IS 9527-6 (1989): Code of practice for design and construction of port and harbour structures, Part 6: Block work [CED 47: Ports and Harbours]

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IS 9527 (Part 6) : 1989
(Reaffirmed 2005)

Indian Standard

DESIGN AND CONSTRUCTION OF PORT AND HARBOUR STRUCTURES — CODE OF PRACTICE

PART 6 BLOCK WORK

भारतीय मानक

पत्तन तथा बंदरगाह संरचना में डिजाइन तथा निर्माण – रीति संहिता

भाग 6 खंड कार्य

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FOREWORD

This Indian Standard (Part 6) was adopted by the Bureau of Indian Standards on 22 September 1989, after the draft finalized by the Ports and Harbours Sectional Committee had been approved by the Civil Engineering Division Council.

In order to assist the design and construction engineers in the field of ports and harbours, the Committee has initiated formulation of Indian Standards covering various aspects of design and construction of ports and harbours. The following are the different parts of the standard proposed to be published out of which Part 1, Part 3 and Part 4 have already been published.

IS 9527 Code of practice for design and construction of port and harbour structures :

Part 1 Concrete monoliths

Part 2 Caissons

Part 3 Sheet pile walls

Part 4 Circular steel pile structures

Part 5 Open pile structure

Part 6 Block work

Part 6 of the standard in the series deals with the criteria for design and construction of block work used in ports and harbour construction. Block work wharf is a gravity structure formed with square or rectangular block of concrete cast on land with or without reinforcement and transported to point of construction to place it in position.

In the formulation of this standard due weightage has been given to international coordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical value (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DESIGN AND CONSTRUCTION OF PORT AND HARBOUR STRUCTURES — CODE OF PRACTICE

PART 6 BLOCK WORK

1 SCOPE

1.1 This standard (Part 6) deals with materials, criteria for design, stability and durability checks, construction procedure and relevant informations of the construction of wharf wall using precast concrete blocks, with particular reference to port and harbour structures.

2 REFERENCES

2.1 The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

3.1 For the purpose of this standard, the definitions as given in IS 2809 : 1972 and IS 7314 : 1974 shall apply, in addition to the following.

3.2 Bed Preparation

Formation of bed (levelling-course) with quarry run and metal to the required width, thickness, levels and gradient along the alignment of wharf wall to facilitate placement of blocks. Concrete can also be used as bedding material.

3.3 Block

Block refers to square or rectangular or any special shape precast cement concrete blocks of different sizes and weights with or without pockets or holes.

3.4 Block, Abutment

To restrict creep, the length of wharf wall usually is divided into smaller reaches, constructing, abutments normally at the end of each berth, thus forming strong points in the stretch of wharf wall. The blocks forming the abutment cast specially for the purpose shall be placed vertically.

3.5 Cellular block is usually a rectangular block with or without bottom. It may be caisson type, H shaped or I shaped depending upon the design selected.

3.6 Back fill

When the wharf wall construction is taken offshore it generally accompanies by a backfill on the rear side mostly done using the dredged materials or land materials like sand. The wharf area comprising structures like transit sheds, stack yards, etc, is developed over the backfill after allowing for sufficient consolidation.

3.7 Block, Interlocking

The interlocking block is the one cast with tongues and grooves and tenons and mortices to provide interlocking in all the three directions.

3.8 Block Launching

Lifting and placing of blocks one over the other in a contiguous fashion vertical or slanting, using a crane or any other rig with the assistance of divers to form the wharf wall to the predetermined section.

3.9 Block, Slice

One of the plane rectangular blocks, placed one over the other in a slanting fashion with inclined faces and is capable of settling independently.

3.10 Block Turning

Blocks specially cast and placed in turning portions of wharf wall with chamfered faces to effect turning of the wharf wall.

3.11 Capping Concrete

The *in-situ* mass concrete portion of wharf wall above block level to crest level, accommodating bollards, fenders and other wharf fixtures and housing service gallery through it.

3.12 Casting Yard

A paved surface of sufficient area capable of withstanding the weight of the machines for lifting and conveying the heavy block, generally provided in shore with water supply and electrical connections to facilitate casting and curing of concrete block till its transport for launching.

3.13 Filter System

The interface on the rearside of wharf wall and the backfill is to be provided with suitable graded filter media to perform the dual function of preventing the migration of backfill particles through the dry joints of the block work and at the same time allowing free drainage of water.

3.14 Foundation Dredging

Removal of material underwater from the sea bed to the predetermined width and depth along the alignment of wharf wall by dragging, digging, sucking or grabbing with or without submarine blasting depending on the nature of sea bed.

3.15 Lifting Gear

Device to be coupled with the hook of the launching crane to facilitate lifting, manoeuvring and placing of blocks.

3.16 Wharf Wall

Wharf wall is a berth structure which provides a vertical surface from the cope of sea bed along the face of the wharf, generally referring to the gravity construction, which receives the wharf fixtures namely, bollards, fenders, track fixtures of cargo handling equipments, and houses the service gallery and ducts (*see* Fig. 1).

4 SYMBOLS

4.1 For the purpose of this standard, the following letter symbols shall have the meaning indicated against each; where other symbols are used they are explained at the appropriate place :

A = bottom area of wall,
B = width of wall at bottom,
e = eccentricity,
F = factor of safety,
H = overall height of wall,
k_A = coefficient of active earth pressure,
$(k_A)_d$ = coefficient of active earth pressure in dry fill,
$(k_A)_s$ = coefficient of active earth pressure in submerged fill,
M = bending moment,
P = bollard pull/mooring pull,
q = intensity of live load surcharge,
W = weight of wall,
Z = modulus of section,
γ = bulk unit weight of soil,
γ' = submerged unit weight of soil,
c = density of concrete in air,
c' = density of concrete in sea water,
s = saturated unit weight of soil,
w = unit weight of sea water,
δ = angle of wall friction,
ϕ = angle of internal friction of fill material,
ϕ_d = angle of internal friction of dry fill,
ϕ_s = angle of internal friction of submerged fill, and
μ = coefficient of static friction.

5 MATERIALS

5.1 Block work shall consist of concrete blocks with or without reinforcement.

5.2 The material used for casting concrete blocks shall be in accordance with IS 456 : 1978. The concrete blocks placed in tidal range or completely immersed in sea water are subject to the attack by the harmful chemicals present in sea water penetrating into the concrete. Care shall be taken to cast concrete blocks impermeable to

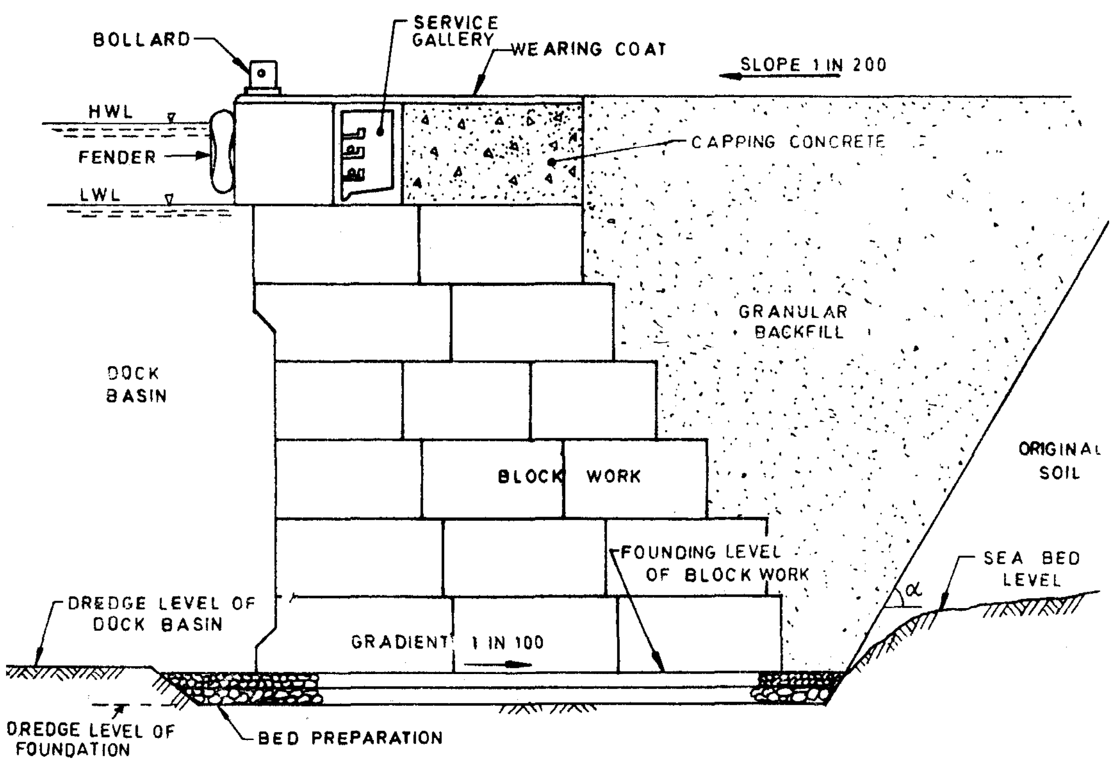


FIG. 1 TYPICAL SECTION OF BLOCK WORK WHARF

such a degree that it is not penetrated by constituents of sea water. Stronger, denser and impervious concrete with selected water cement ratio around 0·50 will give high degree of durability under marine environments.

5.3 The cement used for casting concrete blocks shall be in accordance with **7.33** of IS 4651 (Part 4) : 1989.

5.4 The steel used for reinforcement shall be in accordance with IS 432 : 1982 and IS 1786 : 1985.

5.5 Cover to reinforcement shall be in accordance with **7.3.5** of IS 4651 (Part 4) : 1989.

6 SELECTION

6.1 Block work wharf wall is a gravity structure formed with solid or cellular pre-cast concrete blocks conveyed to the point of construction and placed in position on a prepared rubble bed (levelling course). Blocks are to be so shaped and placed that they will not be damaged while transportation and placing.

6.2 Selection of the size and shape of the block shall depend on methodology of construction and type of equipment available for the handling, transportation and launching of blocks.

6.3 Block work is generally adopted where load bearing soil is present at founding level.

7 TYPES OF BLOCK WORK

7.0 Basically there are four types of block work.

7.1 Block Works with Interlocking Blocks

The blocks shall have tongues and grooves and mortices and tenons to break joints both in vertical and horizontal planes.

7.2 Block Works with Slice Blocks

The blocks shall be square or rectangular with plane surfaces. The arrangement of blocks in layers shall be in a slanting pattern, normally in 1 : 4 slope to break joints and ease in construction.

7.3 Block Works with Cellular Blocks

In this type the cellular blocks of concrete are cast conveyed to point of construction, backfilled and arranged in several layers to form the wall.

7.4 Block Work with Hollow Blocks

In this block work hollow blocks are placed which are subsequently filled with concrete by tremie or other materials.

8 NECESSARY INFORMATION

8.1 For the satisfactory design and construction of block work wharf wall the informations given in **8.2** to **8.8** are necessary.

8.2 Site Investigation Data

As laid down in IS 4651 (Part 1) ; 1974.

8.3 Dredged Level

The level to which the sea bed of the dock basin is maintained to berth the ships.

8.4 Bottom Level of Wharf Wall

In case of gravity construction this refers to the foundation level.

8.5 Backfill Characteristics

8.5.1 *Dry Fill Density*

Unit weight of backfill above highest high water level, after consolidation.

8.5.2 *Submerged Fill Density*

Unit weight of backfill below highest high water level, after consolidation.

8.5.3 *Angle of Internal Friction*

8.6 Sea Water Characteristics

8.6.1 *Density*

The unit weight of sea water based on salinity conditions shall be taken in the pressure calculations on the wharf wall.

8.6.2 *Chemical Analysis*

Information about the chemical substances present in sea water is necessary for the selection of cement.

8.7 Concrete Characteristics

In case of concrete blocks, the unit weight of concrete in air and in sea water shall be taken into account in the stability calculations of the gravity wall.

8.8 In addition to the topographical survey, the controlling dimensions shall be included in the general information. The controlling dimensions are the elevation of top of wharf wall, top level of top course of blocks, the highest water level, low water level and tidal variation dredge level and foundation level [*see* Fig. 3 of IS 4651 (Part 1) : 1974].

9 LOADS AND FORCES

9.1 In the design of the block work wharf wall, account shall be taken of the following types of loads and forces:

a) Dead loads;

b) Live loads;

c) Lateral earth pressure;

d) Differential water pressure;

e) Berthing loads;

f) Mooring loads;

g) Earthquake forces; and

h) Forces due to winds, waves and currents.

9.2 The loads and forces shall be calculated as given in **9.2.1** to **9.2.7**.

9.2.1 *Dead Loads*

The dead weight of the wall shall be calculated considering the wall portion as the portion in front of the vertical plane passing through the rear toe of the wall (*see* Fig. 2).

9.2.1.1 Buoyancy shall be considered in calculating the dead weight by considering the dry and submerged weights of both fill and the wall (*see* Fig. 3).

9.2.2 *Live Loads*

The vertical live loads, surcharged loads and the point loads shall be taken in accordance with IS 4651 (Part 3) : 1974.

9.2.2.1 The surcharge loads shall be considered as acting on the fill only and not on the crest of wharf wall for the worst conditions.

9.2.3 *Earth Pressure*

For calculating the lateral earth pressure on the wall and that due to surcharge loads IS 4651 (Part 2) : 1969 shall be referred to.

9.2.3.1 In case of block work wharf wall with quarry rubbish filter on the rearside, the presence of such filter media relieves certain amount of earth pressure on the wharf wall. However, this may not be considered in the pressure calculations on the conservative side.

9.2.4 *Differential Water Pressure*

Where a tidal lag is expected, the differential water pressure shall be calculated in accordance with **5.4** of IS 4651 (Part 3) : 1974.

9.2.5 *Berthing Load and Mooring Loads*

Berthing load and mooring loads shall be taken

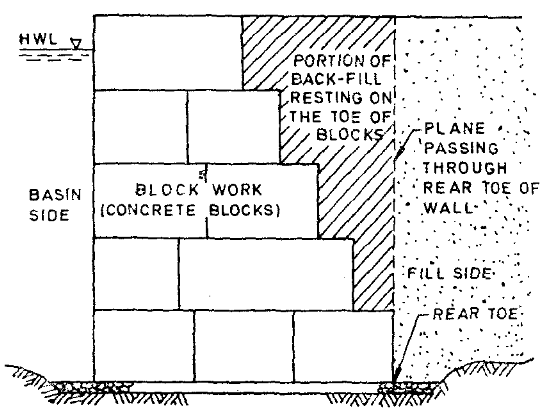


FIG. 2 WALL OF CONCRETE BLOCK TYPE

in accordance with **5.2** and **5.3** of IS 4651 (Part 3) : 1974.

9.2.6 *Earthquake Forces*

Earthquake forces shall be calculated in accordance with **5.5** of IS 4651 (Part 3) : 1974. The seismic coefficient shall be taken in accordance with IS 1893 : 1984.

9.2.7 *Environmental Forces*

Forces due to winds, waves and currents shall be taken in accordance with IS 4651 (Part 3): 1974. Waves in the harbours are small in height and pressures exerted by them add to the stability of a gravity structure and these may be ignored.

9.3 The combination of loads and forces shall be in accordance with IS 4651 (Part 4) : 1989.

10 DESIGN

10.1 Design Criteria

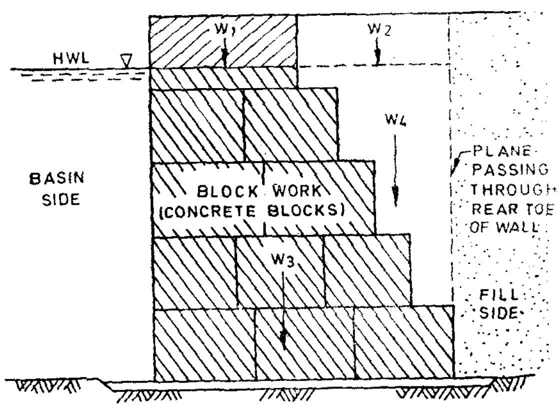
Like any other gravity construction, the criteria for design of block work wharf shall be as follows:

a) The base width of the wall shall be such that the maximum pressure exerted on the foundation does not exceed the safe bearing capacity of the strata;

b) No tension develops anywhere in the cross section of the wall at any level;

c) The wall shall be safe against sliding. Factor of safety against sliding shall be not less than 1·5.

d) The wall shall be safe against overturning. Factor of safety against overturning shall be not less than 1·5 when dead load, live load and earth pressures are considered together with seismic forces, when dead load, live load and earth pressure only are considered, the factor of safety shall be not less than 2; and



Total self weight : $W = W_1 + W_2 + W_3 + W_4$

W_1 — Dry weight of block work above HWL

W_2 — Dry weight of backfill resting on toe of block work above HWL

W_3 — Submerged weight of block work below HWL

W_4 — Submerged weight of backfill resting on toe of block work below HWL

FIG. 3 COMPUTATION OF SELF WEIGHT

e) In the cases, where wall is founded on stiff clay, there are chances of slip of underlying strata as a unit. The wall should be safe against such slip. Factor of safety shall be not less than 1·5 in such cases.

10.2 The design shall be made according to the following sequence:

a) Determination of design conditions,
b) Determination of dimensions and shapes of blocks,
c) Assumption of wall dimensions,
d) Calculation of external loads and forces,
e) Examination of sliding of wall,
f) Examination of overturning of wall,
g) Examination of bearing capacity of foundation,
h) Determination of wall dimensions, and
j) Detailed design.

10.2.1 The design parameters shall be arrived at from the detailed site investigations; laboratory tests and analysis of samples shall be undertaken to assess the factors mentioned in this standard and to determine the design conditions.

10.2.2 The shape and dimensions of the concrete blocks shall be determined by considering the following aspects:

a) Capacity of facilities for casting concrete blocks;
b) Hoisting capabilities of the lifting and launching cranes;
c) Transporting capabilities of tractor, trailers and trucks;
d) Height of wall;
e) Tidal range;
f) Elevation of coping;
g) Solidification of blocks when they are piled in stages;
h) Breaking of vertical and horizontal joints; and
j) Site conditions.

10.2.3 The wall dimensions shall be assumed in the following lines.

10.2.3.1 *Base width*

Base width of the block wall shall be assumed as narrow as possible for economy, yet sufficiently wide for stability against overturning. The base width shall also be sufficient to keep the soil pressure within the safe permissible limits. With fairly heavy surcharge over the backfill, the base width may be assumed between 0·8 to 0·9 of the overall height of the wall measured between the foundation level and the top level of capping concrete.

10.2.3.2 *Overall height*

The height of the block wall shall be chosen such that the top level of the top course of block work is slightly above the high water level to facilitate shuttering works for *in-situ* capping concrete.

10.2.3.3 *Top width*

The top width of the block work shall be chosen to accommodate the capping concrete, the width of which is controlled by factors like operational requirements, minimum clearance of bollards from the wharf edge, space for accommodating tracks for wharf cranes, rail tracks, lane widths, and service gallery.

10.2.4 *Check Against Sliding of Wall*

The tendency of earth pressure is to slide the wall. It is resisted by the friction developed between the bottom of the wall and the foundation below. The safety factor against sliding of wall shall satisfy.

$$F = \frac{R_W \times \mu}{R_H}$$

where

R_W = resultant vertical forces acting on the wall including self weight (*see* **10.2.4.2**),

R_H = resultant horizontal forces acting on the wall (*see* **10.2.4.3**),

μ = coefficient of friction between bottom of the wall and the foundation (*see* **10.2.4.4**), and

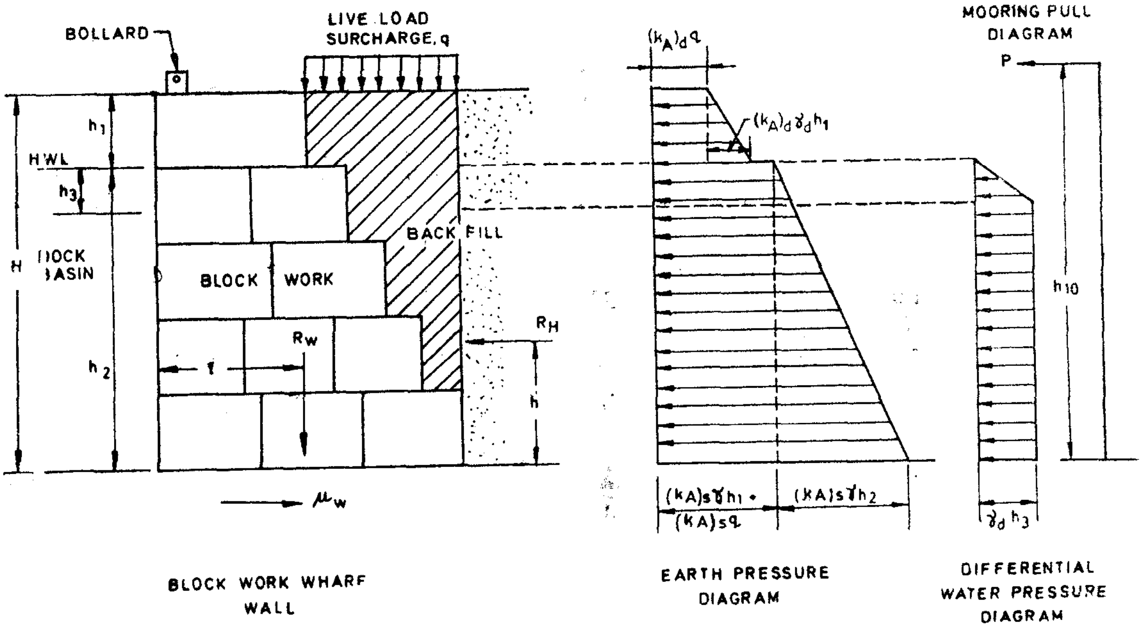
F = safety factor (*see* **10**).

10.2.4.1 Each horizontal joint of the block work shall be checked against sliding considering the respective vertical and horizontal forces at the joint, to ensure stability of wall against sliding in total. This is essential because in some cases the block wall as a whole may be safe but it may not be so in different layers.

10.2.4.2 The resultant of vertical forces shall be the weight of the wall portion excluding the surcharge in front of the plane passing through the rear toe of the wall at the examining level with buoyancy subtracted (*see* Fig. 4). Furthermore, the vertical component of earth pressure if any acting on the plane shall be added.

10.2.4.3 The resultant of horizontal forces shall include the following:

a) Horizontal component of earth pressure acting on the rear plane of the wall portion under consideration with surcharge applied;
b) Differential water pressure;
c) In stability calculation during earthquake, the seismic force derived from the weight of the wall with no buoyancy subtracted shall be considered, in addition to the above (a) and (b). The earth pressure shall be horizontal component of earth pressure during earthquake; and
d) Mooring pull.



NOTE — R_H — Resultant of horizontal forces with surcharge applied

R_W — Resultant of vertical forces excluding surcharge acting on 'wall' portion

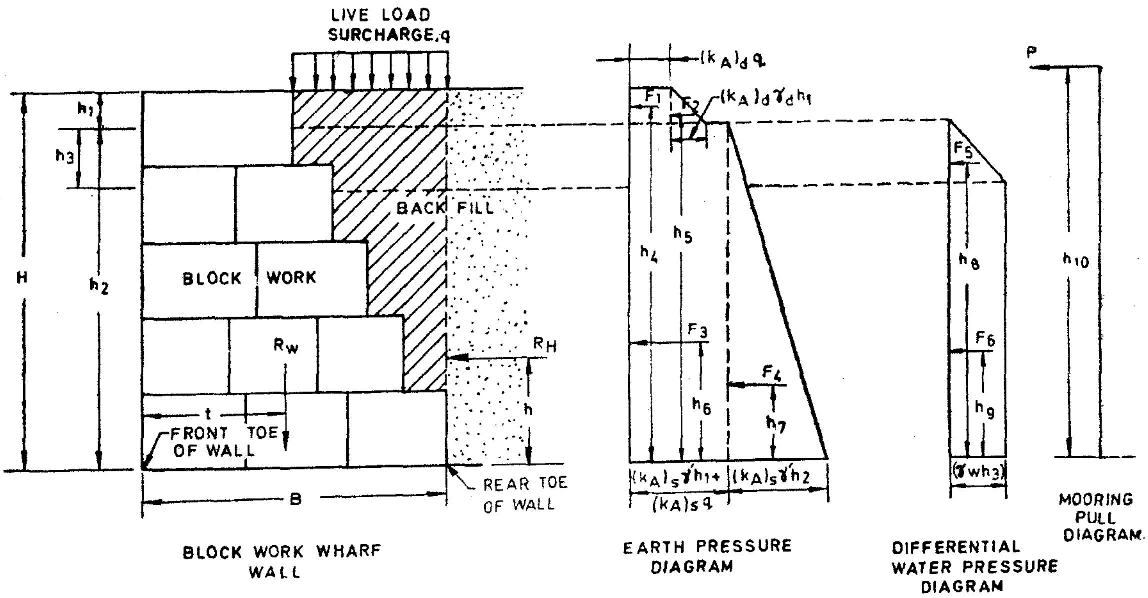
W — Total weight of wall

μ_W — Frictional resistance against sliding

$(k_A)_d$, $(k_A)_s$ — The coefficients of active earth pressure shall be calculated adopting the respective angles of internal friction in dry and submerged conditions

P — Bollard pull metre length $= \dfrac{\text{Design bollard pull}}{\text{Spacing of bollards}}$

FIG. 4 CHECK AGAINST SLIDING OF WALL



NOTE — R_H — Resultant of horizontal forces F_1 to F_6 and P

h — Lever arm of R_H about the front toe of wall

h_4 to h_{10} — Lever arm of horizontal forces about the front toe of wall

R_W — Resultant of vertical forces excluding surcharge effect on wall

t — Lever arm of R_W about the front toe of wall

FIG. 5 CHECK AGAINST OVERTURNING OF WALL

10.2.4.4 For the coefficients of static friction used in stability calculation against sliding, the values given in Table 1 shall be used generally.

Table 1 Coefficients of Static Friction (Under Submerged Condition)

Surface Condition	Coefficients of Friction
i) Concrete against concrete	0·60
ii) Concrete against robble	0·65
iii) Concrete against the bed rock	0·70-80·0*
iv) Concrete against sand	0·45

*Under the standard condition the value should be 0·8 when the bed rock is brittle or includes cracks, or when the sand movement over the bed rock is intensive, the value of coefficient is to be reduced to about 0·7 depending on such condition.

10.2.5 *Check Against Overturning of Wall*

To ensure safety against overturning the safety factor against overturning of wall shall satisfy the following (*see* Fig. 5)

$$F = \frac{R_W \,.\, t}{R_H \,.\, h}$$

where

R_W = resultant of vertical forces acting on the wall;

R_H = resultant of horizontal forces acting on the wall;

t = distance from the application line of the resultant of the vertical forces to the toe of the wall; and

h = height from the application line of the resultant of the horizontal forces acting on the wall, to the bottom of the wall; and

F = safety factor (*see* **10.1**).

10.2.6 *Check Against Maximum Pressure on Strata*

The maximum and minimum pressures on the base of the wall shall be calculated from the formula:

$$P = \frac{R_W}{B}\left(1 \pm \frac{M}{Z}\right)$$

where

P = intensity of pressure of the extreme point of the base,

R_W = weight of the wall per unit length;

B = base width of the wall,

M = resultant moment on unit length of the wall, and

Z = section modulus of unit length of the wall.

The maximum pressure shall not exceed the safe bearing capacity of the strata. Where block wall is resting on rubble or metal mattress, it shall be safe against toe pressure. The toe pressure shall not exceed, 0.4 MPa. The base pressure diagram is shown in Fig. 6.

NOTE — The resultant of the forces shall pass through the middle third of the section.

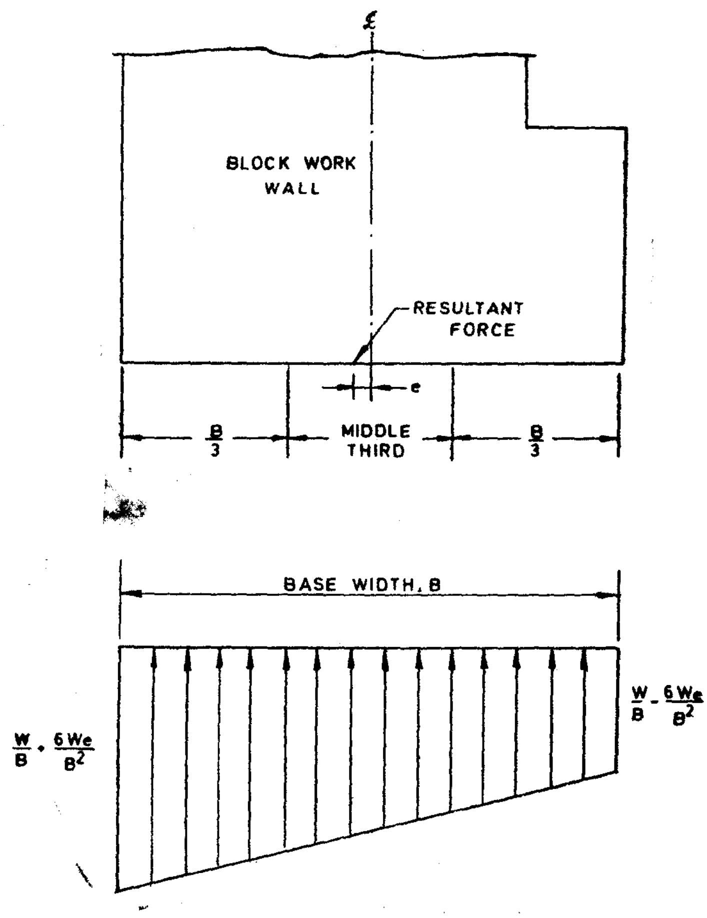


FIG. 6 BASE PRESSURE DIAGRAM

10.3 Effect of Backfill

10.3.1 When the backfill of good quality is used for a blockwork wharf-wall, the wall can be designed by considering the effect of the backfill (*see* Fig. 7).

10.3.2 Effect of earth pressure reduction by backfill material shall be considered as given in **10.3.2.1** and **10.3.2.2**.

10.3.2.1 *When the cross-section of backfill is triangular*

When backfilling is made in triangular shape, which keeps an angle of slope at the intersection between the vertical line passing through the heel of the wall and the ground surface, equal to the angle of repose of the backfill material (*see* Fig. 7A), it may be assumed that all the back of the wall is filled with the same material as the backfill material.

When the reclaiming material is cohesive soil, it should be considered for filling up of sand leak protecting cloth to the surface of the backfill in order that the cohesive soil may not pass through the void of the backfill and does not reach the wall.

10.3.2.2 *When the cross section of backfill is rectangular*

In case of triangular shape backfill with a slope steeper than the angle of repose of the backfill material or any other irregular backfill, the effect should be considered as in the case of rectangular shape backfill which has an equivalent area to the backfill in question.

The effect of the rectangular shape backfill (*see* Fig. 7B) should be considered as follows:

When the width '*b*' of the rectangular shape backfill is larger than the height of the wall, consideration can be made as in the case of triangular backfill (*see* Fig. 7A) and when the width '*b*' is equal to half the height it shall be assumed that mean earth pressure due to the backfill material and the earth pressure due to the reclaimed soil acts on the wall. When the width '*b*' is 1/5th or

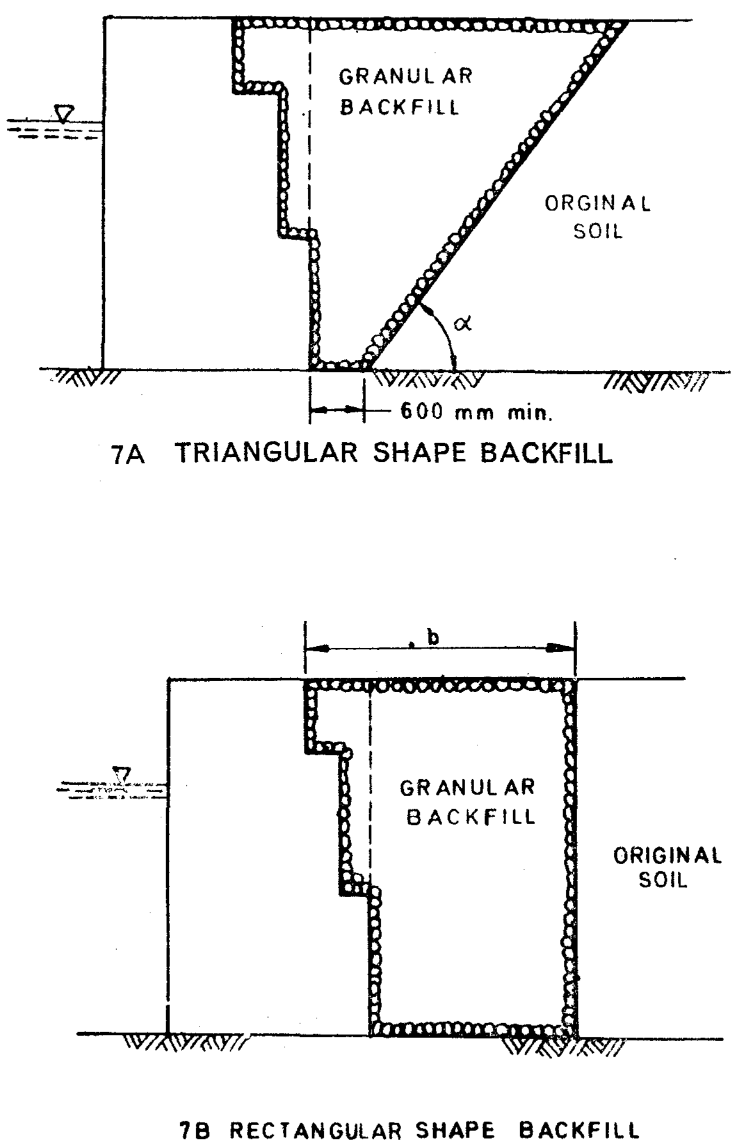


FIG. 7 SHAPES OF BACKFILL

less of the height of the wall, the earth pressure reduction effect due to the backfill should not be considered.

10.4 Detailed Design

The detailed design of a block work wharf wall shall be made for the following:

a) Strength of blocks,

b) Shape and dimensions of key and lifting holes of concrete blocks,

c) Lifting gear for handling blocks,

d) Service galleries and ducts : Design of side walls and roof slab, and

e) Pipe bollards.

10.5 Design of Fender System

The provision and design of suitable fender system shall be as per **9** of IS 4651 (Part 4) : 1989. The design of fender systems such as rubber and pneumatic shall be made generally according to the following sequence:

a) Determination of the ships to be berthed and berthing velocity;

b) Arrangement/disposition of fenders;

c) Calculation of effective berthing energy;

d) Provisional determination of the type and form of fenders;

e) Calculation of enery absorption, reaction force and deflection of the fender; and

f) Determination of the fender.

10.5.1 *Arrangement of Fenders*

The fenders shall be installed as for a continuous quay and so arranged that the ship does not come into direct contact with the wharf before the fenders absorb the specified berthing energy of the ship. Normally they shall be installed either vertically, horizontally, diagonally or in a T-shape with or without chain supports.

10.5.2 *Effective Berthing Energy*

The effective berthing energy shall be calculated in accordance with **5.2** of IS 4651 (Part 3) : 1974.

10.5.3 *Selection of Fenders*

In the selection of rubber and pneumatic fenders the following shall be considered:

a) The berthing force shall be within the allowable load for the wharf; and

b) For the wharf which is subjected to the influence of waves or used by small crafts as well, fenders with high resistance against shearing shall be used.

11 CONSTRUCTION

11.1 Casting of Blocks

11.1.1 A paved surface of sufficient area to accommodate the blocks to be cast in a month shall be got ready before the commencement of casting of blocks. The casting yard shall have areas for collection and stacking of materials, cement godowns, water tanks and work areas for mixers and labour gangs apart from the actual area required for casting of blocks. It shall have water supply network for providing water for casting as well as curing of blocks and also electric supply points. The pavement shall be hard enough for the movement of cranes and trucks engaged in lifting and transportation of blocks.

11.1.2 The number of blocks to be cast every day shall be documented following the order to sequence of placing. This will facilitate the lifting and transportation of blocks in a systematic way without double handling and frequent movement of cranes to longer leads.

11.1.3 Mixing and laying of concrete shall be in accordance with IS 456 : 1978.

11.2 Handling of Blocks

11.2.1 The weight of concrete blocks shall be such that easier handling with available equipment is possible. As the size and number of blocks in case of concrete block work are large, a specially designed lifting gear arrangement is preferable to economise the handling cost (*see* Fig. 8). The lifting gear, generally used, consists of a connecting beam with central hook and a pair of vertical shafts made of 65 mm ϕ mild steel bar with tilting keys at the end. Care shall be taken to design structural component to withstand the shear due to dead weight of the blocks. For handling the blocks, blocks are placed between wooden pieces and locked with the use of tilting keys. The whole assembly is then attached to lifting crane with the help of the lock and transported at the desired place. In casting yard the blocks may be handled by strong slings and steel box section.

11.3 Foundation Preparation

11.3.1 Before commencement of bed preparation for block work construction, a trench of designed size, slope and levels shall be excavated in the sea bed along the alignment (*see* Fig. 9). The layer of loose materials comprising silt, sand and clay overlying the founding level shall be removed.

11.3.2 After reaching the foundation level, the trench shall be made up with rubble and the top 200 mm by graded metal of 50 mm size. The rubble metals will be of appropriate thickness depending on the site condition. If exposed rock is available at the foundation level, either concrete or a thin layer of graded metal of 50 mm size may be used. To guide alignment and levels of bed preparation, steel frames of convenient sizes are placed across the foundation trench and the levels are controlled from shore with the help of a levelling instrument. A lateral gradient of 1 : 100 shall be given to finishing the surface of the metal layer. This inward gradient is for counteracting the differential settlement caused by the horizontal thrust of the backfill. The frames shall be held in position by packing gunnys filled in with metal. The alignment of the frames shall be checked by holding a specially made vertical staff on the 4 corners of the frames and taking readings with a theodolite stationed on the nearby shore. The positioning of frames to levels and checking of alignment shall be done with the assistance of under water divers guided by signalling men.

11.3.3 After the frames are positioned to the alignment and levels, they are filled with rubble and stone metal up to the top surface with the help of divers. The final levelling of the rubble mattress is done by running a screeder along the top surface of the frames.

11.4 Launching of Blocks

11.4.1 The launching of block shall be done by deploying a heavy lift crane coupled with a lifting gear. The starting point of block work construction is the formation of pre-abutment with rectangular blocks of relatively smaller weights of about 10-T and progressing from land towards sea.

11.4.2 The sloping connection of the pre-abutment blocks shall be provided with an *in-situ*

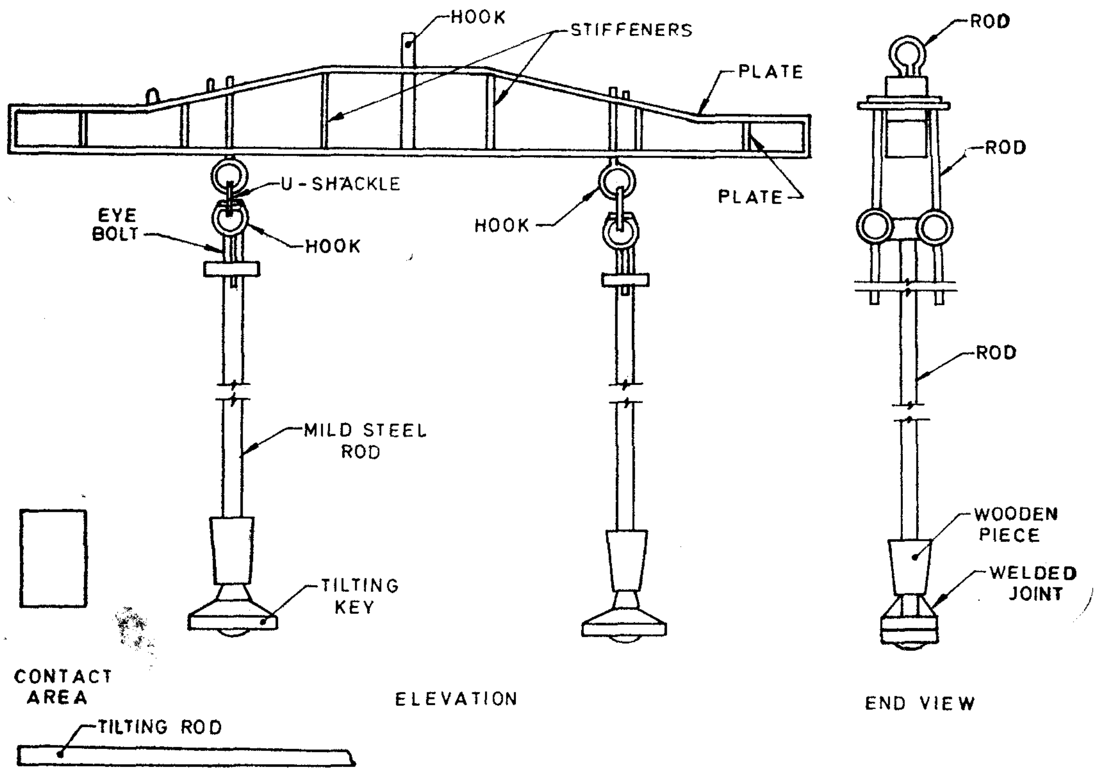
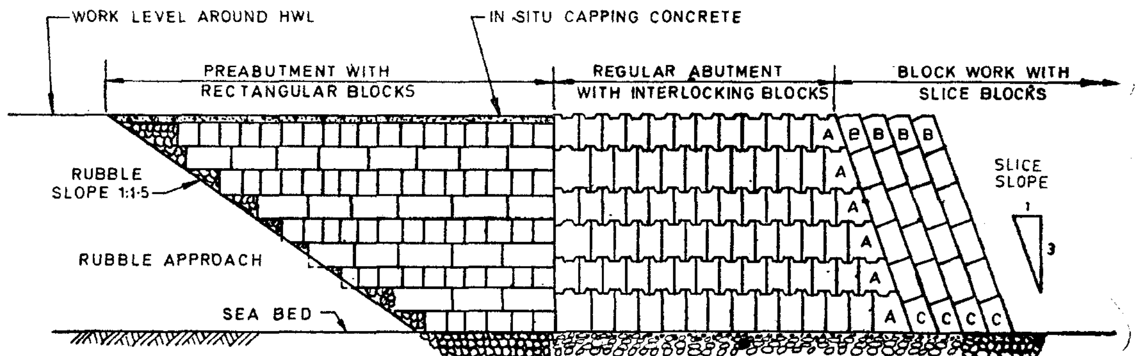


FIG. 8 TYPICAL DETAILS OF LIFTING GEAR FOR HANDLING CONCRETE BLOCKS



A — Special sloping blocks (filler blocks)

B — Top course of blocks with part horizontal part chamfered top face

C — Bottom course of blocks with chamfered bottom face

FIG. 9 TYPICAL LONGITUDINAL SECTION OF PREABUTMENT, REGULAR ABUTMENT AND BLOCK WORK AT COMMENCEMENT capping concrete to hold the blocks together. The pre-abutment serves as a working platform for the block launching crane to proceed with the construction of the first main abutment.

11.4.3 The formation of regular abutment consists of vertical interlocking blocks. The sea-ward end of the abutment is sloping 1 : 3 in case of slice work sharf. Abutments are strong points to counteract the lateral thrust arising out of the initial rows of slices and also to localise the creep. Generally abutments are provided at the start of each berth in block work.

11.4.4 On completion of regular abutment, the first row of the main block work is taken up and completed followed by the next row and so on. Usually two or three divers shall be in duty at any time for guiding the block launching under water. On completion of each row of block work the alignment and the slope shall be checked. Errors, if any, shall be rectified then and there, otherwise they may lead to misalignment and creep.

11.5 Tolerances

11.5.1 *Blocks*

11.5.1.1 The blocks are to be as nearly cubical or rectangular or of the shape specified as possible. No humps on any of the faces is permitted. The blocks shall be constructed to the shape, lines and dimensions shown on the drawings within the tolerances given below:

Deviation from specified dimensions

$= -6$ mm

$+12$ mm

11.5.1.2 The blocks which cannot bed naturally into a stable position should be discarded for the position and replaced by another block. At times blocks may have to be chipped to facilitate the bedding to blocks already placed.

11.5.2 *Blockwork (Wall)*

11.5.2.1 All the blocks have to be packed to minimize void spacing and have to be placed in stable locations individually and the whole blockwork has to be built up to the section specified.

11.5.2.2 Tilt and shift occur in every conceivable direction. Up to certain limits, the tilts and shifts and permitted and their influence on the stability of the blockwork is to be taken care of in the design. The limit is decided by the designer on the basis of his experience and the site conditions. Whenever the tilt and/or shift has exceeded the permissible limits, the stability of the blockwork shall be rechecked and suitable remedial measures if required, should be taken. The cumulative effect of the tilt and shift of the waterfront structure, invariably alters the originally decided wharf line. This may affect the position of the fixtures and may necessitate the redesign of the superstructure.

11.5.2.3 Usually the combined effect of tilt and shift should not be more than $\pm$ 300 mm at top of the blockwork. Shifts up to $\pm$ 300 mm and tilts up to 1 : 60 depending upon the soil conditions and the size and depth of the blockwork are permitted. These limits may however be taken as a guide and may be decided as per site conditions.

11.5.2.4 The tilts and shifts usually do not occur suddenly. These shall be observed at every stage of placement of the blocks and adequate precautions should be taken to rectify the shift and tilt at the respective stage; otherwise these get aggravated.

11.5.2.5 The level and projection of the capping slab, if any, shall be decided by the designer considering the shift/tilt, vessel size(s) and the tidal range.

11.6 Formation of Filter Layer

11.6.1 The construction of blockwork shall be followed by a filter media after leaving sufficient clearance. The filter media generally consists of quarry rubbish and its function is to prevent the passage of fill materials through the joints of blockwork.

11.7 Capping Concrete

11.7.1 Once the blockwork is constructed up to the high water level and filter is formed on the rear side, it shall be followed by an *in-situ* mass capping concrete. The capping concrete is to make the block work function *en-masse*. The capping concrete accommodates the wharf fixtures like fenders, bollards, ladders, crane tracks, railway tracks ducts and service gallery for running water supply, power and communication cables. Expansion joints shall be left in the capping concrete in accordance with IS 456 : 1978.

11.8 Controls

11.8.1 The workmanship, inspection and testing shall be in accordance with IS 456 : 1978.

11.8.2 The levels of foundation, blockwork and capping concrete, the slope of blockwork, verticality of berthing face, alignment of blockwork and capping concrete shall be controlled continuously to obtain the blockwork as per the designed cross sections.

11.9 Work Programme

11.9.1 The components involved in the construction of blockwork wharf are closely inter-related and inter-dependent. A well defined work programme preferably in the form of PERT/CPM network is essential to coordinate the construction activities without interruption. The critical item of the blockwork construction is always the foundation preparation and more attention is, therefore, required on this item of work to avoid slippages in construction schedules.

ANNEX A

(*Clause* 2.1)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
432 : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
456 : 1978	Code of practice for plain and reinforced concrete (*third revision*)
1786 : 1985	Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*)
1893 : 1984	Criteria for earthquake resistant design of structures (*fourth revision*)
2809 : 1972	Glossary of terms and symbols relating to soil engineering (*first revision*)
4651 (Part 1) : 1974	Code of practice for planning and design of ports and harbours : Part 1 Site investigation (*first revision*)
4651 (Part 2) : 1969	Code of practice for planning and design of ports and harbours : Part 2 Earth pressures
4651 (Part 3) : 1974	Code of practice for planning and design of ports and harbours : Part 3 Loading (*first revision*)
4651 (Part 4) : 1989	Code of practice for planning and design of ports and harbours : Part 4 General design considerations (*second revision*)
7314 : 1974	Glossary of term relating to port and harbour engineering

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