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व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 47/टी-4 **24 जून 2025**

तकनीकी समिति: पत्तन, पोताश्रय् और अपतट अधिष्ठापन विषय समिति, सीईडी 47

प्राप्तकर्ता:

क) सिविल इंजीनियरी विभाग परिषद, सीईडीसी के सभी सदस्य
ख) सीईडी एवं 47 इसके पैनल के सभी सदस्य
ग) रूचि रखने वाले अन्य निकाय।

महोदय/महोदया,

निम्नलिखित मसौदा संलग्न है:

प्रलेख संख्या	**शीर्षक**
सीईडी 47 (28189)WC	**पत्तनों और पोताश्रयों की योजना और रूप — रीति संहिता भाग 4 सामान्य रूप रेखा के लिए विचार का भारतीय मानक मसौदा** [IS 4651 (भाग 4) *का पाँचवा पुनरीक्षण*] ICS 93.140

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WIDE CIRCULATION DRAFT

Our Ref: CED 47/T-4 **24 June 2025**

TECHNICAL COMMITTEE: PORTS, HARBOURS AND OFFSHORE INSTALLATIONS SECTIONAL COMMITTEE, CED 47

ADDRESSED TO:

a) All Members of Civil Engineering Division Council, CEDC
b) All Members of CED 47 and its panels and working group
c) All other interested

Dear Sir/Madam,

Please find enclosed the following draft:

Doc. No.	Title
CED 47 (28189)WC	**Draft Indian Standard Planning and Design of Ports and Harbours — Code of Practice** **Part 4 General Design Considerations** [*Fifth Revision* of IS 4651 (Part 4)] ICS 93.140

Kindly examine the attached draft and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard.

Last Date for Comments: 29 July 2025

Comments if any, may please be made in the enclosed format and emailed at ced47@bis.gov.in or sent at the above address. Additionally, comments may be sent online through the BIS e-governance portal, www.manakonline.in.

In case no comments are received or comments received are of editorial nature, kindly permit us to presume your approval for the above document as finalized. However, in case comments, technical in nature are received, then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website www.bis.gov.in.

Thanking you,

Yours faithfully,

Sd/-
(Dwaipayan Bhadra)
Scientist ‘E’ & Head
Civil Engineering Department
Email: ced47@bis.gov.in

Encl: As above

FORMAT FOR SENDING COMMENTS ON BIS DOCUMENTS

(Please use A-4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/table/fig etc. be started on a fresh box. Information in column 3 should include reasons for the comments and suggestions for modified working of the clauses when the existing text is found not acceptable. Adherence to this format facilitates Secretariat's work) {Please e-mail your comments to ced47@bis.gov.in

DOC. NO.- CED 47 (28189) WC

TITLE: Draft Indian Standard Planning and Design of Ports and Harbours — Code of Practice Part 4 General Design Considerations

[*Fifth Revision* of IS 4651 (Part 4)] ICS 93.140

LAST DATE OF COMMENTS: **29/07/2025**

NAME OF THE COMMENTATOR/ORGANIZATION: ________________________

Sl No.	Clause/ Para/ Table/ Figure No. commented	Type of Comment (General/ Technical/ Editorial)	Comments/ Modified Wordings	Justification of Proposed Change
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NOTE- Kindly insert more rows as necessary for each clause/table, etc.

<u>BUREAU OF INDIAN STANDARDS</u>

DRAFT FOR COMMENTS ONLY

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Draft Indian Standard

Planning and Design of Ports and Harbours — Code of Practice
Part 4 General Design Considerations

[*Fifth Revision of IS 4651 (Part 4)*]

PORTS, HARBOURS AND OFFSHORE INSTALLATIONS SECTIONAL COMMITTEE, CED 47	Last Date of Comments **29 July 2025**

FOREWORD

(*Formal clauses to be added later*)

Based on the need felt towards formulating Indian standard recommendations relating to various aspects of waterfront structures, the IS 4651 series of standards were established. This standard is one of this series formulated on this subject and deals with general design considerations. The other parts in the series are given below:

Part 1 Site investigation
Part 2 Geotechnical Engineering
Part 3 Loading
Part 5 Layout and functional requirements

This standard (Part 4) was first published in 1969 and was subsequently revised in 1979, 1989, 2014, and 2023.

In the fourth revision in 2023, the revised provisions included several important additions and elaborations. The impact of water level rise due to tsunamis and the method for calculating the resulting hydrostatic force on vertical face structures were addressed and included. A partial load factor for the capacity of quick release mooring hooks (QRMH) was introduced. Further, both transient and sustained load combinations for checking crack width, as well as deflection limits considering long-term effects along with corresponding load combinations, were incorporated. The load factors relevant to foundation design were specified. Detailed elaboration was provided on crane and machine operating loads as well as extreme loads. Operating and extreme mooring forces while using QRMH were included. The existing clause regarding the exposure zone and nominal thickness of cover was elaborated to enhance clarity. The clause on reaction force of the fender was modified, and reinforcement detailing of piles was elaborated with reference to ductility requirements.

The fifth revision of this standard has been taken up to incorporate further modifications necessary in the light of comments received from the users of this Standard. The following significant changes have been made in this revision:

1) In terminology extreme load and normal load clauses modified.

2) Partial load factors for shrinkage, creep and temperature have been included.
3) Partial load factors for quick release mooring hook (QRMH) force operational and QRMH force extreme has been modified.
4) Clause on Disposition of Fenders has been modified.
5) In deck elevation, minimum deck top level clause has been included.
6) Water level rise due to tsunami and the method of calculation of hydrostatic force due to tsunami of vertical face structure has been modified in Annex B.

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

PLANNING AND DESIGN OF PORTS AND HARBOURS - CODE OF PRACTICE
PART 4 GENERAL DESIGN CONSIDERATIONS

[*Fifth Revision of IS 4651 (Part 4)*]

Ports, Harbours and offshore Installations Sectional Committee, CED 47	Last Date of Comments **29 July 2025**

1 SCOPE

This standard (Part 4) deals with general design considerations for Port and Harbour structures.

2 REFERENCE

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 TERMINOLOGY

For the purpose of this standard, the definitions of terms given in IS 7314 and the following shall apply.

3.1 Added Mass

The surge, sway, heave, roll, pitch and yaw motion of the body in the fluid will generate resistance of fluid against these motions and introduce a pressure field on the submerged surface. The component of force due to this pressure distribution in phase with body acceleration is added mass and the component of force in phase with body velocity is damping.

3.2 Erection Stresses

The stresses produced due to pile gantry during construction, EOT crane, container crane and skid beams etc.

NOTE — Erection stresses for container crane is generally not required to be considered as the time when container crane is off-loaded from the ship to the berth, the deck of the berth is completed in all respect in that particular stretch. Thus, that part of the deck is already designed to carry even the moving and traction load of the container cranes.

3.3 Extreme Load

The wave load to be considered during storm with 100 year return period. The occurrence of extreme wave and extreme current may not happen simultaneously.

3.4 Marine Growth

The marine growth is growth of marine organisms around the substructure like the pile surface and deck bottom surface if sufficient air gap is not provided.

3.5 Normal Load

The normal load is the load to be considered during operation of the structure. The operating load for wind shall be as per specification of crane or 20 m/s whichever is lower. The operational wave and current load is recommended to be with one year return period or as per the specification of port user.

3.6 Temporary Load

The loads during construction stage including construction live load.

3.7 Splash Zone

The splash zone is defined as the zone between the chart datum and the design wave height above the mean high water springs.

4 LOADS, FORCES AND STRESSES

4.1 The loads, forces and stresses to be considered in designing the structures are the following:

a) Dead load (*DL*) (Including the weight of marine growth);
b) Vertical live load;
c) Impact or dynamic effect of live load; (crane load operating or extreme)
d) Forces caused by the tractive effort or braking of vehicles, cranes, ship loader/unloader, material handling equipment, etc;
e) Centrifugal forces of vehicles moving on curve;
f) Earth pressure;
g) Hydrostatic and hydrodynamic forces;
h) Berthing forces from vessels;
j) Mooring forces;
k) Forces due to wind;
m) Secondary stresses (stresses due to shrinkage, creep, temperature, etc as applicable);
n) Erection stage stresses;
p) Live load (*LL*);
q) Seismic forces or earthquake loads; and
r) Tsunami force.

4.2 The above mentioned loads, forces and stresses should be worked out on the basis of provisions in IS 4651 (Part 3) and other relevant Indian Standards.

4.3 The hydrostatic force due to Tsunami of vertical face structure shall be calculated as per Annex B.

5 COMBINATIONS OF LOADS, FORCES AND STRESSES

5.1 All members shall be designed to sustain safely the effect of the combination of various loads, forces and stresses (*see* **4.1**) that can possibly co-exist. All calculations shall distinctly tabulate the various combinations of above loads and stresses covered by the design. The load combinations given in Table 1 and Table 2 should be considered in limit state and working stress designs respectively.

Table 1 Partial Load Factors for Loads in Limit State Design
(*Clause* **5.1**, **6.2.2** *and* **7.1.2**)

Sl No.	**Loading**	**Partial Load Factor**					
		Limit State of Serviceability		**Limit State of Collapse**			
		Short Term	Long Term	Normal	Extreme/ Survival	Temporary	Reversal
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Dead load (*DL*)	1.0	1.0	1.5	1.2	1.2	0.9
ii)	Live load						
	a) Dynamic load (*DyL*)	1.1	0.5	1.5	1.2	1.2	0.9
	b) Static(*LL*)	1.0	0.5	1.5	1.2	1.2	0.9
iii)	Earth pressure (*EP*)	1.0	1.0	1.2	1.0	1.0	1.0
iv)	Hydrostatic force (*HyF*)	1.0	-	1.0	1.0	1.0	1.0
v)	Wave and current force (*WL* and *CL*)	1.0	-	1.2	1.0	1.0	1.0
vi)	Berthing force(*BF*)	1.0	-	1.5	1.0	-	1.5
vii)	Mooring force(*MF*)	1.0	-	1.5	-	-	1.5
viii)	Working wind force (*WWiF*)	1.0	-	1.0	-	-	-
ix)	Extreme wind force (*EWiF*)	-	-	-	1.2	-	1.5
x)	Shrinkage	-	1.0	-	-	-	-
xi)	Creep	-	1.0	-	-	-	-
xii)	Temperature (TempL)	-	1.0	-	-	-	-
xiii)	Seismic Force (*EL*)	1.0	-	-	1.2	-	1.5

Sl No.	Loading	Partial Load Factor					
		Limit State of Serviceability		Limit State of Collapse			
		Short Term	Long Term	Normal	Extreme/ Survival	Temporary	Reversal
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
xiv)	Tsunami Force (*TL*)	-	-	-	1.2	-	-
xv)	Secondary Stresses (*SS*)	1.0		-	-	-	-
xvi)	QRMH Force - Operational (*QFO*)	1.0	-	-		-	-
xvii)	QRMH Force – Extreme (*QFE*)	-	-	-	1.0	-	-

NOTES

1 If dead load alone is only combined with wind/seismic force, the partial load factor of +1.5, -1.5 shall be considered for wind/seismic forces under normal operating conditions similar to IS 456 and IS 1893 (Part 1).
2 DL+ 50 percent of uniformly distributed Live Load shall be considered for seismic force estimation.
3 Importance factor of 1.5 shall be taken for water front structures for seismic design.
4 Tsunami load shall be considered in design of structures with additional scour due to Tsunami.
5 Additional weight due to marine growth shall be considered in dead load case. Weight of marine growth shall be calculated from its density and thickness of the marine growth around the structure. As a general guideline it is to be taken as 100 mm, if the location is known to have higher marine growth.
6 Limit state of serviceability load combinations shall be given as below:

a) Transient Load Combination for crack width check only
 1) 1.0(*DL*) + 1.1(*DyL*) + 1.0(*LL* + *EP* + *HyF* + *WL* + *CL* + *BF* + *WWiF* + *SS*)
 2) 1.0(*DL*) +1.1(*DyL*) + 1.0(*LL* + *EP* + *HyF* + *WL* + *CL* + *MF* + *WWiF* + *SS*)
b) Sustained load combination for crack width check
 1) 1.0(*DL*) + 0.5(*LL*) + 1.0(*EP*)
c) Short term deflection estimate for design of expansion joint
 1) 1.0(*DL*) + 1.1(*DyL*) + 1.0(*LL* + *EP* + *HyF* + *WL* + *CL* + *EL* + *SS*)

7 Horizontal deflection check for long term effect shall be limited to L/250, Where L shall be from point of zero deflection below dredge level till top idealized level.

a) 1.0(*DL*) + 0.5(*LL*) + 1.0(*EP* + TempL) + 1.0 *WWIF* + 1.0 *WL* (operating) + 1.0 *CL* (operating)
b) 1.0(*DL*) + 0.5(*DyL* (operating) + *LL*) +1.0(*EP*) + 1.0 *WWIF* + 1.0 *WL* (operating) + 1.0 *CL* (operating)

For shrinkage, creep and temperature loads, IS 456 and IS 875 (Part 5) may be referred.
8 For normal loading berthing energy shall be considered for BF calculation. For extreme loading, ultimate berthing energy shall be considered for BF calculation.

9 Limit State of collapse load combinations

a) Normal load condition
 1) 1.5(*DL* + *DyL* + *LL*) + 1.2(*EP*) + 1.0(*HyF*) + 1.2(*WL* + *CL*) + 1.5(*BF*) + 1.0(*WWiF*)
 2) 1.5(*DL* + *DyL* + *LL*) + 1.2(*EP*) + 1.0(*HyF*) + 1.2(*WL* + *CL*) + 1.5(*MF*) + 1.0(*WWiF*)
 3) 1.5 (*DL*+*IL*)

b) The seismic load condition
1) 1.2(*DL*+ *IL* ± *EL*)
2) 1.5(*DL* ± *EL*)
where *IL* is Imposed load such as weight of stairways, handrails, equipment reactions and super structures etc.

c) Extreme/Survival load condition
1) 1.2(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*) + 1.0(*BF* / *QC*)
2) 1.2(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*) + 1.2(*EL*)
3) 1.2(*DL* + *DyL* + *LL*) + 1.0(*EP*) +1.2(*TL*)
4) 1.2(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*) + 1.2(*EWiF*)

d) Temporary load condition
1) 1.2(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*)

e) Reversal load condition
1) 0.9(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*) + 1.5(*BF* or *MF*)
2) 0.9(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*) + 1.5(*EWiF*)
3) 0.9(*DL* + *DyL* + *LL*) + 1.0(*EP*) + 1.0(*HyF* + *WL* + *CL*) ± 1.5(*EL*)

10 For Foundation design of piles adequate factor of safety for skin friction and end bearing should be considered as recommended in IS 2911 along with load factor of 1 for load combination of Limit state of collapse.
11 Operating wave and operating current
12 *OWL* – Operating wind load
13 Extreme wave and extreme current load for 100 year return period shall be considered for the Extreme survival load combination.

Table 2 Increase in Permissible Stresses
(*Clauses* **5.1** *and* **7.1.2**)

Sl No.	**Combination of Loads**	**Increase in Permissible Stresses**		**Increase in Allowable Foundation Capacity**
		Reinforced Concrete	**Other Materials Such as Steel and Timber**	
(1)	(2)	(3)	(4)	(5)
i)	*DL* + *LL* + impact of braking or traction or vehicles + centrifugal forces of vehicles	Nil	Nil	Nil
ii)	*DL* + *LL* with impact, braking or tractive and centrifugal forces + earth pressure, percent	15	15	15
iii)	*DL* with/without *LL* including impact, braking or tractive and centrifugal forces + earth pressure + hydrodynamic and hydrostatic forces + berthing or mooring forces, percent	25	$33\frac{1}{3}$	25
iv)	Wind forces on structures + load combination of (i), (ii) or (iii)		*See* IS 875 (Part 3)	

Sl No.	Combination of Loads	Increase in Permissible Stresses		Increase in Allowable Foundation Capacity
		Reinforced Concrete	Other Materials Such as Steel and Timber	
(1)	(2)	(3)	(4)	(5)
v)	Seismic forces + load combination (i), (ii) or (iii) - Berthing or Mooring forces		*See* IS 1893 (Part 1)	
vi)	Secondary stresses + load combination of (i), percent	15	15	15
vii)	Erection stage stresses with *DL* and appropriate *LL* + earth pressure + hydrostatic and hydrodynamic forces + wind forces, percent	15	$33\frac{1}{3}$	25

5.2 Crane/machine operating loads [**4.1** (b), **4.1** (d) and **4.1** (e)] along with dead load [**4.1** (a)], combined with wind load specified by the manufacturer for operation should be taken for design purposes.

5.3 Crane/Machine Extreme Loads — Load specified by manufacturer for storm condition shall be considered appropriately. Also the limiting deflection shall be as per manufacturer's specification or based on crane load capacity.

5.4 As berthing of vessel is deemed to be done in relatively calm conditions, the berthing forces may not be considered to occur simultaneously with crane/machine operating load [**4.1** (b), **4.1** (d)] and [**4.1** (e)], wind loads [**4.1** (k)] or seismic forces [**4.1** (q)].

5.5 Wind load [**4.1** (k)] and seismic forces [**4.1** (q)] need not be deemed to act simultaneously.

5.6 Seismic forces [**4.1** (q)] need not be combined with erection stage stresses [**4.1** (n)], berthing forces [**4.1** (h)] and mooring forces [**4.1** (j)].

5.7 Tsunami forces [**4.1** (r)] need not be combined with erection stage stresses [**4.1** (n)], berthing forces [**4.1** (h)] or mooring forces [**4.1** (j)] and secondary stresses [**4.1** (m)].

5.8 For QRMH (Quick release Mooring Hook),

Operating Mooring force *MF* (QRMH force - Operational) = 0.55 x n x *SWL*
Extreme Mooring force *MFE* (QRMH force - Extreme) = *SWL*+ (n-1) x 0.8 x *SWL*

Where, n is the number of hooks and SWL is safe working load of hook. *n* x *SWL* shall be greater than the mooring line force calculated by considering wind speed of 30 m/s for LNG vessel or other liquid vessel. The capacity of the hook shall equal to or more than the minimum breaking load of mooring rope.

6 METHOD OF DESIGN

6.1 Structures and structural elements may be designed by limit state method.

6.1.1 RCC and prestressed concrete members can be designed by limit state method whereas for designing structures with other material, working stress method should be adhered to.

6.2 Limit State Method

In the limit state method of design, a structure is considered unfit for use when it reaches a particular state called limit state at which it ceases to fulfill the function or satisfy the conditions for which it is designed. The structure shall be designed to withstand safely all loads liable to act throughout its life and it shall also satisfy the serviceability requirements, such as, limitations on deflection and cracking, etc.

6.2.1 All relevant limit states shall be considered in design to ensure an adequate degree of safety and serviceability. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

6.2.2 *Partial Safety Factors for Loads*

The values for the partial safety factor given in Table 1 shall normally be used.

6.2.3 *Partial Safety Factor for Material Strength*

When assessing the strength of a structure or structural member for the limit state of collapse, the values of partial safety factors shall be taken as 1.5 for concrete and 1.15 for steel.

6.3 Working Stress Method

Working stress method or permissible stress method may also be adopted in the designs till such time the complete changeover to the limit state method is made in other relevant Indian Standards on the subject. However as the limit state method is more rational and adoptable, the designs may be carried out by limit state method.

7 PERMISSIBLE STRESSES

7.1 The following permissible stresses shall be adopted for the working load method of design:

7.1.1 When the load items mentioned in **4.1** (a) to **4.1** (r) are considered for possible appropriate combination, the following shall be applicable, subject to the stipulations contained in **7.1.2**:

a) For reinforced concrete structural members, the permissible stresses shall be as specified in IS 456,

b) For prestressed concrete structural members, the permissible stresses shall conform to those specified in IS 1343,
c) For structural steel members, the permissible stresses shall be as specified in IS 800,
d) For timber structural members, the permissible stresses shall be as specified in IS 883, and
e) For timber or concrete piles, the safe bearing capacity, and/or factor of safety shall be in accordance with IS 2911 (Part 2), IS 2911 (Part l/Sec 1 to 3) and IS 2911 (Part 1/Sec 4).

7.1.2 *Increase in Permissible Stresses*

Under various combinations of loading, for use in working stress design, the partial load factor of 1.0 shall be used for loads given in Table 1. The permissible stresses in normal loading may be exceeded up to the limit as indicated in Table 2 provided in no case does the stress exceed the yield stress or 0.2 percent of the proof stress of the material concerned.

8 CHOICE OF CONSTRUCTION MATERIAL

8.1 The basic criteria adopted in the general choice of construction material, such as, easy availability, easy working, mechanical properties suited to the purpose for which it is to be used and economic considerations, hold equally good for dock and harbour structures. The durability under the environmental condition, however, is of particular importance in these marine structures. The aggressive action of sea water and/or the marine environment on the principal construction materials, such as, steel, concrete and timber require special attention.

8.2 Structural Steel

8.2.1 Unless otherwise specified, the steel shall conform to IS 2062.

8.2.2 The corrosion of steel varies in different conditions of sea air or sea water exposure. Severe corrosion, however, occurs in saline water and under marine growth, specially in the splash zone and in the reaches of the tidal range with alternate wetting and drying. Steel buried in ground is also subjected to corrosion under certain conditions.

8.2.3 Any one or a combination of the following remedial measures may be taken against the corrosion:

a) *Cathodic Protection*

   Corrosion of steel completely immersed under water or buried in ground (where possibility of electrolytic corrosion exists) can be substantially eliminated, and corrosion of steel alternatively exposed to wet and dry condition can be significantly protected by cathodic protection using an impressed current system or sacrificial anode system.

b) *Increased Section/Reduced Stresses*

Where the cathodic protection is not practical or the maintenance doubtful, extra thickness of metal or section may be considered for providing an economic solution. The actual recommendations as to the minimum metal thickness depend upon the nature of the structure and its projected life. As a general rule, it may be considered that any mild steel used in marine structure, should have a minimum thickness of 6 mm when cathodic protection is provided, and a minimum thickness of 10 mm when cathodic protection is not provided. In any case, no structural steel should be used in marine conditions without protective coatings.

c) *Use of Special Steel*.

Special alloy steels, such as, like those with 2 percent copper content can significantly arrest corrosion.

d) *Jacketting with under Water Micro Concrete in Splash Zone*

Special care has to be taken in the splash zone where the protection could be given by a underwater micro concrete by jacketting with suitable anti washout polymer based cementitious grout.

NOTE — Any other suitable method with proper justification to the satisfaction of user may also be used.

8.3 Concrete

8.3.1 Concrete has extensive use in harbour structures, such as, dock walls and floors, piles, sheet piles, caissons and monoliths, deck structures for jetties and wharves and breakwater armour blocks, apart from the use in dock buildings and in other structures above ground.

8.3.2 The concrete structures built in aggressive environment are subject to attack by sea water penetrating into the mass. Concrete shall be made impermeable to such a degree that it is not penetrated by the constituents of sea water. The most dense concrete will give the best result. Concrete grade not less than M 35 for RCC, M 20 for PCC and M 40 for prestressed concrete construction shall be used. Concrete grade not less than M 15 shall be used in mass concrete construction.

8.3.3 The use of special type of cement and the total cement content in concrete also require careful consideration. Portland slag cement (*see* IS 455) should preferably be used for marine structures. As an alternative, ordinary Portland cement (*see* IS 269) /Portland Pozzolona Cement [*see* IS 1489 (Part 1 and Part 2)] may be used. The minimum cement content and maximum water cement ratio for all grades of concrete for RCC and prestressed concrete construction shall be in conformity to IS 456.

8.3.4 As cracking in concrete members is to be minimized, reduced stresses are recommended for concrete and steel to be used in the design of RCC members subject to marine environments unless the structure is checked against the formation of cracks. The stresses in steel may be reduced to 165 N/mm^2 in working stress design. As a guide, assessed surface width of cracks at points nearest to the main reinforcement should not exceed 0.004 times the cover of the main reinforcement or maximum crack width in different zones given in Table 3, whichever is minimum. Limit State of serviceability load combinations shall be considered for crack width calculation.

Table 3 Maximum Crack Width in Different Zones
(*Clause* **8.3.4**)

Sl No.	**Exposure Zone**	**Maximum Crack width (mm)**	
		Sustained Load	Transient Load
(1)	(2)	(3)	(4)
i)	Atmospheric zone: - above splash zone and where direct wave or spray impingement is infrequent	0.2	0.3
ii)	Splash zone: - zone between the chart datum and 1.6 times operating significant wave height above the mean high water springs	0.1	0.2
iii)	Continuous seawater immersion zone: - below splash zone upto seabed level	0.2	0.3
iv)	Below seabed level	0.3	0.3

NOTES

1 *Sustained Load* **–** Dead load plus 50 percent of full uniformly distributed live load + earth pressure.

2 *Transient Load* – Dead load plus berthing load and full crane load or full live load uniformly distributed + earth pressure.

8.3.5 Nominal thickness of cover (cover is concrete cover to all the reinforcement) is to be provided for the structures in marine atmosphere. It is recommended for structures immersed in sea water, in splash zone nominal cover shall be 75 mm and for all other exposure conditions (the zones above deck level, immersed and below mud line), the nominal cover shall be 50 mm as specified in Table 4.

Table 4 Nominal Thickness of Cover in Different Zones
(*Clause* **8.3.5**)

Sl No.	**Exposure Zone**	**Adequate thickness of cover(mm)**
(1)	(2)	(3)
i)	Atmospheric zone – above splash zone and where direct wave or spray impingement is infrequent	50
ii)	Splash zone – zone between the chart datum and the design wave height above the mean high water springs	75
iii)	Continuous seawater immersion zone – below splash zone upto seabed level	75
iv)	Below seabed level	50

8.3.6 The use of precast concrete elements is preferred for marine structures as they are cast under strict quality control and, therefore, are able to withstand the destructive influence of marine environments better.

8.3.7 All the Limit State of serviceability load combinations excepting the one under seismic combination and long term deflection combination shall be used for maximum crack width check of structural members and not for checking the deflection. The permissible deflection of berthing structure need not be checked for berthing or mooring load combinations. The seismic load combination for limit state of serviceability shall be used for checking the deflection of the berthing structures near the expansion joints at the deck level. The deflection for the berthing structure need not be controlled by limiting the deflection of pile at the soil/dredge level.

8.4 Timber

8.4.1 Timber has wide use in dock and harbour structures. It can be used for sheet piles, bearing piles, structural members in jetties, fenders, rubbing strips transit sheds and warehouses, as structural members and/or for door and window frames.

8.4.2 The hazards which face timber are the attack by fungi and insecticides; and in sea water the attack by the marine borers. When used in dockside buildings the design shall be primarily guided by provisions of the relevant standards and protection against the attack of fungi and insecticides. The timber used in marine structure, particularly if subjected to fluctuating tides, is prone to attacks by marine borers and require preservative treatment.

8.4.3 An effective preservative treatment of timber is creosoting which is normally applied by pressure impregnation (*see* IS 401).

9 FENDERS

9.1 Purpose

The fenders shall absorb the impact of berthing vessel and also the chatter of the moored vessel in order to avoid damages to the vessel and to the structure. Functionally, fenders shall accomplish the following purposes:

a) Absorb the berthing energy or impact of vessels and transmit a designed or calculated force to the structure, which shall not exceed the allowable hull pressure,
b) The pressure exerted from the fenders system does not exceed the ship's hull pressure capacity. Hold the vessel off the face of the structure and avoid rubbing against the structure and consequent damages to the vessel and the structure, and
c) Impart the thrust from berthing loads to the structure at predetermined or design points.

9.2 Type of Fenders

The fenders may be made of rubber, steel, timber, brushwood, rope, concrete and similar material. Rubber has come into extensive use for fender system. Amongst various types, there may be hollow-cylindrical or rectangular rubber fenders, sandwich type known as Raykin fender buffer, steel spring fenders, wood-springing type fenders, horizontal and vertical timber fenders, fender piles, brushwood fenders, gravity-type fenders, torsion fenders, floating fenders, rolling fenders, obstruction types, etc. The choice of material and the type of fender shall be judiciously made to serve the specific purpose in the particular case.

9.2.1 Fixed fenders are fixed or mounted to the berthing structures. The fixed fenders are again sub divided into the following:

a) Buckling Fenders
b) Non Buckling Fenders

9.3 Design

The design of the fenders shall be dependent on the following parameters and they should be designed for berth loads from ships as specified in IS 4651 (Part 3):

a) *Size of Ship*

The fender capacity shall depend upon the ship size.

b) *Berthing Velocity*

The berthing velocity under various conditions and type of vessel shall be adopted as specified in IS 4651 (Part 3).

c) *Importance of Structure*

The design of the fenders shall take into account the importance of consequences suffered by the ship and the berthing structure in case of an eventual accident due to insufficient energy absorption capacity.

d) *Energy Absorption*

Various types of fenders absorb energy in various ways but in most of them, the kinetic energy of the ship is stored in energy of strain. Shear permits the absorption of larger amount of energy than tension and compression. Flexure does not permit an efficient use of material as only a small percentage of the material of the fender may reach the allowable stresses. Torsion permits a good use of all the materials of a fender, particularly if tubes with thin walls are used. The flexibility of the berthing structure together with that of the fendering system may be taken into consideration in computing the total energy absorption capacity of the whole system. Any accepted method of analysis (such as beams on elastic foundation) may be adopted for such computation.

e) *Reaction Force and Deflection of the Fender*

The maximum amount of reaction force of a fender system on ship shall be chosen taking into account:

1) The strength of hull; and
2) The strength of the berthing structure.

The manufacturers of proprietary fenders usually supply the energy absorption, deflection and reaction force characteristics of the specific fenders. These should be adopted in design. It is, however, recommended that a factor of safety of 2.0 should be applied over the calculated berthing energy.

f) *Disposition of Fenders*

The disposition of the fenders shall depend upon the location of the berths, the type of berthing structure, conditions of berthing, etc. In case of continuous berth, the longitudinal spacing should not normally exceed 0.1 *L* where *L* is the length of the longest ship. In case the berth is handing multiple vessel sizes suitable fender spacing (greater then 0.15 times the Length of smallest vessel) shall be provided. For Island berths longitudinal spacing of primary fenders should be in the range of 0.25 *L* to 0.4 *L* where *L* is the length of the ship. If the range of design vessels is large liner, an outer set of primary fender would become necessary The vertical as well as horizontal disposition of fenders shall be so designed as to prevent the ship's hull and/or berthing structure being damaged under all tidal conditions. Ship's bow radius and approach and flair angle and in specific cases, may extend from the cope level to the low water level.

10 EXPANSION JOINTS

10.1 A sufficient number of expansion joints shall be provided depending upon the type of the structure, the sub-soil and the atmosphere conditions in order to accommodate movements arising from shrinkage, temperature changes and some yielding of the foundation. The steel reinforcement shall be so designed that it also acts to provide the shrinkage and temperature cracks.

10.2 As a general rule, a length of 60 m to 300 m between the expansion joints is recommended for structures, such as solid quay walls or pile supported deck structures. Expansion gap shall be provided however in general depending on type of structure, type of soil and deflection during earthquake. The expansion gap shall be calculated considering Limit State of Serviceability load combinations and provide suitably. The crane track shall be designed suitably at expansion joints. For suspended deck resting on flexible long piles, length of the expansion joint shall be based on the detailed analysis of the whole structure.

10.3 The expansion joints in the sections shall be keyed where horizontal forces are required to be transferred to the adjoining section and shall be so designed that changes in the length of the sections are not hindered. The arrangement of keys for vertical support shall depend on the soil conditions, the construction of the structure and the type of its loading. The expansion joints shall be covered to prevent the backfill from being washed out.

11 BERTHING STRUCTURE SPECIFICATIONS

11.1 Deck Elevation

11.1.1 *Minimum Deck Top Level*

The minimum deck top level shall be equal to (Mean High water spring + 50 percent of design wave height + sea level rise of 0.3 m). The design wave height can be assumed as 1.6 to 1.8 times significant wave height for a return period of 100 years. The Slamming force is to be considered if the deck is subjected to slamming due to wave / storm surge / Tsunami.

For fishing harbours and small crafts (Passenger and fishing vessels), deck elevation can be lower then estimated as per extreme loading. However, different landing levels shall be considered taking into account the tidal range. The deck may be submerged during extreme events and the design shall consider the forces during such events.

In case of extension of the existing structure as a contiguous structure then the level of the new berth can be same as that of existing berthing facility.

11.2 Bracing of the Piles and Temporary Bracings

A pile driven at an inclination to the vertical to provide resistance to horizontal forces is known as brace pile. Design of bracing must consider the lateral forces due to currents, waves, earthquake, berthing and mooring etc. Sometimes bracing of the piles shall be done to strengthen the structure. In the case of temporary bracing, structure shall be checked before and after the removal of temporary bracings.

11.3 Reinforcement Detailing of Piles

The minimum shear reinforcement need not be provided when maximum shear stress calculated is less than half the permissible stress in accordance with clause **26.5.1.6** of IS 456. For ductility requirement in piles 12 mm diameter stirrups shall be provided at a spacing of 150 mm c/c for distance of *L* / 6 from the top for piles in seismic zone 3, 4 and 5. Effective length of the pile shall be taken based on sway and non-sway frame condition as per Annex E of IS 456.

12 INTEGRITY TEST/ FREE VIBRATION TEST OF BERTHING STRUCTURES

The free vibration test shall be carried out to know the natural frequency of the structure by pushing the structure using a TUG boat. The Free vibration response of the structure can be recorded using three acceleration pick-ups mounted orthogonally. This test can be repeated after any natural calamity to assess the damage of the structure.

ANNEX A
(*Clause* **2**)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
IS 269 : 2015	Ordinary portland cement - Specification (*Sixth Revision*)
IS 401 : 2001	Preservation of timber — Code of practice (*fourth revision*)
IS 455 : 2015	Portland slag cement — Specification (*fifth revision*)
IS 456 : 2000	Plain and reinforced concrete — Code for practice (*fourth revision*)
IS 800 : 2007	General construction in steel — Code of practice (*third revision*)
IS 875	Design loads (other than earthquake) for buildings and structures — Code of practice
(Part 3): 2015	Wind loads (*third revision*)
(Part 5): 1987	Special loads and combinations (*second revision*)
IS 883 : 2016	Design of structural timber in buildings — Code of practice (*fifth revision*)
IS 1343 : 2012	Prestressed concrete — Code of practice (*second revision*)
IS 1489	Portland pozzolana cement — Specification
(Part 1): 2015	Fly ash based (*fourth revision*)
(Part 2): 2015	Calcined clay based (*fourth revision*)
IS 1893	Criteria for earthquake resistant design of structures
(Part 1): 2016	General provisions and buildings (*sixth revision*)
IS 2062 : 2011	Hot rolled medium and high tensile structural steel – Specification (*seventh revision*)
IS 2911	Design and construction of pile foundations: — Code of practice
(Part 1)	Concrete piles
Sec 1: 2010	Driven cast *in-situ* concrete piles (*second revision*)
Sec 2: 2010	Bored cast *in-situ* concrete piles (*second revision*)
Sec 3: 2010	Driven precast concrete piles (*second revision*)
Sec 4: 2010	Precast concrete piles in prebored holes (*first revision*)

IS No.	*Title*
IS 269 : 2015	Ordinary portland cement - Specification (*Sixth Revision*)
(Part 2): 2021	Timber piles (*second revision*)
IS 4651 (Part 3): 2020	Planning and design of ports and harbours — Code of practice Part 3 Loading (*second revision*)
IS 7314: 2023	Port and harbour engineering — Glossary of terms (*first revision*)

ANNEX B
(*Clause* **4.3**)

FORCES DUE TO TSUNAMI

B-1 TSUNAMI FORCES

The hydrostatic force due to hydrostatic head and tsunami flow velocity can be estimated from,

$$F_{\mathrm{h}} = \frac{1}{2}\rho g\left[(h + 3\eta)^2 + \frac{u_{\mathrm{t}}^2}{g}(h + 3\eta)\right]$$

where,

ρ is the seawater density;

g is the gravitational acceleration;

h is the water depth at the toe of the structure;

η is 1/3 of the tsunami run up given in table 5 and is equal to the tsunami height at 10 m water depth; and

u_{t} is the water particle velocity

$$u_i = \sqrt[2]{g(h + \eta)}$$

Where u_i is in m/s, g is in m/s^2 and η is in m

If the wave height is less than $(h + 3\eta)$, suitable correction to be made in the equation

B-2 The tsunami wave height at 10 m water depth can be calculated as 1/3 times tsunami runup at the coast as given Table 5. The above equation calculates if the height of the wall is more than the tsunami run-up above the design water level. However, if the wall height is less than $(h + 3\eta)$, then suitably, the total hydrostatic force can be estimated. The static pressure force due to flow velocity head is adopted to be uniform throughout the water depth. However, for transparent structures such as open pile type structures, the hydrostatic force can be neglected.

B-3 The water level rise due to Tsunami shall be as per Table 5. The hydrostatic force due to Tsunami of vertical face structure shall be calculated as per **B-1** and for offshore berthing structures air gap of 0.5 m shall be given above tsunami water level.

Table 5 Water level raise due to Tsunami
(*Clause* **B-2** *and* **B-3**)

Sl No. (1)	Location (2)	Run up (m) (3)
a)	**Tamilnadu**	
i)	Katupalli	-
ii)	Ennore Creek	-
iii)	Light House Chennai	2.2
iv)	Kottivakam	3.9
v)	Mutukadu	3.1
vi)	Thalanguda, Cuddalore	2.7

vii)	Silver beach, Thevanampattinam, Cuddalore	4.6
viii)	Parankipettai, Centre for Biological sciences	2.3
ix)	Poompuhar	4.7
x)	Tharangambadi Village	3.6
xi)	Karikal Beach	3.5
xii)	Nagore	4.8
xiii)	Nagapattinam Port	3.6
b)	**Kerala**	
i)	Thiruvananthapuram	1.5
ii)	Kollam	3
iii)	Kayamkulam	4.5
iv)	Azhikkal	5
v)	Alapuzha to Kozhikode	1.0-3.5
c)	**South Andaman**	
i)	JNRM college, Aberden	2.9
ii)	Bamboo Flat	3.5
iii)	Wandoor	3.9
iv)	Chidiyatopu	4.5
d)	**North Andaman**	
i)	Diglipur	1.5
ii)	Rangat	1.5
e)	**Little Andaman**	
i)	Hut Bay	5.0
f)	**Car Nicobar**	
i)	Malacca	7.0
g)	**Great Nicobar**	
i)	Campbell Bay (central)	3.0
ii)	Campbell Bay (North)	6.0

NOTE — The Run up shown in table is with respect to local mean sea level. in case of alternate location, the nearest location as per the table can be considered or site specific data can be collected for the run off and the same can be considered.