BUREAU OF INDIAN STANDARDS

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भारतीय मानक **मसौदा**

रासायनिक प्रक्रियाओं के लिए पात्र और उपकरणों की लाइनिंग – रीति संहिता

भाग 10 ईट एवं टाइल

(पहला पुनरीक्षण)

Draft *Indian Standard*

LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES — CODE OF PRACTICE

PART 10 BRICK AND TILE

(*First Revision*)

ICS 71.120.10

Chemical Engineering Plants and Related Equipment Sectional Committee, MED 17	Last date for receipt of comments: **16 March 2025**

FOREWORD
(*Formal clause will be added later on*)

This standard was first published in 1974. This standard is being revised to keep pace with the latest technological developments and international practices. Also, in this revision, the standard has been brought into the latest style and format of Indian Standards, and references of Indian Standards, wherever applicable have been updated.

This standard has been issued in several parts. Brick and tile lining is covered in this part, the other types of linings are covered in the remaining parts of this standard. The other parts issued in this series are:

Part 1 Rubber Lining
Part 2 Glass Enamel Lining
Part 3 Lead Lining
Part 4 Lining with Sheet Thermoplastics

Part 5 Epoxide Resin Lining
Part 6 Phenolic Resin Lining
Part 7 Corrosion and Heat Resistant Metals
Part 8 Precious Metals
Part 9 Titanium

The lining contractor should approve the suitability of those details of design that affect the efficiency of the finished lining. Annex B gives the details of information to be exchanged at that stage.

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 : 2022 'Rules for rounding off numerical values (second revision)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft *Indian Standard*

LINING OF VESSELS AND EQUIPMENT FOR CHEMICAL PROCESSES — CODE OF PRACTICE

PART 10 BRICK AND TILE

(*First Revision*)

1 SCOPE

This standard (Part 10) lays down the recommendations on the design of vessels for brick and tile lining, methods of application of lining, inspection and testing.

2 REFERENCES

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

3 MATERIALS

3.1 Types of Bricks

3.1.1 In this part of code, the term 'brick' includes tiles as well as bricks of special shapes.

3.1.2. Basically, the lining of chemical vessels fall into the groups given in **3.1.2.1** to **3.1.2.7**.

3.1.2.1 *Red and blue acid resisting bricks* (*see IS 4860*)

Most engineering quality bricks are resistant to acids, alkalis and organic chemicals, with the exception of hydrofluoric acid and concentrated caustic alkalis, especially at elevated temperatures. However, for very dilute (1 percent) hydrofluoric acid conditions a reasonable life may be expected from the blue type of acid resisting brick. Attention is drawn to the fact that commercial phosphoric acid contains traces of hydrofluoric acid.

3.1.2.2 *Fireclay or similar type bricks*

These types of bricks might be used where a combination of elevated temperatures and/or corrosive and erosive conditions are encountered. These materials also have certain thermal shock resistance.

3.1.2.3 Highly vitrified linings, like industrial porcelain, chemical stoneware, fusion-cast basalt, glass and fused silica units.

3.1.2.4 Carbon, including grades of bricks impregnated with resins to reduce their porosity and to meet the particular corrosive conditions. These materials are particularly useful for contact with hydrofluoric acid and have good resistance to thermal shock.

3.1.2.5 *Silicon carbide*

These materials consist of bonded silicon carbide; they have excellent acid resistance with particular resistance to abrasion and erosion. In addition they have high thermal conductivity and are used where heat transfer or thermal shock resistance are important.

3.1.2.6 *Special ceramic materials*

Sintered alumina and silicon nitride are examples. A wide range of other special ceramic materials is becoming commercially available for use under unusual ‘conditions, for example, thermal shock resistance under corrosive conditions.

3.1.2.7 *Heat insulating materials*

The most generally used insulating materials for this purpose are fired diatomite bricks. Such materials are used where it is necessary to protect an outer casing from high temperature, like in duct lining conveying hot corrosive gases.

3.1.3 Bricks used for the lining of vessels shall be accurately shaped as well as of uniform dimension to enable them to be laid with the thinnest possible joints; with bricks manufactured according to IS 4860, it shall be possible to achieve joints of the order of 3 mm.

The properties specified, agreed between user and lining contractor shall be apparent porosity, acid solubility, uniformity of dimensions, freedom from visual defects like cracks, internal laminations, etc. Some methods of testing are described in IS 2839.

3.2 Corrosion-Resistant Mortars

3.2.1 Attention is drawn to the fact that many corrosion-resistant mortars cannot be applied directly to concrete and metals without the use of an intermediate layer or primer.

3.2.1.1 Corrosion-resistant mortars are generally slow to set and harden under cold and cool temperature conditions and it is best to work at temperatures in the range 25°C to 30°C.

2.2.1.2 Bricks and lining tiles shall be clean and dry; the latter condition is usually be obtained by drying and storing under warm conditions. This also helps to maintain warm working conditions.

3.2.1.3 Vessels and tools used for mixing mortars on site shall be clean. Alternatively, use may be made of loose disposable polythene lining in vessels used for mixing. Where proprietary mortars are used, the manufacturer’s instructions shall be adhered to.

3.2.1.4 Corrosion-resistant mortars fall into several distinct categories. It will be seen that a wide variety of mortars is now available.

3.2.2 *Hydraulic Cement Mortars*

3.2.2.1 Hydraulic cement mortars consist of mixtures of suitable inert fine aggregates (clean sharp sand) with a hydraulic binder, such as portland, high alumina or supersulphated cement. While such mortars may have a useful resistance to many aggressive conditions, they are not comparable with special mortars described in **3.2.3**, **3.2.4**, **3.2.5** and **3.2.6**; In cases of doubt, cement manufacturers shall be consulted before the cement is used.

3.2.2.2 Portland cement mortars as a general guide may be taken to contain calcium silicate gel, and to resist any agent which does not attack this material. Thus their resistance to alkaline media and to non-polar organic materials is good, but it is generally considered that they should not be used in conditions having acidity less than *p*H 6.

3.2.2.3 High-alumina cement mortars are in many respects complementary to Portland cement mortars. In place of the calcium silicate they contain aluminium hydroxide gel, and are in general sensitive only to materials which attach this component. While they thus resist many organic materials, and also many acid conditions provided the *p*H is not less than 4, they shall not be used in contact with caustic alkalis.

3.2.2.4 Super-sulphated cement differs in composition from high-aluminium and portland cements, but like the former contains no calcium silicate when hardened. It thus resembles high-aluminium cement in its resistance to acid conditions (provided the *p*H is not less than 3.5) and to many organic materials but its resistance to alkaline conditions is more akin to that of portland cement.

3.2.2.5 In designing hydraulic cement mortars the thickness of the joint dictates the maximum size of the aggregate. This in turn affects the proportion of cement to aggregate, for the finer the aggregate, the richer in cement the mix shall be if the mortar is to be installed, at an acceptable low water/cement ratio. Excessively high water/cement ratios shall always be avoided, as this not only reduces the cohesiveness of the fresh mortar but also causes weakness and permeability in the hardened mortar.

3.2.2.6 Portland cement and super-sulphated cement mortars shall be designed so that, at a water/cement ratio not exceeding 0.5, they have adequate work ability to permit proper filling of the joints. High alumina cement gives rather more fluid mixes, and for the applications mentioned a water/cement ratio of 0.4 shall not be exceeded or cohesiveness may be lost and permeability increased.

3.2.2.7 Mixtures of different types of hydraulic cement shall never be used in chemical resistance work, and no contaminant likely to affect hardening and durability shall be allowed to enter the mix from tools, water or any other source. The method of proportioning and mixing shall be such that successive batches are homogeneous and of effectively constant composition. Batches shall be of such a type that they are used up within 1 h after mixing and no retempering shall be permitted.

3.2.2.8 To ensure correct hardening completed joints shall be prevented from losing moisture during the initial hardening period, for 24 h in the case of high alumina cement, 3 days in the case of portland and 4 days in the case of supersulphated cements. This may be most effectively achieved by covering the work with an impermeable plastics film or by using proprietary curing membrane.

3.2.3 *Silicate Mortars*

Silicate mortars are based on the selected sodium or potassium silicate solutions, inert fillers and hardening agents to enable these to set at ambient temperatures. They resist attack by practically all acids with the exception of hydrofluoric acid and concentrated pure phosphoric acid and phosphoric acid containing traces of hydrofluoric acid. After pretreatment (immersion or brushing on) with strong acid solutions (concentrated hydrochloric acid or 25 percent sulphuric acid) they are reasonably resistant to static water and neutral solutions at ambient temperatures. If more dilute acids are used the water resistance is reduced. It is also possible to increase the resistance of silicate mortars to hot water and even dilute alkalis by suitable heat treatment. The appropriate heat treatment will vary with circumstance but a typical heat treatment will be heating for several hours at 120°C.

Conventional silicate mortars are inherently permeable. Those using silicofluoride type hardening agents are prone to loss of adhesion between brick and mortar under acid conditions. By the use of halogen free hardening agents, that is, some esters and amines, mortars are available with reduced permeability and greater retention of adhesion under acid conditions. Silicate mortars may be used at higher temperatures than other corrosion resistant mortars.

3.2.4 *Rubber Latex Mortars*

Rubber latex mortars comprise a suitably stabilized concentrated natural rubber latex and a powder based on a mixture of a hydraulic cement, usually high-alumina cement, with inert fillers and sands. They set and harden by a combination of coagulation of the rubber latex and hydration of the cement. Rubber latex mortars are resistant to water, dilute acids and alkalis generally in the *p*H range of 2 to 12. They are attacked by many organic materials and by oxidizing conditions. Their big advantage over other corrosion resistant mortars is that they may be applied under a wide variety of climatic conditions except frost and may be applied to damp surfaces. Where differential movement occurs the additional resilience of these mortars may be an advantage. It is also possible to formulate mortars of this type based on synthetic rubber latices but little experience is available to date.

3.2.5 *Sulphur Bonded Mortars*

Sulphur bonded mortars are based on powdered sulphur combined with inert fillers, supplied either in powder form or cast into blocks, So called ‘plasticized sulphur cements’ also incorporate small quantities of organic compounds or polymers which increase their resistance to thermal shock.

They have to be applied by special techniques in a molten form. The inherent high shrinkage of these mortars may be minimized by adjustment of the fillers. Sulphur bonded mortars shall not be used at temperatures in excess of 80 °C.

Sulphur bonded mortars have good resistance to water, inorganic acids up to medium strengths and to mild alkalis, like sodium carbonate. They are attacked by even dilute caustic alkalis. A valuable feature is their resistance to hydrofluoric acid and nitric acid up to about 45 percent concentration.

3.2.6 *Resin Bonded Mortars*

Resin bonded mortars are based on synthetic resins in syrup form, inert fillers and hardening agents for the resin. Several types are available based on phenolic, furane, cashewnut shell liquid, polyester and epoxide resins. The chemical resistance of these mortars varies somewhat widely and as they are normally available as proprietary products it is most important that the user discusses his requirements fully with the supplier and also if possible makes tests under working conditions.

In general, many types are resistant to acids, alkalis (including caustic alkalis) and organic compounds. They are, therefore, of great value in many processes and conditions having alternating acid and alkali conditions. Their chief limitation is to oxidizing conditions, such as nitric and chromic acids.

Most resin mortars are rather slow in setting and hardening under cold and cool conditions but with temperatures in the 25 °C to 30 °C range will normally be set and hard within 24 h. During this time they shall be protected with waterproof sheeting. They shall always be applied to clean and dry surfaces as the presence of moisture may prevent complete setting and hardening.

All these types of mortar have a potential health hazard and it is essential that appropriate precautions be taken in their use.

3.3 Compatibility of Corrosion-Resistant Mortars and Protective Membranes

Generally, the majority of corrosion-resistant mortars and protective membranes are compatible and may be placed in direct contact without any significant reaction or damage between the two, but attention is drawn to the following combinations which may require special precautions:

a) Silicate mortar with lead or stainless steel membranes; here it is essential that the silicate mortar is based on halogen free hardening agents;
b) Silicate mortar with glass reinforced polyester laminates used as membranes; here it is essential that the polyester resin used in the laminate has good resistance to caustic alkalis;
c) Phenolic or furan type resin mortars with lead or stainless steel membranes; here it is essential to pre-coat the metal surface with a special primer;

d) Polyester resin mortar with natural or synthetic rubber or plasticized PVC membranes; here there is a possible softening effect of free styrene in the resin mortar on the membranes. This hazard is not very serious as most polyester resin mortars set and harden fairly rapidly.

In all the above cases consultation shall be made with the mortar supplier and the lining contractor and their specific recommendations obtained and implemented.

4 DESIGN OF VESSELS AND EQUIPMENT FOR LINING

4.1 Steel Vessels

4.1.1 Steel vessels lined with corrosion resistant bricks or tiles are used where corrosive or erosive conditions are severe and where such vessels are not ruled out by other considerations. They are rarely used as jacketed vessels, because of the poor thermal conductance of the brick lining. They may also be unsuitable where sudden changes of temperature are involved or where the chemical conditions may be such that no mortar is suitable as in the case of concentrated nitric acid alternating with caustic alkali. The instance in which ceramic linings are technically unsuitable are rare however, and usually the choice between a brick-lined vessel and one lined with another material or made from another material, is governed by cost, weight and reliability; in many cases there is no reasonable alternative.

4.1.2 In general it is recommended that the vessels to be fitted with a corrosion resistant lining shall be of welded construction from carbon steel plates using fusion welded butt-joints wherever possible. The inner weld face shall be ground off flush and smooth in order to ensure that the lining is set tight against the shell as this limits the movement of the lining and thus minimizes the risk of joint cracking because of thermal or other movement.

4.1.3 Wherever possible the shape shall be simple and symmetrical, such as cylindrical with ends either flat, conical or dished and with as large a radius as possible in any corners which occur. Irregular shapes may be lined but will be more difficult and costly.

4.1.4 Vessels shall be fabricated and tested in accordance with recognized standards of good design and practice to suit the operating conditions with the thickness of the shell and ends being adequate to meet the loads imposed by the lining and to meet the required strength under operating pressures and temperatures. For guidance on these requirements reference may be made to IS 2825 and IS 803. Vessels shall be rigid enough to prevent deflection from breaking the brittle jointing material used in linings. Floors may be fully supported.

4.1.5 The drawing of the vessel shall give full details of construction and the method of lining shall also be shown.

4.2 Concrete Constructions

Concrete constructions may be lined with ceramics successfully but it will be clear that if seepage occurs such construction cannot be repaired as simply as a metal vessel (into which a patch can fairly easily be welded).

4.2.1 For this reason the constructions shall conform to IS 3370 (Part 1), IS 3370 (Part 2), IS 3370 (Part 3) and IS 3370 (Part 4). The hydraulic test shall be made before starting to install the lining.

4.2.2 The cement used for the concrete shall as far as possible be chosen to minimize damage to the concrete in the event of the contents accidentally seeping through the lining in service. Nevertheless, since the resistances of hydraulic cement are limited, a suitable protective membrane shall be installed between the lining and the concrete structure. However, where a membrane is installed, no relaxation in the standard of fixing the lining shall be permitted.

5 DESIGN AND INSTALLATION OF LININGS

5.0 General

The consequences of a failure of a brick lining are often serious and high-class workmanship is therefore vitally necessary. The standards required are quite different from ordinary bricklaying standards; careful work is essential using well made bricks of uniform size. Misshapen, undersized, and oversized bricks shall be rejected. Every joint shall be completely filled with mortar and, by buttering and squeezing to eliminate air bubbles, solid joints not thicker than 3 mm shall be produced. When using mortars which flow readily it is sometimes necessary to shore the bricks in position to retain a fair face. When work is continuous, the laying speed shall be controlled to avoid squeezing out the jointing of previous courses.

Proportioning and fixing of the mortars requires care to ensure correct workability and setting; where proprietary mortars are used the manufacturer’s recommendations shall be followed. Account shall be taken of any unusual ambient temperature conditions or dampness, and where necessary, weather protection shall be provided. To meet these requirements, the use of both specially trained fixers and labourers with careful supervision is necessary.

5.2 Protective Membranes

It is advisable in vessel lining to provide a continuous membrane protection applied directly to the metal, concrete or other surface to be lined. This consists of a continuous sheet, as applied or as formed like lead, rubber, asphalt, sheet plastics material or glass reinforced plastics. The membrane behaves effectively as the primary protection, the inner brick lining acting as a protection for the membrane from excessively high temperature, abrasion or other mechanical damage. Protection of the membrane from heat and corrosion is particularly important in ducting carrying hot gases. Nevertheless, every care shall be taken to make the brick lining as perfect as possible. The brick or tile lining shall in any case be designed to have inherent structural stability.

The joints of a membrane lining shall not protrude sufficiently to distort the fair face of the brick lining.

5.2.1 Whatever the material used the membrane shall be held tight against the shell to give firm backing for the brickwork and be carried through branches, over flanges, etc. Trapped air or solvent shall be avoided because of the danger of disruptive forces on the brickwork during subsequent heating.

5.2.2 The same procedures as described in other parts of this code for these materials are adopted for membranes behind brickwork except that thinner layers may be acceptable and a lead lining may be of sheet lead and need not necessarily be homogenous. Where applied in the sheet form the tack welding of the lead to the shell shall be the preferred method to obviate protrusions.

5.3 Choice of Lining Material

The choice of the class of lining material and mortar, the design of the individual lining units and of the lining as a whole depends only on the experience of the user and/or lining contractor having regard to the particular conditions of installation and use.

5.4 Design of Joint between Floor and Wall

The joint between flat floors and walls may be made in one of the following ways:

a) The floor may be laid first right to the shell wall, thus avoiding a continuous vertical joint;
b) The wall may be built first and the floor laid to it, the vertical joint thus being visible for inspection; and
c) A cove may be used to provide the junction between floor and wall, thus avoiding a joint at the most vulnerable point. If coves of the required dimensions are readily available this method of construction is preferred.

5.5 Lining of Floors and Foundations

5.5.1 *General*

The areas in the vicinity of vessels and other equipment handling corrosive fluids are inevitably subject to accidental leaks or spillage. Steps shall therefore be taken to protect foundations, structural members and underground services from damage.

5.5.1.1 The information required by the designer responsible for the work includes knowledge of the permeability of the soil together with analysis of solid and ground water or any fill material which has been used, where corrosive conditions may exist, and an assessment of the origin of such corrosive conditions : plant layout showing layout of floor mounted equipment, drains and other locations where deliberate or accidental discharge of corrosive materials may occur; the chemical composition of such corrosive material together with temperature and rates or likely quantities of continuous or intermittent discharge; proposed methods of floor cleaning like shovelling, washing with hot or cold water, etc.

5.5.1.2 In view of the importance of protecting foundations and structural members the objective wherever possible shall be to achieve inherent resistance to attack rather than surface protection. However, this is frequently not possible in which case a protective system shall be used which provides perfect protection. A small failure may cause serious damage and may be extremely difficult to repair, consequently a practical solution shall be found to even the smallest problem in design detail.

5.5.1.3 In some cases, instead of a-protective system designed to last the full life of the plant, the best engineering solution may lie in the choice of a cheap, easily replaced material. For example, in an area normally uncontaminated there may be a risk of a major acid spillage. A concrete screed over a suitable membrane could be satisfactory provided the overall design, including the drainage system, were capable of resisting such a spillage. The concrete screed could be sacrificed and replaced without damage to any other part of the system. Where this procedure is followed, discussion with the equipment designers is necessary to ensure the facility for subsequent replacement of the screed.

5.5.2 *Foundations*

High quality concrete shall be used for all foundations. It shall be ensured that deterioration of the concrete does not occur which could cause damage to any protective floor covering and lead to more serious damage. Floors shall be sloped to connecting drain channels located clear of main columns, services, etc. The floor slope shall preferably be 1 in 40 but shall not be less than 1 in 60 under any circumstances. Surrounding kerbs shall be high enough to retain any quantities of spillage that are reasonably foreseeable.

5.5.2.1 Drainage of floors shall be by open channels wherever possible to facilitate cleaning; piped drains under such floors being inaccessible shall be kept to a minimum.

5.5.2.2 Where surface protection is provided all concrete pits and drain channels below ground shall be safeguarded against the effects of ground water pressure; this shall be done by tanking or other effective means however shallow the depth.

5.5.2.3 The stability of the concrete base slab is vital to the success of the protective floor surfacing and in cases of doubtful ground stability piling shall not be considered as an unreasonable expense. Where spillage is possible down structural columns or vessel supports, such columns or supports shall be provided with welded skirts to protect the base-plate or foundation plinths.

5.5.3 *Protective Membrane*

As with vessel linings, the membrane interlayer behind brick or tile surfaces (usually polythene, polyisobutylene or plasticized PVC) is to be regarded as the primary protection and the design to be made accordingly; it shall not be treated as a second line of defence. Provision shall be made to ensure freedom of relative movement between the brickwork and the sub floor, thus when palyisobutylene membranes arc used, for example, and stuck dawn to the concrete they shall be covered with a layer of building paper or polythene film to prevent adhesion to the brickwork. In general, it shall be noted that such sticking down is done in order to facilitate construction and is not a primary requirement. Consequently action shall not be taken which might be detrimental to the effectiveness of the complete work merely in order to stick down a membrane, where organic solvents may be present polythene shall be used in preference to either polyisobutylene or plasticized PVC.

5.5.4 *Expansion Joints*

Particular care shall be taken in the construction of expansion joints especially where a protective membrane is used behind brick or tile surfaces. The joint shall not penetrate this membrane as otherwise the whole function of the membrane in providing a liquid tight seal will be lost.

The choice of material for the expansion joint will depend upon the corrosive conditions to be met with and shall be agreed after discussion between the user and the flooring contractor, one of the more suitable being types based on polysulphide synthetic rubbers. The general principles given in **5.5.4.1** and **5.5.4.2** are recommended.

5.5.4.1 *Floors without continuous membranes*

Expansion joints shall be generally provided at the periphery of all areas and this will be the case adjacent to walls and also around columns and other upstands which project through the normal floor surface.

Expansion joints shall also be provided to correspond with any expansion joints in the sub-floor or base. In certain cases, because of the arrangements of the tiling or paviors, this may not be possible but the bond shall be broken as close to the expansion joint as possible by means of strips of building paper in the tiling.

In cases where there is frequent or continuous spillage of hot liquids the above provisions shall be provided and also additional expansion joints shall be provided in the floor surface so as to give bays not larger than 12×12 m.

5.5.4.2 *Flows with continuous membranes*

In general it is, of course, inadvisable to cut through the membrane in order to provide an expansion joint and therefore expansion joints will be confined to the tiling or paving construction. Most of the conventional membranes have some degree of resilience or ‘give’ which will help in itself to provide some measures of expansion joint effect. Expansion joints in the tile or paving floor shall be provided at all periphery areas and around columns and upstands. These will normally be sited one tile course away from the periphery which may often be in the form of a cove. In these cases the membrane will usually be turned up for a short distance around the upstands to give complete protection in these areas.

5.5.5 *Bricks or Tiles*

Cutting of bricks shall be reduced to a minimum not only because this reduces the cost but because the cutting of bricks increases the difficulty of making a good job.

5.5.5.1 Where drain channels are provided the concrete base to the invert shall first be stepped at intervals so as to make the steps equal to the thickness of one brick course. After the membrane has been applied the side-walls are then built with little or no cutting required; sloping screed in suitable corrosion-resistant mortar is laid to form the fall between the steps following which the drain invert is to be laid in plain brickwork.

5.5.5.2 Similarly where kerbs are provided along a sloping floor surface it is unnecessary to cut bricks in order merely to produce horizontal joints in the kerb.

5.5.5.3 Where small items of equipment, such as pumps are installed the brick of the tile lining on the floor shall be carried continuously beneath the plinth, the latter being formed in brickwork alone or concrete protected by brickwork. In many cases timber plinths or bearers may be preferable.

5.5.5.4 Structural steel columns shall be protected by founding the base below floor level and casing the column in concrete 300mm above the floor. The protective system used for the floor shall be carried up this casing.

5.5.6 *Surface Protection*

In some situations surface protection may be provided with epoxide resin self-leveling screed but this has rather limited application and is not suitable for severe corrosive conditions, hot spillage or where cleaning operations, such as shovelling, may cause mechanical damage. A floor which will tolerate somewhat more severe conditions is provided by, an epoxide resin screed sealed with a resin-rich surface to reduce porosity. Where epoxide resin coatings are employed the concrete shall be clean, dry and free from laitence and contamination. The invert and lower walls of drain channels shall always be brick lined to withstand drain cleaning operations.

Where maintenance work or coating of old concrete is necessary it may be preferable to use an epoxide resin ‘membrane’ rather than a sheet membrane.

5.6 Installation of Lining

Though it is possible to go into great detail about methods of lining in a code of practice of this nature only general principles are indicated.

5.6.1 Before lining is commenced the surfaces to be lined shall be thoroughly cleaned and dry; where these surfaces are of ferrous metal they shall be free from loose scale and rust. For outdoor installations a temporary weather protection, for example, waterproof sheeting, may be necessary. It may be necessary in some cases to prime the surfaces to prevent interaction with the mortar. Clarification of this point shall be obtained with the supplier of the mortar.

Where no membrane is used the shell of a vessel or other surface shall, after cleaning and if necessary, priming, be skimmed with mortar and the backs of the bricks well buttered to ensure both a continuous layer behind the lining and good contact between bricks and shell thereby minimizing movements which could cause cracking. With a membrane good contact only is necessary and the initial skimming may be omitted.

5.6.2 Close dimensional tolerances of the bricks or tiles are desirable especially for width and depth. Closer tolerances on a particular dimension may be achieved by sizing the bricks with a sizing machine. They may then be sorted into groups which are all within 1 mm for this dimension. Thin joints may be achieved by using bricks in one group for each course. It is likely that it will be possible to buy bricks ready sized, though at some extra cost. In order to preserve close tolerances, cutting and trimming shall only be done with a brick saw or grinding wheel, not with a hammer and chisel.

5.6.2.1 Tongued and grooved tiles shall be used attention is drawn to the necessity to preserve this beneficial feature, by making certain that the tongue or groove is not chipped, and that-every joint is filled, particularly where closures are inserted. Closures shall be cut so as to maintain the minimum joint thickness specified. Various other forms of interlocking tiles are also available.

5.6.2.2 Some vessels may be most economically lined wholly, or nearly so, using rectangular bricks or tiles of standard sizes which are convenient to handle and are, in general dimensionally accurate. Other shapes and sizes are also used.

5.6.2.3 In some cases it may be impracticable to use standard rectangular shapes, for example, a small diameter vessel is better lined with arch or circle bricks. To avoid unnecessary expense the use of a large number of special shapes, shall, if possible, be avoided; it is nearly always possible to use standard shapes, cutting with a brick saw where necessary unless much cutting is required which may then necessitate purpose-made bricks or tiles.

5.6.3 Bonded brickwork shall be used, and in double linings the joints in the two layers shall not coincide. In laying the floor the pattern shall be such that the minimum of cutting is required at the perimeter (*see* Fig. 1).

5.6.3.1 Closures are a source of weakness in corrosion-resistant brickwork and various schemes have been devised to minimize the number required depending on the type of the tile, size and shape of vessel, etc. Great care is necessary in fitting them to ensure that the joints are well filled. The most satisfactory method is to use a brick cut diagonally into two wedges which may be fitted easily with well filled, tight joints of the thickness specified.

5.6.3.2 The simple arrangement for lining the walls of vertical tanks is to lay separate courses, with continuous horizontal joints. Joints between floor and wall requires only one closure per course (*see* **5.4**). If continuous horizontal joints are thought undesirable because of the possibility erosion of the mortar the bricks are laid in a diagonal pattern, as shown in Fig. 2. Wooden battens are first wedged in place, and bricklaying carried out as in Fig. 2A. When the cement has hardened, the battens are removed, the bricklaying is continued as in Fig. 2B. The remainder of the wall is then lined as in Fig. 2C and 2D, with one wedge-type closure per course. If the vessel is too deep for this procedure, say more than 2 m deep, the top of the first stage may be left with a ‘toothed-edge’ finish, and the second stage built up as before, with closures inserted in the gaps as the work proceeds (*see* Fig. 3). However, working to a toothed edge is undesirable and, if used, only wedge closures shall be employed.

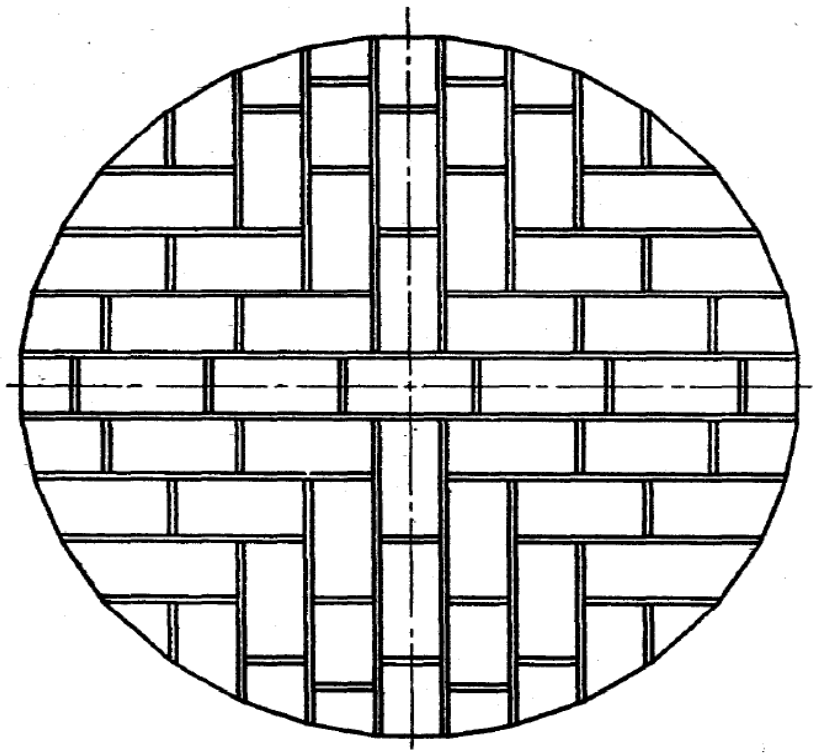

FIG. 1 LINING FOR FLAT BOTTOM USING STANDARD BRICKS OF BLOCKS

5.6.3.3 Branches are the most troublesome part of any brick or tile lining and unless these are properly designed and constructed they are potential sources of leakage. For small branches special lining pieces may be used which are in effect flanged pipes, the flanges being of such shape and thickness that they form part of the vessel lining. Alternatively, a plain stoneware pipe may be cemented into the branch, flush with the lining. For pipes up to 150 mm diameter a special large tile with a hole to fit the pipe may be fitted; for large diameter openings circle or arch bricks shall be used.

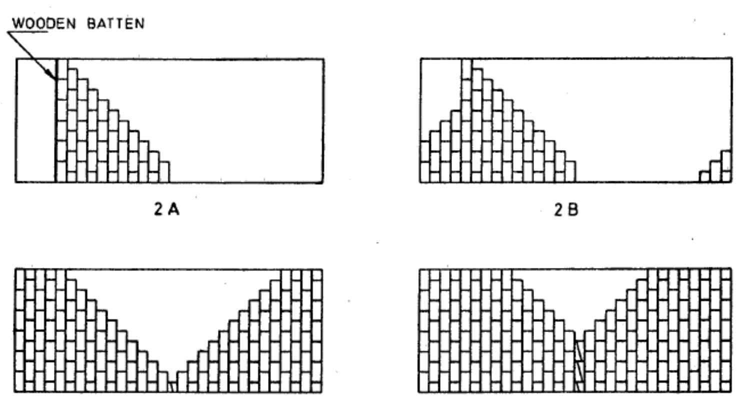

FIG. 2 ORDER OF LAYING FOR VERITCAL WALLS IN FLAT BOTTOMED VESSELS OF DEPTH LESS THAN 2.0 m USING STANDARD BRICKS

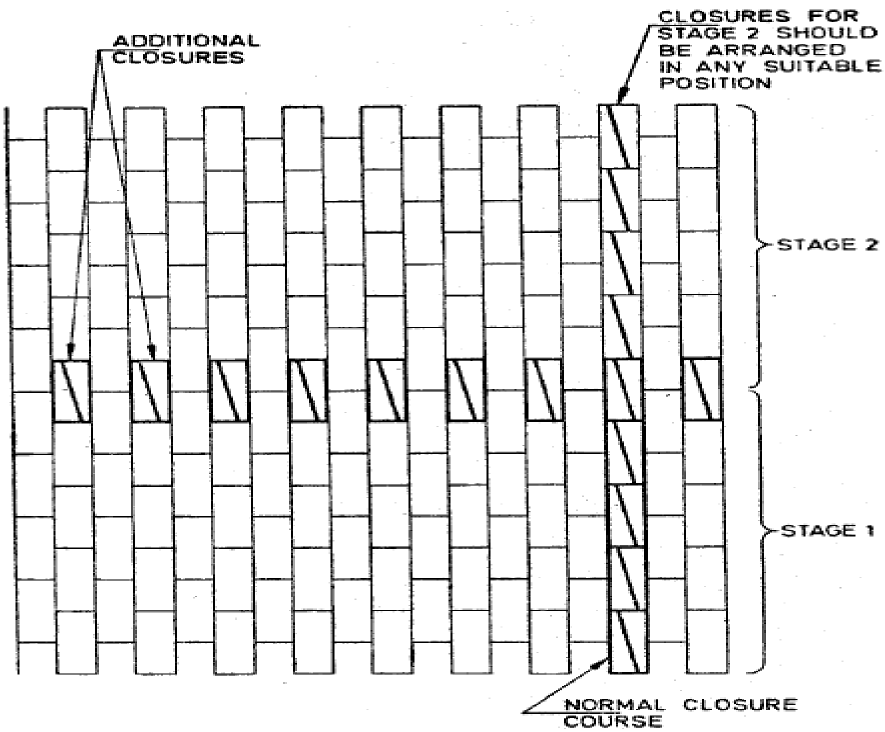

FIG. 3 ORDER OF LYING FOR VERICAL WALLS IN FLAT BOTTOMED VESSELS OF DEPTH GREATER THAN 2.0 m USING STANDARD BRICKS (TOOTHED EDGE ARRANGEMENT)

5.6.3.4 It shall be noted that unless the stoneware pipe is held rigidly in position, excessive pressure from the outside may force it and the adjoining tiles inwards. The pipe itself may be made with a conical end which bears against the end of the branch; it is pressed home and ground of flush and cannot be forced inwards. Fig. 4A, 4B and 4C show some typical arrangements, that in Fig. 4C generally gives the soundest construction. Plastics or special metal linings may be used in branches, in which case the lining shall be flanged, the flange being adjacent to the flange of the branch.

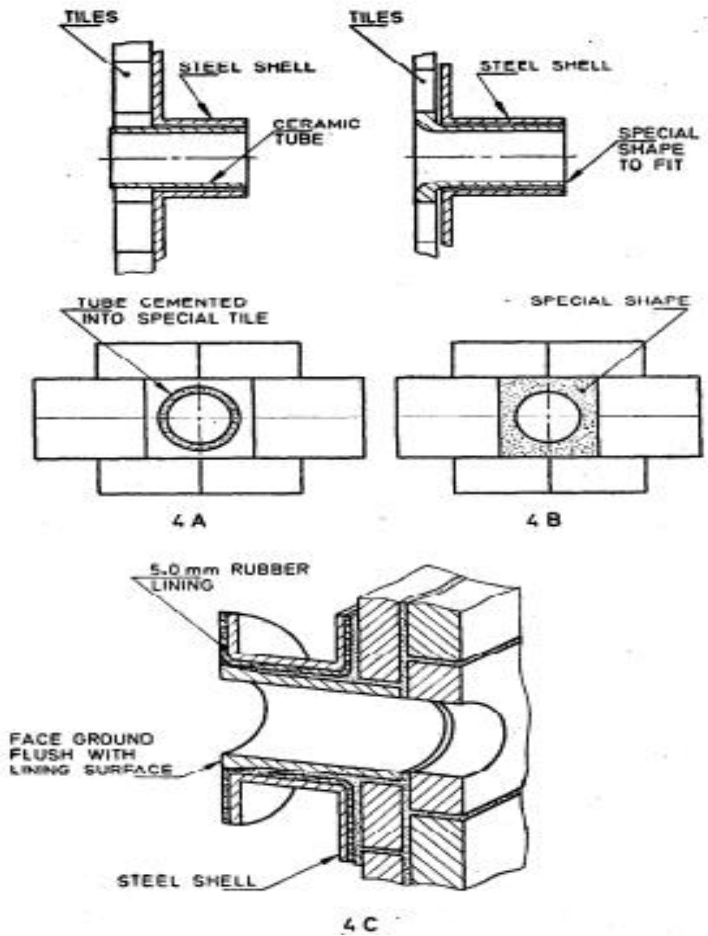

Fig. 4 ARRANGEMENT OF BRANCHES IN LINING

5.7 Prestressed Ceramic Linings

5.7.1 Prestressed ceramic linings are limited to lining for cylindrically shaped mild steel vessels and similar equipment, but the vessels may have domes or coned ends.

5.7.1.1 By means of the prestressing technique a major limitation of ceramic linings to steel vessels can be overcome. The coefficient of thermal expansion of most ceramic linings is about half that of mild steel. As a result, with the use of liquids at elevated temperatures, there is a tendency for the steel shell or outer to expand to a greater degree than the inner ceramic lining, in spite of some temperature drop through the thickness of the lining. There is thus a tendency for the steel shell to move outward from the ceramic lining and subject the latter to tensile stresses. Cracks may then develop (usually in the joints) or gaps may form behind the lining and allow the liquid in the tank to reach the steel outer shell.

5.7.1.2 Attempts shall be made to minimize this difficulty by increasing the thickness of the ceramic lining and so increasing the temperature drop though the lining. Whilst this may be of help it does not completely solve the problem in all cases and the costs are very considerably increased.

5.7.2 Special corrosion resistant mortars are available which have the property of swelling slightly under suitable heat treatment without diminishing their adhesion to the ceramic units used for the lining of, or to the steel outer shell of, the vessel; their use results in a prestressed lining. This puts the steel shell in tension whilst the ceramic lining is in compression.

Ceramic linings withstand compressive stresses well. The prestressing operation is carried out by filling the lined vessel with a liquid and slowly bringing the temperature and pressure up to a designed excess over the maximum proposed working temperature and pressure. These conditions are held for some hours and then the vessel is allowed to cool down very slowly to the normal ambient conditions. After this treatment the ceramic lining will remain permanently in compression provided the prestressing temperature and/or pressure is not exceeded. It is necessary that the prestressing operation is carried out within a few weeks of the installation of the lining as after this period of time the swelling property of the mortar is lost.

5.7.3 Owing to the calculations that are necessary for the successful installation of a prestressed lining the use of such a lining shall only be made after full consultation with the designer. The joints in such a lining may be significantly wider than that recommended in 4.1.

6 SUPERVISION, TESTING, INSPECTION AND REPAIR

6.1 Supervision, Testing and Inspection

It is not easy to apply any test to ceramic linings. The only satisfactory method of ensuring a sound job is to have experienced supervision during erection, to see that the mortar is correctly mixed, that the technique is correct and that joints are of the correct width and are properly filled. Attention shall also be paid to the following:

a) Brick cutting shall be done by a saw and not by hand;
b) Mortars shall not be re-tempered once they have started to set, and
c) For most mortars the bricks shall be completely dry before and after laying until the mortar has hardened.

6.1.1 These and similar points shall be watched by an inspector, but once the work is completed there is no easy way testing the structure.

6.1.2 Provision shall be made for the work to be accepted or rejected stage by stage before the mortar hardens to such an extent that removal of unsatisfactory work may cause damage.

6.2 Repair

If a failure occurs in a ceramic lining, as shown either by examination of the lining, or more usually by attack on the shell, it is always tempting to carry out a local repair. This may sometimes be done by forcing in an appropriate mortal or by repointing, and this may be successful temporarily.

It is often found, however, that unless the fault may be clearly seen the repair is ineffective. Penetration of the shell may occur far away from the origin of the fault, the liquor having flowed between the shell and the lining to accumulate further down. Moreover, the cutting out of the lining may, unless very carefully done, start cracks in the adjacent sound lining. It may be found to be quicker and cheaper in the long run to replace the entire lining at the earliest opportunity, and at the same time to make the shell completely sound by replacing holed or badly thinned areas. However, when patching is necessary, the area to be patched shall be cut out using a diamond saw to minimize disturbance.

Most corrosion-resistant mortars will not harden in contact with wet ceramic and any acid present on the surface may cause flash setting. If an attempt is made to repair a lining, great care is, therefore, necessary to ensure that the surrounding surfaces are clear and dry. They may be well washed with water and then dried by a blast of hot air. The mortar shall then be applied immediately, preferably using a cement modified to give quick setting. In this way a successful repair may be possible, provided the lining left in place is sound.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
IS 803 : 1976	Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks (first revision)
IS 2041 : 2024	Steel plates and strips for pressure vessels used at moderate and low temperature — Specification (fourth revision)
IS 2825 : 1969	Code for unfired pressure vessels
IS 2839 : 1964	Specification for industrial stoneware
IS 3370 (Part 1) :2021	Concrete Structures for Retaining Aqueous Liquids - Code of Practice : Part 1 General Requirements (Second Revision)
IS 3370 (Part 2) : 2021	Concrete Structures for Retaining Aqueous Liquids - Code of Practice : Part 2 Plain and Reinforced Concrete (Second Revision)
IS 3370 (Part 3) :2021	Concrete Structures for Retaining Aqueous Liquids - Code of Practice : Part 3 Prestressed Concrete (First Revision)
IS 3370 (Part 4/Sec 1) : 2021	Concrete Structures for Retaining Aqueous Liquids - Code of Practice: Part 4 Design Tables: Section 1 Plates (First Revision)
IS 3370 (Part 4/Sec 2) : 2021	Concrete Structures for Retaining Aqueous Liquids - Code of Practice: Part 4 Design Tables: Section 2 Rectangular tanks (First Revision)
IS 3370 (Part 4/Sec 3) : 2021	Concrete Structures for Retaining Aqueous Liquids - Code of Practice: Part 4 Design Tables: Section 3 Circular tanks (First Revision)

IS 4860 : 1968	Specification for acid - Resistant bricks

Annex B

(*Foreword*)

EXCHANGE OF INFORMATION

B-1 Early consultation and exchange of information shall take place between the lining contractor and all parties concerned in the design, manufacture, erection and use of the vessels and equipment to be lined. Complete and accurate scale drawings shall be made available to all parties concerned.

The consultation shall cover the following:

a) Site conditions, which affect this work, including, location on site and weight of the lined vessel;
b) Safety measures to be taken during lining on site;
c) Construction of equipment to be lined, location of welds, type and finish of joints and internal and external supports, general method of lining with regard to structural stability;
d) Nature and concentration of media for which vessel and equipment is required;
e) Apparent porosity and acid solubility of lining material;
f) Operating temperatures and pressures;
g) Other factors influencing material stress;
h) Presence of abrasives in contents and potential local erosion by fluids; and
j) Internal or external installations and means of access, lifting facilities, etc.