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(Reaffirmed 1999)

Indian Standard

CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

PART I GENERAL REQUIREMENTS

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

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Indian Standard

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PART I GENERAL REQUIREMENTS

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CODE OF PRACTICE FOR CONCRETE STRUCTURES FOR THE STORAGE OF LIQUIDS

PART I GENERAL REQUIREMENTS

0. FOREWORD

0.1 This Indian Standard (Part I) 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 cannot be guaranteed to possess a uniform safety margin 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 materials and the climatic conditions. The need was, therefore, felt to lay down uniform requirements of structures for the storage of liquids giving due consideration to these factors. In order to fulfil this need, formulation of this Indian Standard code of practice for concrete structures for the storage of liquids [IS : 3370-1965] was undertaken. This part deals with general requirements. Three other parts of the code are the following:

Part II Reinforced concrete structures
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 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 figures 1 to 7 given in this code are only diagramatic and are intended merely to illustrate the definitions and principles given in the code and need not be treated as preferred designs.

0.8 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, and

Institution of Civil Engineers, London.

0.9 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 I) lays down the general requirements for the design and construction of concrete structures, plain, reinforced or prestressed concrete, intended for storage of liquids, mainly water.

The requirements applicable specifically to reinforced concrete liquid retaining structures are covered in Part II.

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

†Code of practice for prestressed concrete.

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

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 deterimental 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. MATERIALS

2.1 The requirements for materials shall be governed by **4** of IS : 456-1964* and **4** of IS : 1343-1960† for reinforced concrete and prestressed concrete members, respectively, with the following additional requirements:

a) *Porous aggregates* — Under no circumstances shall the use of porous aggregates, such as burnt clay and broken brick or tile, be allowed for parts of structure either in contact with the liquids on any face or enclosing the space above the liquid.

b) *Prestressing steel* — The prestressing steel for prestressed concrete members of the structure shall comply with the requirements of either IS : 1785-1961‡ or IS : 2090-1962§.

2.2 Jointing Materials — Joint, fillers, joint sealing compounds, water bars and joint cover plates shall conform to the requirements of relevant Indian Standards.

3. CONCRETE MIX

3.1 Provisions in **5** of IS : 456-1964* and **4.2.5** of IS : 1343-1960† shall apply for reinforced concrete and prestressed concrete members, respectively, subject to the following further requirements:

a) Except in case of thick sections as described in **7** and parts of structure neither in contact with the liquid on any face nor enclosing the space above the liquid, concrete mix weaker than M 200 shall not be used.

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

†Code of practice for prestressed concrete.

‡Specification for plain hard drawn steel wire for prestressed concrete. (Since revised and split into two parts).

§Specification for high tensile steel bars used in prestressed concrete.

b) The minimum quantity of cement in the concrete mix shall be not less than 330 kg/m^3 in reinforced concrete work, 360 kg/m^3 in post tensioned prestressed work and 380 kg/m^3 in pretensioned prestressed work. The maximum quantity of cement in the concrete mix shall preferably not exceed 530 kg/m^3 of concrete.

c) The design of the mix shall be such that the resultant concrete is sufficiently impervious. The mix obtained in accordance with the above, if fully compacted, will generally give a degree of impermeability adequate for all ordinary purposes. In special circumstances, the engineer-in-charge should satisfy himself that an adequate permeability is obtained by percolation tests.

3.2 Pneumatic Mortar

3.2.1 The grading of fine aggregates for pneumatic mortar should conform in general to grading zone I or II specified in Table 3 of IS : 383-1963*.

NOTE — Pneumatic mortar is mortar applied pneumatically through a suitable nozzle; it is used, for example, as cover to external prestressing steel. or as internal rendering.

3.2.2 The proportions of pneumatic mortar should be such that the ratio (by weight) of cement content to fine aggregate is neither less than 0·3 nor more than 0·5.

3.2.3 A suitable mix for final cover coat of pneumatic mortar is 50 kg cement, 4·5 kg hydrated lime and 140 kg of dry sand of such size that it will pass through 2·36 mm IS Sieve.

3.3 Imperviousness of Concrete Mix — In the construction of concrete structures for the storage of liquids, the imperviousness of concrete is an important basic requirement. The permeability of any uniform and thoroughly compacted concrete of given mix proportions is very largely dependent on the water-cement ratio. While an increase in this ratio leads to an increase in the inherent permeability, a very much reduced water-cement ratio of a mix with a given cement content may cause compaction difficulties and thus may prove equally harmful. For a given mix made with particular materials, there is a lower limit to the water-cement ratio which can be used economically on any job. It is essential to select a richness of mix compatible with available aggregates, whose particle shape and grading have an important bearing on workability which must be suited to the means of compaction selected. Efficient compaction preferably by vibration is essential. In practice, it is usually convenient, particularly when dealing with thin congested reinforced sections, to specify a cement content sufficiently high to ensure that thorough compaction is obtainable while maintaining a sufficiently low water-cement ratio. In

*Specification for coarse and fine aggregate from natural sources for concrete (*revised*). (Since revised).

thicker sections, where a reduction in cement content might be desirable to restrict the temperature rise due to cement hydration, a lower cement content is usually permissible, partly because the overall permeability of the section is reduced by the greater thickness and partly because less congested conditions may permit thorough compaction of a somewhat drier mix.

While proper attention must be paid in achieving a mix of inherently low permeability, it should be recognized that common and more serious causes of leakage in practice, other than cracking, are defects such as segregation and honey combing and in particular all joints are potential source of leakage.

The mixes as specified in **3**, if fully compacted, will give a degree of permeability adequate for all ordinary purposes. In special circumstances, where necessary, the engineer should satisfy himself by a percolation test, that an adequate degree of impermeability is obtained.

4. SITE CONDITIONS

4.1 The following conditions of the site in relation to the functional and structural requirements of the liquid retaining (storage) structure materially influence the methods of design and the cost of the structure:

a) Physical characteristics of soil in which the liquid retaining structure may be partly or wholly enclosed and also the physical and geological features of the supporting foundations,

b) Extent of water-logging at the site, and

c) Chemical properties of the soil and of the ground water.

4.2 In making the choice of the site and in the preparation of the design the factors mentioned in **4.1** should be taken into account generally as indicated below:

a) *External earth pressure* — Relief from external earth pressures either wholly or partially should not generally be relied upon, unless the operation of such pressures throughout the service life of the liquid retaining structure is ensured. On the other hand, walls of the liquid retaining structure shall be checked for external pressures under empty or partially-empty conditions.

b) *Water-logged ground* — If in the sitting of a liquid retaining structure, water-logged ground cannot be avoided, the dangers of the external water pressure shall be carefully guarded against by the following:

1) Designing the structure to resist such pressure under empty or partially-empty conditions and taking precautions to prevent floating and ensuring stable equilibrium under all conditions of internal and external loads. It is advisable to make the

design such that the minimum gravity weight exceeds the uplift pressure by at least 20 percent.

2) Providing under floor drainage to reduce the level of the external water as far as local conditions permit.

3) Providing relief valves discharging into the liquid retaining structure when the external pressure exceeds the internal pressure; this arrangement is feasible only in cases when the liquid retaining structure is not required for the storage of liquids which should not be contaminated.

4) Designing both internal and external faces of the walls and floor as water retaining faces, where the walls and floors of the liquid retaining structure are submerged in water or water bearing soils.

c) *Stability* — The equilibrium and safety of structure and parts of it against sliding and overturning especially when the structure is founded on a side long or sloping ground, shall also be checked.

d) *Settlement and subsidence* — Geological faults, mining, earthquakes, existence of subsoils of varying bearing capacities may give rise to movement or subsidence of supporting strata which may result in serious cracking of structure. Special considerations should be given in the preparation of the design, to the possible effect of subsidence or movement of the foundation strata.

e) *Injurious soils* — Chemical analysis of the soil and ground water is essential in cases where injurious soils are expected to exist, as concrete structure may suffer severe damage in contact with such soils. The use of sulphate resisting cement will increase the resistance to the action of certain injurious soils but may not afford complete safeguard. An isolating coat of bituminous or other suitable material may improve the protective measures.

5. PROTECTION AGAINST CORROSION

5.1 The type of liquid to be retained should be considered in relation to the possibility of corrosion of steel or attack on concrete with corrosion waters (as in the case with certain natural waters), it is desirable to use richer and denser concrete and provide increased cover to steel. Considerations may also be given to the use of special cements, such as, sulphate-resisting cement or high alumina cement. Where attack is likely to be appreciable the provision of an impervious protective lining should be considered.

6. CONTROL OF CRACKING

6.1 Design of liquid retaining structures has to be based on the avoidance of cracking in the concrete having regard to its tensile strength. Important causes of cracking in concrete and measures to be adopted for avoiding them are given below.

6.1.1 Design of reinforced concrete members should be made in accordance with the usual principle of ignoring the tensile resistance of concrete. Additionally, it should also be ensured that the calculated tensile stress on the liquid retaining face of the equivalent concrete section (after allowing for the steel area in equivalent concrete units) does not exceed the limits prescribed by this standard [*see* Table 1 of IS : 3370 (Part II) - 1965*] assuming in the calculations that the entire section of the concrete (including cover) participates in resisting the direct and flexural loads. The permissible limits of tensile stress in the concrete for calculations relating to resistance to cracking will naturally provide a much smaller margin of safety against ultimate tensile strength of concrete because the consequences of cracking are usually much less serious than those of structural failure.

In members less than 225 mm thick, the requirement of limiting the tensile stress as given in **6.1.1** shall also be applied to the face remote from the water retaining face.

6.1.2 Plain concrete liquid retaining structures or members 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.

6.1.3 The design of prestressed concrete members is based upon ' no tension ' being developed in the concrete section under service conditions. The design of prestressed concrete shall however be further checked against cracking of the liquid retaining face with a load factor against cracking of **1.2**.

6.1.4 Cracking may also result from the restraint to shrinkage, free expansion and contraction of concrete due to temperature and shrinking and swelling due to moisture effects. Such restraint may arise from:

a) the interaction between reinforcement and concrete during drying shrinkage,

b) the boundary conditions at the foundations or other parts of the structure, and

c) the differential conditions through the large thickness of massive concrete. Some of the methods employed to control or prevent such cracking are given in **6.1.4.1** to **6.1.4.6**.

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*Code of practice for concrete structures for the storage of liquids, Part II Reinforced concrete structures.

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

6.1.4.1 Correct placing of reinforcement, use of small sized bars and use of deformed bars lead to a difused distribution of cracks.

6.1.4.2 The risk of cracking due to overall temperature and shrinkage effects may be minimized by limiting the changes in moisture content and temperature to which the structure as a whole is subjected. Underground reservoirs can remain permanently wet. It will be advantageous if during construction of such reservoirs thin sections below final water level could be kept permanently damp. It will, however, be impracticable to maintain permanent wetness in elevated structures which unavoidably may be left empty for a period.

6.1.4.3 Cracks can be prevented in thick walls (or even in thinner sections) by avoiding the use of thick timber shuttering which prevent the easy escape of the heat of hydration from the concrete mass. Due to such heat of hydration, the concrete wall is raised to a relatively high temperature which will be retained during the period the concrete hardens. On removal of the form work, as the temperature of concrete falls to that of the surrounding air, the concrete contracts. Such contraction will take place without cracking if the free movement of the wall is unrestricted, but cracks may subsequently develop where one or more of the edges are restrained.

6.1.4.4 The risk of cracking can also be minimized by reducing the restraints on the free expansion or contraction of the structure. With long walls or slabs founded at or below ground level, restraints can be minimized by the provision of a sliding layer. This can be provided by founding the structure on a flat layer of concrete (*see* Note) with interposition of some material to break the bond and facilitate movement. However, the length of the wall that can be kept free of cracks by the use of a sliding layer in its foundation is strictly limited and is related to the tensile strength of the wall section. In approximate terms, the tensile strength has to be sufficient to overcome the resistance to sliding of one half of the length of the wall. Control of cracking thus requires subdivision of the structure into suitable lengths separated by movement joints. The maximum length desirable between joints will depend on the tensile strength of the wall and may be increased by suitable reinforcement. The effectiveness of movement joints in controlling cracking will depend not only on their spacing but often on their precise location. This is a matter of experience and may be characterized as the place where cracks would otherwise develop, for example, at changes of section. The location of all movement joints should be indicated on the drawings.

NOTE — In normal circumstances this flat layer of concrete may be weaker than that used in other parts of the structure, but not weaker than M 100 specified in IS : 456-1964*. Where, however injurious soils or agressive ground water are expected, the concrete should not be weaker than M 150 specified in IS : 456-1964*, and if necessary a sulphate resisting or other special cement should be used.

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

6.1.4.5 Where reservoirs are used for reception or storage of hot liquids, allowance should be made for the additional stresses produced by difference in temperature between inside and outside of the reservoir. The severity of the temperature gradient through the concrete can sometimes be reduced by internal insulation.

6.1.4.6 Whenever development of cracks or overstressing of the concrete in tension cannot be avoided, the concrete section should be suitably strengthened. In making the calculations either for ascertaining the expected expansion or contraction or for strengthening the concrete section, the following values of the coefficient of expansion due to temperature and coefficient of shrinkage may be adopted:

Coefficient of expansion	11×10^{-6}/°C
Coefficient of shrinkage	initial shrinkage on first drying 450×10^{-6} of the original length; drying shrinkage 200×10^{-6} of the original length

6.2 Sustained stresses due to temperature and shrinkage effects may be modified by the occurrence of creep. This is often advantageous, for instance, if the reservoir is filled at a slow rate (a procedure which is usually adopted) the margin of safety against cracking may be increased by the occurrence of creep. This procedure also has the advantage that resaturation of the concrete before it is fully loaded will reduce the contribution which drying shrinkage might make to the formation of cracks.

6.3 Where reservoirs are protected with an internal impermeable lining, the requirement that all cracking of the concrete be avoided should be retained unless it is established on the basis of tests or experience that the lining has adequate crack bridging properties.

7. THICK SECTIONS

7.1 Thick sections shall be those parts of structure which have thickness greater than 450 mm. There is a likelihood of cracking in such sections as a consequence of temperature rise during hydration of the cement and subsequent cooling. Such cracking is not easy to control by reinforcement. The following are some of the measures that may be adopted for reducing the likelihood of cracking:

a) Magnitude of the temperature rise should be restricted by limiting the cement content, or by using a type of cement with a low rate of heat of evolution or adopting suitable construction methods. Portland cements with lower rates or strength development generally give lower rates of heat evolution. In such cases the permissible stresses shall conform to requirements of **3.3**. Temperature rise may also be restricted by casting the concrete in shallow lifts at intervals of a few days so as to allow the escape of part of heat from the exposed upper surface.

b) Steep temperature grading will occur by sudden chilling of the concrete surface. This should be avoided, for instance, some protection may be required when removal of heavy timber form-work coincides with on set of cold weather.

c) Restraint to overall contraction may be limited by provision of movement joints and by provision of suitable sliding layer (*see* **6.1.4.3** and **6.1.4.4**). Another cause of restraint which may lead to cracking occurs when a substantial lift of concrete is cast upon a cold foundation. A better procedure is to avoid excessive disparity in temperature between successive lifts and where practicable to introduce shallow lifts when starting from or resuming work on a cold foundation.

7.2 While concreting in thick sections, the requirements of IS : 456-1964* shall apply as far as possible.

8. JOINTS

8.1 Joints shall be categorized as below:

a) *Movement Joints* — There are three categories of movement joints:

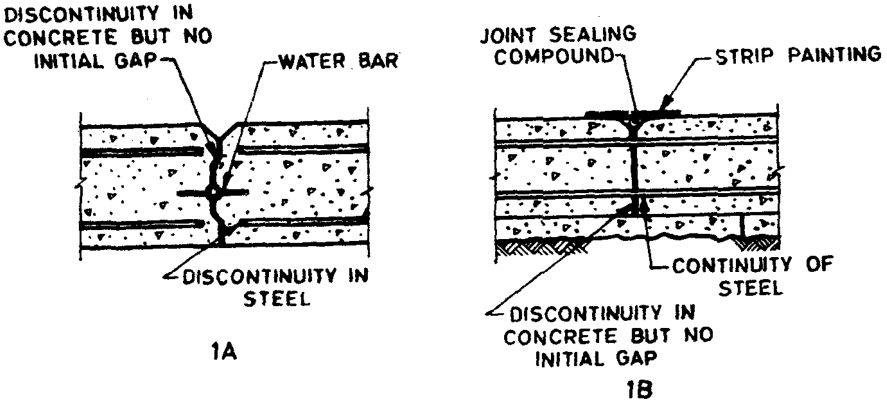
1) *Contraction joint* — A movement joint with a deliberate discontinuity but no initial gap between the concrete on either side of the joint, the joint being intended to accommodate contraction of the concrete (*see* Fig. 1).

A distinction should be made between a complete contraction joint (*see* Fig. 1A) in which both concrete and reinforcing steel are interrupted, and a partial contraction joint (*see* Fig. 1B) in which only the concrete is interrupted, the reinforcing steel running through.

2) *Expansion joint* — A movement joint with complete discontinuity in both reinforcement and concrete and intended to accommodate either expansion or contraction of the structure (*see* Fig. 2).

In general, such a joint requires the provision of an initial gap between the adjoining parts of a structure which by closing or opening accommodates the expansion or contraction of the structure. Design of the joint so as to incorporate sliding surfaces, is not, however, precluded and may some times be advantageous.

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



1A Complete Contraction Joint   1B Partial Contraction Joint

FIG. 1 TYPICAL CONTRACTION JOINTS

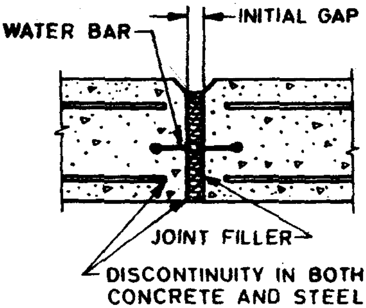


FIG. 2 A TYPICAL EXPANSION JOINT

3) *Sliding joint* — A movement joint with complete discontinuity in both reinforcement and concrete at which special provision is made to facilitate relative movement in place of the joint.

A typical application is between wall and floor in some cylindrical tank designs (*see* Fig. 3).

b) *Construction Joint* — A joint in the concrete introduced for convenience in construction at which special measures are taken to achieve subsequent continuity without provision for further relative movement, is called a construction joint. A typical application is between successive lifts in a reservoir wall (*see* Fig. 4).

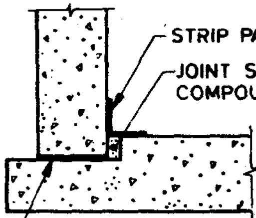


FIG. 3 A TYPICAL SLIDING JOINT

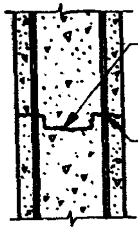


FIG. 4 A TYPICAL CONSTRUCTION JOINT

The position and arrangement of all construction joints should be predetermined by the engineer. Consideration should be given to limiting the number of such joints and to keeping them free from possibility of percolations in a similar manner to contraction joints.

c) *Temporary Open Joints* — A gap temporarily left between the concrete of adjoining parts of a structure which after a suitable interval and before the structure is put into use, is filled with mortar or concrete either completely (Fig. 5A) or as provided below, with the inclusion of suitable jointing materials (Fig. 5B and 5C). In the former case the width of the gap should be sufficient to allow the sides to be prepared before filling.

Where measures are taken for example, by the inclusion of suitable jointing materials to maintain the watertightness of the concrete subsequent to the filling of the joint, this type of joint may be regarded as being equivalent to a contraction joint (partial or complete) as defined above.

8.2 Design of Joints — Design of a movement joint should aim at the following desirable properties for its efficient functioning:

a) The joint should accommodate repeated movement of the structure without loss of watertightness.

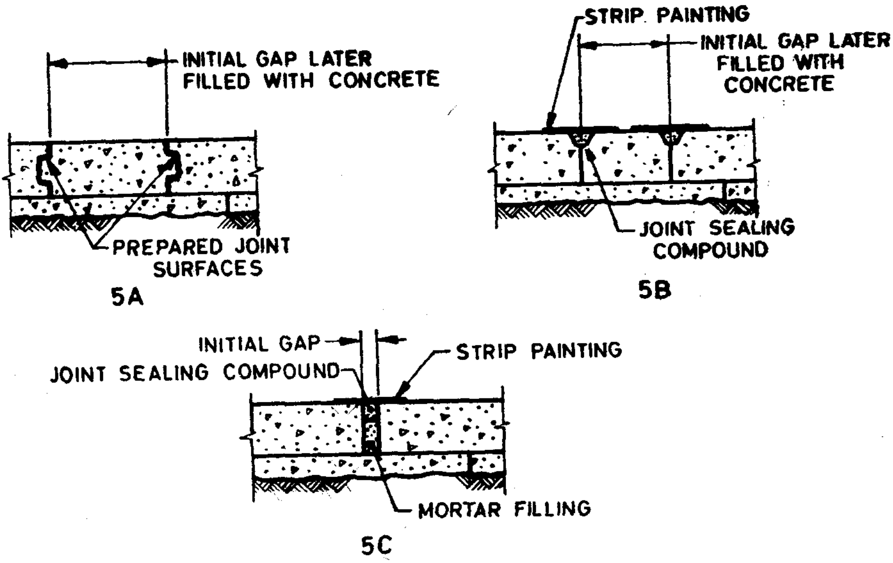


Fig. 5 Typical Temporary Open Joints

b) The design should provide for exclusion of grit and debris which would prevent the closing of the joint.

c) The material used in the construction of movement joints should have the following properties:

1) it should not suffer permanent distortion or extrusion and should not be displaced by fluid pressure.

2) it should not slump unduly in hot weather or become brittle in cold weather.

3) it should be insoluble and durable and should not be affected by exposure to light or by evaporation of solvent or plasticisers.

4) in special cases, the materials should be non-toxic, taintless or resistant to chemical and biological action as may be specified.

8.3 Spacing of Joints — Unless alternative effective means are taken to avoid cracks by allowing for the additional stresses that may be induced by temperature or shrinkage changes or by unequal settlement, movement joints should be provided at the following spacings:

a) In reinforcement concrete floors, movement joints should be spaced at not more than 7·5 m apart in two directions at right angles. The wall and floor joints should be in line except where sliding joints occur at the base of the wall in which case correspondence is not so important.

b) For floors with only nominal percentage of reinforcement (smaller than the minimum specified), the concrete floor should be cast in panels with sides not more than 4·5 m.

c) In concrete walls, the vertical movement joints should normally be placed at a maximum spacing of 7·5 m in reinforced walls and 6 m in unreinforced walls. The maximum length desirable between vertical movement joints will depend upon the tensile strength of the walls, and may be increased by suitable reinforcement. Thus when a sliding layer is placed at the foundation of a wall, the length of wall that can be kept free of cracks depends upon the capacity of wall section to resist the friction induced at the plane of sliding. Approximately the wall has to stand the effect of a force at the plane of sliding equal to weight of half the length of wall multiplied by the coefficient of friction.

d) Amongst the movement joints in floors and walls as mentioned above, expansion joints should normally be provided at a spacing of not more than 30 m between successive expansion joints or between the end of the structure and the next expansion joint, all other joints being of the contraction type.

e) When, however, the temperature changes to be accommodated are abnormal or occur more frequently than usual as in the case of storage of warm liquids or in uninsulated roof slabs, a smaller spacing than 30 m should be adopted, (that is a greater proportion of the movement joints should be of the expansion type) When the range of temperature is small, for example, in certain covered structures, or where restraint is small, for example, in certain elevated structures none of the movement joints provided in small structures upto 45 m length need be of the expansion type. Where sliding joints are provided between the walls and either the floor or roof, the provision of movement joints in each element can be considered independently.

8.4 Making of Joints — Joints shall generally be made according to the broad principles discussed in **8.4.1** to **8.4.3**.

8.4.1 *Construction Joints* — These should be set at right angles to the general direction of the member (*see* Fig. 4). The position and arrangement of construction joints should be determined by the engineer at the design stage and indicated on the drawings.

The surface film of the first-placed concrete should preferably be removed whilst the concrete is still green to expose the aggregate and leave a sound irregular surface. This may be effected by spraying with water, or air and water, assisted by light brushing, where necessary. If the concrete has been allowed to harden, it will be necessary to achieve the desired surface by hacking the whole of the surface, care being taken to avoid damaging the aggregate.

While the remainder of the concrete should be kept continuously wet, curing of the joint surface may be suspended a few hours before concreting is to be resumed so as to permit no more than superficial drying of the joint surface. Just before concreting is resumed, the roughened joint surface should be thoroughly cleaned and freed from loose matter, preferably, without re-wetting, and then treated with a thin layer of cement grout, worked well into the surface, or treated with cement/sand mortar in which water/cement and sand/cement ratios do not exceed those in the new concrete. Special care should be taken to avoid segregation of the concrete along the joint plane and to obtain thorough compaction.

Alternatively, for horizontal joints the layer of grout or mortar may be omitted, provided that the workability of first batches of concrete placed in contact with the joint is slightly increased.

8.4.2 *Movement Joints* — These require the incorporation of special materials in order to maintain watertightness whilst accommodating relative movement between the sides of the joint. Suitable materials for this purpose are referred to in **8.5**.

Movement joints, particularly those in floor and roof, also require protection against the entry of debris which may interfere with the closing of the joints.

8.4.2.1 *Contraction joints* — The joints face of the first-cast concrete should be finished against a stopping-off board, or vertical end shutter, which, in the case of a partial contraction joint, should be notched to pass the reinforcement.

Steps should be taken to prevent any appreciable adhesion between the new and the old concrete.

The joint should be suitably treated so as to maintain watertightness during movement of the joint (*see* Fig. 6 and **8.5**)

8.4.2.2 *Expansion joints* — These require the provision of an initial gap between the concrete faces on the two sides of the joint and this can be conveniently done by the use of materials discussed in **8.5**. The initial width of this gap should be specified by the engineer and should be sufficient to accommodate freely the maximum expansion of the structure. In determining the initial width, regard should be paid to the requirements of the jointing materials. These will normally require the maintenance of a certain minimum width of gap during maximum expansion of the

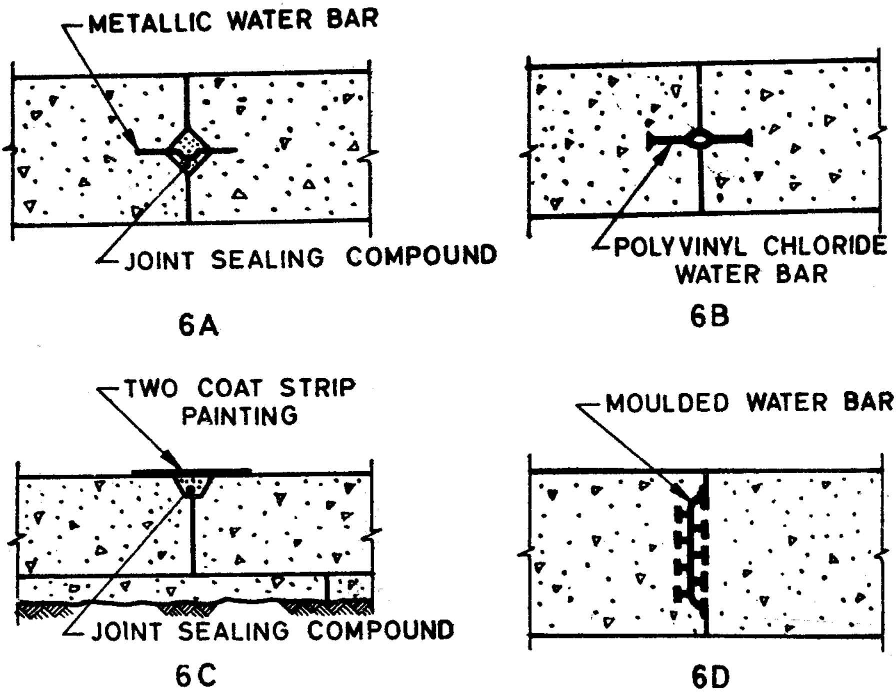


FIG. 6 TYPICAL DETAILS SHOWING USE OF JOINTING MATERIALS IN MOVEMENT JOINTS (CONTRACTION TYPE)

structure. The joint should be suitably treated so as to maintain watertightness during movement of the joint (*see* **8.5** and Fig. 7).

8.4.2.3 *Sliding joints* — The two concrete faces of a sliding joint should be plane and smooth.

Care should be taken by the use of a rigid screeding board or other suitable means to make the top of the lower concrete as flat as possible. This surface can usefully be improved by finishing with a steel float and rubbing down with carborundum.

Bond between the concrete of the two components should be prevented by painting or by inserting building paper or other suitable material.

The joint should be suitably treated so as to maintain watertightness during movement of the joint.

8.4.3 *Temporary Open Joints* — The concrete on both sides of the joints should be finished against stopping off boards.

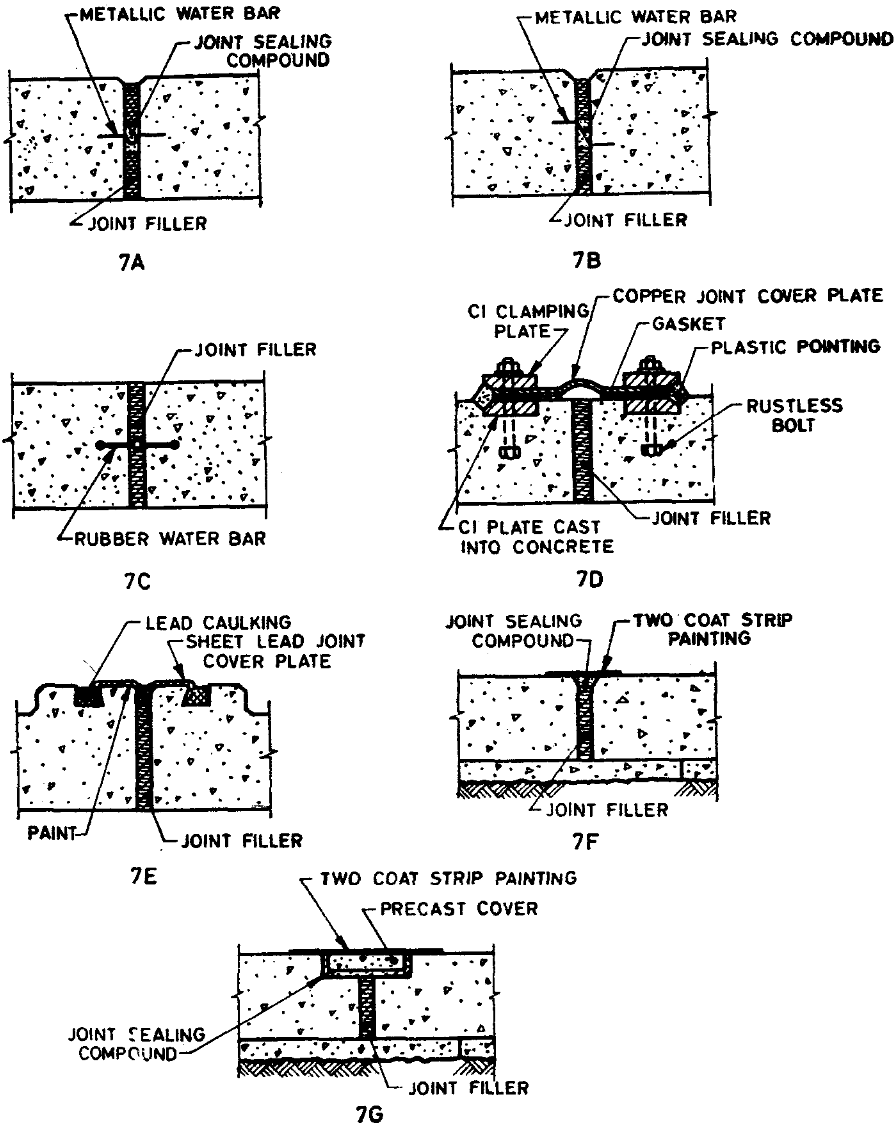


FIG. 7 TYPICAL DETAILS SHOWING USE OF JOINTING MATERIALS IN MOVEMENT JOINTS (EXPANSION TYPE)

In order to minimize the extent of subsequent movements due to shrinkage the joint should be left open until shortly before the reservoir is put into service and then filled in with mortar or concrete of specified proportions. Where possible, the joint should be filled when the temperature is low.

Immediatly before filling the gap, the joint faces should, if possible, be thoroughly cleaned and prepared in the same way as for construction joints (*see* **8.4.1**).

Where it is intended to treat this type of joint as equivalent to a contraction joint for the purpose of this code, the joint should be suitably sealed so as to maintain watertightness during subsequent movement of the joint.

8.5 Jointing Materials — Jointing materials may be classified as follows:

a) Joint fillers,

b) Water bars and joint cover plates, and

c) Joint sealing compounds (including primers where required).

8.5.1 *Joint Fillers* — Joint fillers are usually compressible sheet or strip materials used as spacers. They are fixed to the face of the first placed concrete and against which the second placed concrete is cast. With an initial gap of about 30 mm, the maximum expansion or contraction that the filler materials may allow may be of the order of 10 mm.

Joint fillers, as at present available, cannot by themselves function as watertight expansion joints. They may be used as support for an effective joint sealing compound in floor and roof joints. But they can only be relied upon as spacers to provide the gap in an expansion joint, the gap being bridged by a water bar (*see* Fig. 7).

8.5.2 *Water Bars* — Water bars are preformed strips of impermeable material which are embeded in the concrete during construction so as to span across the joint and provide a permanent watertight seal during the whole range of joint movement. The most usual forms of water bars are strip with a central longitudinal corrugation (*see* Fig. 6A and 7A), Z shaped strip (*see* Fig. 7B), and a central longitudinal hollow tube (*see* Fig. 6B and 7C) with thin walls with stiff wings of about 150 mm width. The material used for the water bars are copper bars, sheet lead, natural or synthetic rubbers (*see* Fig. 7C) and plastics such as polyvinyl chloride (PVC) (*see* Fig. 6B). Galvanized iron sheets may also be used with the specific permission of the engineer-in-charge provided the liquids stored or the atmosphere around the liquid retaining structure is not excessively corrosive, for example, sewage.

Of the metals available copper is most suitable for use as water bar as regards ductivity and resistance to corrosion in air, water and concrete.

It may, however, be attacked by some wastes. If sheet lead is used, it should be insulated from concrete by a good coat of bituminous or suitable composition. Natural and synthetic rubbers and plastics have very considerable advantage in handling, splicing and in making intersections.

With all water bars, it is important to ensure proper compaction of the concrete. The bar should have such shape and width that the water path through the concrete round the bar should not be unduly short.

The holes sometimes provided on the wings of copper water bars to increase bond shorten the water path and may be disadvantageous. The water bar should either be placed centrally in the thickness of the wall or its distance from either face of the wall should not be less than half the width of the bar. The full concrete cover to all reinforcement should be maintained.

The strip water bars at present available in the newer materials need to be passed through the end shutter of the first-placed concrete. It can be appreciated, however, that the use of the newer materials make possible a variety of shapes or sections. Some of these designs, for example, those with several projections (*see* Fig. 6D), would not need to be passed through the end shutter and by occupying a bigger proportion of the thickness of the joint would also lengthen the shortest alternative water path through the concrete.

8.5.3 *Joint Cover Plates* — Joint cover plates are sometimes used in expansion joints to avoid the risk of a fault in an embedded water bar. The cover plate may be of copper or sheet lead. If copper cover plate is used it should be clamped to the concrete face on each side of the joint using suitable gaskets to ensure watertightness (*see* Fig. 7D). If sheet lead is used, the edges may return into grooves formed in the concrete and be made completely watertight by lead caulking (*see* Fig. 7E). Faces of the concrete to which sheet lead is to be fixed should be painted with bituminous or other suitable composition and the lead sheet should be similarly coated before fixing.

8.5.4 *Joint Sealing Compounds* — Joint sealing compounds are impermeable ductile materials which are required to provide a watertight seal by adhesion to the concrete throughout the range of joint movement. The commonly used materials are based on asphalt, bitumen, or coal tar pitch with or without fillers, such as lime stone or slate dust, asbestos fibre, chopped hemp, rubber or other suitable material. These are usually applied after construction or just before the reservoir is put into service by pouring in the hot or cold state, by trowelling or gunning or as preformed strips ironed into position. These may also be applied during construction such as by packing round the corrugation of a water bar. A primer is often used to assist adhesion and some local drying of the concrete surface with the help of a blow lamp is advisable. The length of the shortest water path through the concrete should be extended by suitably painting the surface of the concrete on either side of the joint.

The main difficulties experienced with this class of material are in obtaining permanent adhesion to the concrete during movement of the joint whilst at the same time ensuring that the material does not slump or is not extruded from the joint.

In floor joints, the sealing compound is usually applied in a chase formed in the surface of the concrete along the line of the joint (*see* Fig. 7C). The actual minimum width will depend on the known characteristics of the material. In the case of an expansion joint, the lower part of the joint is occupied by a joint filler (*see* Fig. 7F). This type of joint is generally quite successful since retention of the material is assisted by gravity and, in many cases, sealing can be delayed until just before the reservoir is put into service so that the amount of joint opening subsequently to be accommodated is quite small. The chase should not be too narrow or too deep to hinder complete filling and the length of the shortest water path through the concrete should be extended by suitably painting the surface of the concrete on either side of the joint. Here again a wider joint demands a smaller percentage distortion in the material.

An arrangement incorporating a cover slab, similar to that shown in Fig. 7G, may be advantageous in reducing dependence on the adhesion of the sealing compound in direct tension.

Using of sealing compounds for vertical joints is not very successful. A stepped-joint instead of a straight through-joint with a water bar incorporated in the joint and sealing compound packed round the corrugation of the water bar would be much more successful.

9. CONSTRUCTION

9.0 Unless otherwise specified in this code, and subject to the following additional recommendations, the provisions of IS : 456-1964* and IS : 1343-1960† shall apply to the construction of reinforced concrete and prestressed concrete liquid retaining structures, respectively.

9.1 Thick Sections — The precautions necessary in the construction of thick sections shall be observed as per requirements of **7**.

9.2 Joints — Joints shall be constructed in accordance with requirements of **8**.

9.3 Mixing and Placing of Pneumatic Mortar

9.3.1 *Mixing* — The aggregate and cement should be mixed in an approved mechanical mixer and delivered from an approved mechanical

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

†Code of practice for prestressed concrete.

digester. The minimum amount of water should be injected into the mixture as this will ensure maximum density of the mortar.

9.3.2 *Placing* — The pneumatic mortar should be applied with an approved nozzle by a skilled operator. The velocity of the material leaving the nozzle should be maintained uniform and should be such as to produce minimum rebound of sand.

9.3.3 *Curing* — Immediately after pneumatic mortar has been placed it should be protected against premature drying by shading from strong sunshine and shielding from the wind. As soon as it has hardened just sufficiently to avoid damage it should be thoroughly wetted and thereafter kept wet continuously for at least seven days. Adequate protection against fluctuations in temperature by shading and shielding, shall also be given.

9.4 Construction of Floors

9.4.1 *Floors Founded on the Ground*

9.4.1.1 The ground should be covered with an at least 75 mm thick plain concrete screed of composition as described in **6.1.4.4**. Floors cast on the ground should be in not less than two layers, the bottom layer of which may comprise or replace the plain concrete screed. When the screed forms an integral part of the floor slab forming one of the two layers then the mix for screed shall conform to the requirements of **3**.

9.4.1.2 A layer of building paper or other suitable material should be laid between successive layers.

9.4.1.3 The layers, other than the plain concrete screed, if used, should be placed in panels, the sides of which should not exceed 7·5 m in the case of reinforced slabs and 4·5 m in the case of plain slabs.

The tendency for the development of cracks in the upper layer of paving slab or a reservoir floor is greatly diminished if the reinforcement is discontinuous through the joints and it is recommended that the floor panels be laid in chessboard fashion (all the ' black ' or all the ' white ' squares first). The edges of the panels in the bottom layer may be butt-jointed and the panels in the various layers should be arranged to break joint.

9.4.2 *Suspended Floors* — Floors which are not directly supported on the ground should be cast in panels, the sides of which should not exceed 7·5 m. At joints in suspended floors, the surface of the panels for a width not less than the thickness of the panel on each side of the joint should be primed and painted with at least two coats of bituminous or other approved paint.

9.4.3 *Junction of Floor and Walls* — Where the wall is designed to be monolithic with the bottom slab, a suitable arrangement of reinforcement and form-work shall be made to facilitate the form-work to fit tightly and avoid leakage of cement paste from newly deposited concrete as such leakage if allowed to take place is very liable to cause porosity in the finished concrete. One such arrangement is by providing a continuous upstand section of the wall cast at the same time, as, and integrally with, the slab; the height of this upstand must be sufficient to enable the next lift of form-work to fit tightly and avoid leakage of the cement paste from the newly deposited concrete.

9.5 Construction of Walls

9.5.1 In all cases where the reinforcing steel is discontinuous at vertical contraction joints, the walls should be constructed in alternate panels with as long a pause as practicable before the concrete is placed in the intervening panels.

9.5.2 Where the reinforcement is continuous through vertical joints in walls, construction in alternate panels may result in a greater tendency to the development of cracks in those panels which are cast between two earlier placed panels, the existence of which increases restraint of the natural shrinkage of the intermediate panel.

9.5.3 The height of any lift should not exceed 2 m unless special precautions are taken to ensure through compaction throughout by mechanical vibration or by other suitable means.

9.5.4 All vertical joints should extend the full height of the wall in unbroken alignment.

9.6 Surface Finish to Prestressed Concrete Cylindrical Tanks — The circumferential prestressing wires of a cylindrical tank should be covered with a protective coat, which may be pneumatic mortar, having a thickness that will provide a minimum cover of 40 mm over the wires.

9.7 Formwork

9.7.1 *Removal of Formwork* — The requirements shall conform to **20.2.3** of IS : 456-1964*.

9.7.2 Bolts passing completely through liquid-retaining slabs for the purpose of securing and aligning the form-work should not be used unless effective precautions are taken to ensure water-tightness after removal.

9.8 Lining of Tanks — The type of liquid to be stored should be considered in relation to the possibility of corrosion of the steel or attack on the

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

concrete. Provision of an impermeable protective lining should be considered for resistance to the effects of corrosive liquids. Certain natural waters exhibit corrosive characteristics and in such cases it is important to obtain a dense impermeable concrete and with a higher cement content. An increased cover to the steel is also desirable. Use of sulphate resisting portland cement, pozzolana cement, or blast-furnance slag cement may in certain cases be advantageous.

10. TESTS ON STRUCTURE

10.1 In addition to the structural test of the structure, as given in **21.3** of IS : 456-1964*, the tanks shall also be tested for watertightness at full supply level as described in **10.1.1, 10.1.2** and **10.1.3.**

10.1.1 In the case of tanks whose external faces are exposed such as elevated tanks, the requirements of the test shall be deemed to be satisfied if the external faces show no signs of leakage and remain apparently dry over the period of observation of seven days after allowing a seven day period for absorption after filling.

10.1.2 In the case of tanks whose external faces are submerged and are not accessible for inspection, such as underground tanks, the tanks shall be filled with water and after the expiry of seven days after the filling, the level of the surface of the water shall be recorded. The level of the water shall be recorded again at subsequent intervals of 24 hours over a period of seven days. The total drop in surface level over a period of seven days shall be taken as an indication of the watertightness of the tank. The engineer-in-charge shall decide on the actual permissible nature of this drop in the surface level, taking into account whether the tanks are open or closed and the corresponding effect it has on evaporation losses. For many purposes, however, underground tanks whose top is covered may be deemed to be water-tight if the total drop in the surface level over a period of seven days does not exceed 40 mm.

10.1.3 If the structure does not satisfy the conditions of test, and the daily drop in water level is decreasing, the period of test may be extended for a further seven days and if specified limit is then reached, the structure may be considered as satisfactory.

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

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AMENDMENT NO. 1 COTOBER 1982

TO

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

PART I GENERAL REQUIREMENTS

Alterations

(*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.'

(*Page 6, clause 3.1, last line*) - Substitute 'impermeability' *for* 'permeability'.

(*Page 7, clause 3.3, line 13*) - Substitute 'impermeability' *for* 'permeability'.

(BDC 2)

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