strength of concrete shall be assumed to have the values specified in Table 1.

TABLE 1 LIMITING TENSILE STRENGTH OF CONCRETE FOR ESTIMATION OF RESISTANCE TO CRACKING IN PRESTRESSED CONCRETE MEMBERS

MINIMUM WORK CUBE (15 cm SIDE) STRENGTH OF CONCRETE AT 28 DAYS kg/cm ²	DIRECT TENSILE STRENGTH kg/cm ²	BENDING TENSILE STRENGTH kg/cm ²
(1)	(2)	(3)
350	16	32
400	17	34
450	18	36
500	19	38
550	20	40
600	21	42
650	22	43

*Code of practice for prestressed concrete.

3.4 Permissible Stresses in Steel

3.4.1 The permissible stresses in prestressing steel and the modulus of elasticity of steel shall be as specified in IS : 1343-1960*.

3.4.2 Where circumferential wires or bars are tensioned by means of jacks, the losses due to friction may be found by reducing the coefficient of friction to 80 percent of that given in IS : 1343-1960*.

3.5 Shrinkage and Creep of Concrete — The provisions regarding shrinkage and creep shall comply with the requirements of IS : 1343-1960*.

3.5.1 Where reservoirs are protected with an internal impermeable lining, consideration should be given to the possibility of concrete eventually drying out. Unless the engineer is satisfied that the lining has sufficient crack-bridging properties, allowance for the increased effect of drying shrinkage should be made in the design.

3.6 Losses in Prestress — While assessing the stresses in concrete and steel during tensioning operations and later in service, due regard shall be paid to all losses and variations in stress resulting from creep of concrete and steel, the shrinkage of concrete, the shortening of concrete at transfer, friction and slip of anchorage. Requirements in this respect specified in IS : 1343-1960* shall be complied with.

4. FLOORS

4.1 Provision 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 on ground, its floor may be constructed of concrete with the nominal percentage of reinforcement (not less than 0.15 percent of gross cross-sectional area of concrete) provided that it is established that the ground will carry the load without appreciable subsidence in any part and that the concrete floor is cast in panels not more than 4.5 metres square with contraction or expansion joints between. In such cases a screed layer of concrete not less than 75 mm thick shall first be placed on the ground and covered over with a sliding layer of bitumen paper or other suitable material to destroy the bond between the screed and floor concrete.

4.2.1 Under normal circumstances the screed layer shall not be of grade not leaner than M100 specified in Table 3 of IS : 456-1964‡; where

*Code of practice for prestressed concrete.

†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*).

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injurious soils or aggressive water are expected, the screed layer shall be of grade not leaner than M150 specified in Table 3 of IS : 456-1964* and if necessary a sulphate resisting or other special cement should be used.

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 wall to expand or contract separately from the floor, or to prevent moments at the base of the wall owing to its fixity with 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 Effect of Earth Pressure — When a reservoir wall is built in the ground or has earth embanked against it, relief in bending moment due to simultaneous action of water pressure inside the wall and earth pressure outside the wall may be made, provided that:

- a) there is no risk of slip in the embankment or fear of a reduction in the earth pressure arising from shrinkage or other causes; and
- b) the earth pressure allowed by way of relief in the bending moment caused by internal water pressure should be the minimum which can be relied upon under the most unfavourable conditions possible, including those under which the reservoir is to be tested for watertightness.

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 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 tanks 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 tank is subjected to internal gas 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.

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.

6.2.2 In tanks having fixed or floating covers the gas pressure developed above liquid surface shall be added to liquid pressure.

6.3 Watertightness — In case of tanks intended for the storage of water for domestic purposes, the roof shall be made watertight. This may be achieved by limiting the stresses as for the rest of the tank, or by the use of a covering of waterproof membrane or similar other efficient means.

6.4 Protection Against Corrosion — Protective measures shall be provided to the underside of the roof to prevent it from corrosion due to condensation, or alternatively, the underside of the roof shall be designed as a liquid retaining face, particular care being taken that the stipulations regarding minimum cover to reinforcement are adhered to.

7. CYLINDRICAL TANKS

7.1 Stresses — In the design of prestressed concrete cylindrical tanks, the following stresses in steel and concrete after allowing for all losses should be investigated and their values should be within the limits prescribed in **3.3** and **3.4**, except where otherwise specified below:

- a) Maximum tensile stress in hoop steel or longitudinal steel at working load should not exceed the limits specified in **3.4**.
- b) The principal compressive stress in concrete should not exceed one-third of the specified works cube strength.
- c) The average shear stress on the gross cross-section of the concrete should not exceed $\frac{1}{6}$ of the specified works cube strength.
- d) When the tank is full, there should be a compression in the concrete at all points of at least 7 kg/cm^2 .
- e) When the tank is empty, there should at no point be a tensile stress greater than 10 kg/cm^2 . Where the tank is to be emptied and filled at frequent intervals, or may be left empty for a prolonged period, it is desirable to design the tank so that there is a residual compression when the tank is empty as well as when full.

7.2 The base of the wall may be designed either fixed with the floor or as sliding or hinged at the junction with the floor.

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7.2.1 Except in case of unyielding solid rocky sub-grade, care should be taken to minimize the danger or local settlement. This can be done by designing the floor as a thin membrane and by providing a foundation ring under the wall.

7.3 When at the base of the wall, hinged or sliding conditions prevail:

- a) any advantage offered by the restraining effects should be ignored, and
- b) the moments in the region of the wall base in the direction parallel to axis of the tank (usually vertical) caused by the restraining effects of prestressing at the wall base should be counted for. Values given in tables in IS : 3370 (Part IV) * may be helpful to assess these moments.

7.4 The ring prestressing should be designed in all cases on the assumption that the wall-foot is free to slide without frictional resistance. When the foot of the wall is free to slide, a longitudinal moment should be assumed on the basis of a restraint equal to one-half of that provided by a pinned foot. In other cases the longitudinal moment should be assessed on the actual degree of restraint at the wall-foot.

7.5 Allowance should be made for the longitudinal moment induced by the transverse stressing in the partially wound condition. The maximum value of the flexural stress in the longitudinal section from this cause may be assumed to be numerically equal to 0.3 times the ring compression stress.

7.6 Prestressing should be provided in the transverse and longitudinal cross-section so as to contain these effects within the critical stresses specified.

7.7 Prestressing wire may be placed outside the walls generally, provided this is protected with pneumatic mortar to provide 40 mm cover over the wire. In malignant atmospheres, such as in heavy industrial areas or near the sea the cables should be placed inside the walls and grouted.

7.8 When the stressing of the prestressing wires is proposed to be carried out with wires in position, anchorages may advantageously be staggered and placed at suitable points of the cylinder with a view to off setting the heavy frictional losses.

7.9 The worst conditions of stresses resulting from the pressure of contained liquid, surrounding pressure, if any, temperature, shrinkage, restraint from roof, etc, should be considered.

7.10 Necessity of prestressing the cylinder wall in the direction of the axis of the cylinder (vertical) should always be investigated.

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

7.11 Longitudinal prestressing may be replaced with a reinforced concrete section satisfying the requirements of IS : 3370 (Part II)-1965*.

8. DETAILING

8.1 Concrete Cover — The minimum cover to prestressing rods, wires or cables, and to sheathings and spacers, if present, shall be 35 mm on the liquid face.

8.1.1 For faces away from the liquid and for parts of structure not in contact with the liquid, the cover shall conform to the requirements of IS : 1343-1960†.

8.2 Spacing of Prestressing Steel — The requirements of IS : 1343-1960† shall be complied with.

9. WORKMANSHIP, INSPECTION AND TESTING

9.1 In addition to the requirements specified in IS : 3370 (Part I)-1965‡, the requirements of IS : 1343-1960† shall be complied with.

*Code of practice for concrete structures for the storage of liquid : Part II Reinforced concrete structures.

†Code of practice for prestressed concrete.

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

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TO

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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 I 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)