Indian Standard

CODE OF PRACTICE FOR PLANNING AND DESIGN OF PORTS AND HARBOURS

PART III LOADING

(First Revision)

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Indian Standard
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PART III LOADING

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part III) (First Revision) was adopted by the Indian Standards Institution on 15 March 1974, after the draft finalized by the Ports and Harbours Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A great need has been felt for formulating standard recommendations relating to various aspects of waterfront structures. This standard is one of a series of Indian Standards proposed to be formulated on this subject. IS: 4651 (Part I)-1974* relates to site investigation. This part (Part III) deals with loading. This standard was published in 1969. In first revision, besides other changes, details on ships characteristics and the methods for determining wave forces have been added.

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

0.4 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, shall be rounded off in accordance with IS : 2-1960†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part III) deals with the loading on waterfront structures. It covers vertical live loads, horizontal forces due to berthing, bollard pulls, wave forces, currents and winds; reference is given to earthquake forces.

*Code of practice for planning and design of ports and harbours: Part I Site investigation (*first revision*).

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

2. DEFINITIONS OF SHIP TONNAGES

2.1 Gross Registered Tonnage — Usually designated as GRT, is broadly the capacity in cubic feet of the spaces within the hull, and of the enclosed spaces above the deck available for cargo, stores, passengers and crew, with certain exceptions, divided by 100.

Thus 100 cubic feet of capacity is equivalent to 1 gross ton.

2.2 Net Registered Tonnage — Usually designated as NRT, is derived from the gross tonnage by deducting spaces used for the accommodation of the master, officers, crew, navigation, propelling machinery and fuel.

2.3 Dead Weight Tonnage — Usually designated as DWT, is the weight in tons (of 2 240 lb) of cargo, stores, fuel, passengers and crew carried by the ship when loaded to her maximum summer load line.

2.4 Displacement Tonnage — Is the actual weight of the vessel, or the weight of water she displaces when afloat and may be either 'loaded' or 'light'.

Displacement, loaded, is the weight, in long tons, of the ship and its contents when fully loaded with cargo, to the plimsoll mark or load line.

Displacement, light, is the weight, in long tons, of the ship without cargo, fuel and stores.

3. SHIP CHARACTERISTICS

3.1 Relationship between the various tonnages are generally as follows:

Type of Ship	*Gross Registered Tonnage* (GRT)	*Net Registered Tonnage* (NRT)	*Dead Weight Tonnage* (DWT)	*Displacement Tonnage*
(1)	(2)	(3)	(4)	(5)
Large sea going vessels	1	0·6	—	—
Small sea going vessels	1	0·4	—	—
Freighters	1	—	1·5	2
Large tankers	1	—	2	*see* **3.1.2**
Large combined carriers	1	—	1·8	1·9
Large passenger ships	1	—	—	1
Passenger ships	1	—	1	—
Inland water way craft	1	0·8	—	—
Other types of ships	1	—	1·2	—

3.1.1 For bulk carriers, relationship between GRT and DWT is generally as follows:

$$DWT = 1{\cdot}649\ GRT + 1\ 462$$

3.1.2 For tankers, relationships between DWT and DT are generally as follows:

DWT	25 000	50 000	80 000	100 000	125 000	225 000 and above
DT/DWT	1·32	1·26	1·25	1·20	1·17	1·15

3.2 Ship Dimensions — For preliminary design purposes the ship dimensions given in Appendix A may be used. For detailed design ship dimensions appropriate to the type of service required may be obtained from a Register of Shipping, such as Lloyds Register of Shipping.

4. DEAD LOADS

4.1 All dead loads of and on structures relating to docks and harbours should be assessed and included in the design.

5. LIVE LOADS

5.1 Vertical Live Loads

5.1.1 Surcharges due to stored and stacked material, such as general cargo, bulk cargo, containers and loads from vehicular traffic of all kinds, including trucks, trailers, railway, cranes, containers handling equipment and construction plant constitute vertical live loads.

5.1.2 *Truck Loading and Uniform Loading* — The berths shall be generally designed for the truck loading and uniform loading as given in Table 1.

TABLE 1 TRUCK LOADING AND UNIFORM LOADING

FUNCTION OF BERTH	TRUCK LOADING (IRC CLASS)	UNIFORM VERTICAL LIVE LOADING T/m²
(1)	(2)	(3)
Passenger berth	B	1·0
Bulk unloading and loading berth	A	1 to 1·5
Container berth	A or AA or 70 R	3 to 5
Cargo berth	A or AA or 70 R	2·5 to 3·5
Heavy cargo berth	A or AA or 70 R	5 or more
Small boat berth	B	0·5
Fishing berth	B	1·0

NOTE — The relevant Indian Road Congress (IRC) codes may be referred for axle load. The spacing of the loads may be changed to suit individual design requirements.

5.1.3 *Crane Loads* — Concentrated loads from crane wheels and other specialized mechanical handling equipment should be considered. An impact of 25 percent shall be added to wheel loads in the normal design of deck and stringers, 15 percent where two or more cranes act together, and 15 percent in the design of pile caps and secondary framing members.

5.1.4 *Railway Loads* — Concentrated wheel loads due to locomotive wheels and wagon wheels in accordance with the specification of the Indian Railways for the type of gauge and service at the locality in question.

5.1.5 For impact due to trucks and railways one-third of the impact factors specified in the relevant codes may be adopted.

5.1.6 *Special Loads* — Special loads like pipeline loads or conveyor loads or exceptional loads, such as surcharge due to ore stacks, transfer towers, heavy machinery or any other type of heavy lifts should be individually considered.

5.1.7 When the live loads act on the fill behind the structure, such as in a sheet pile wharf so that the loads are transmitted to the structure through increased earth pressure the retaining structure may be designed for uniformally distributed equivalent surcharge of half the value given in col 3 of Table 1. In cases where higher load intensity is expected the actual value of surcharge may be taken.

5.1.8 If truck cranes are to be used in cargo handling, or if the backfill in a retaining structure is proposed to be placed with earth moving equipment of the crawler type, the uppermost portion of the waterfront structures, including the upper anchorage system should be designed according to the following loadings, whichever of the two is more unfavourable:

a) Live load of 6·0 tonnes per square metre from back edge of the coping inboard for a 1·50-m width.

b) Live load of 4·0 tonnes per square metre from the back edge of the coping inboard for a 3·5-m width.

5.2 Berthing Load

5.2.1 *Berthing Energy* — When an approaching vessel strikes a berth a horizontal force acts on the berth. The magnitude of this force depends on the kinetic energy that can be absorbed by the fendering system. The reaction force for which the berth is to be designed can be obtained and deflection-reaction diagrams of the fendering system chosen. These diagrams are obtainable from fender manufacturers. The kinetic energy, E, imparted to a fendering system, by a vessel moving with velocity V m/s is given by:

$$E = \frac{W_D \times V^2}{2g} \times C_m \times C_e \times C_s$$

where

W_D = displacement tonnage (DT) of the vessel, in tonnes;

V = velocity of vessel in m/s, normal to the berth (*see* **5.2.1.1**);

g = acceleration due to gravity in m/s^2;

C_m = mass coefficient (*see* **5.2.1.2**);

C_e = eccentricity coefficient (*see* **5.2.1.3**); and

C_s = softness coefficient (*see* **5.2.1.4**).

NOTE — Some authorities believe that it is difficult to establish consistent mathematical relationship between approach velocity of a vessel and the energy of impact because of many unknown and uncontrollable factors. A statistical approach based on recorded measurement of approach velocities and berthing energy at some British Petroleum Company tanker terminals provides a sound basis for design criteria than mathematical calculations based on velocity. According to Dent and Saurin* the following criteria for berthing energy should be considered adequate:

a) For off-shore terminals with average exposure condition

1) Fender capacity at each end of the jetty 2·30 tonne-metre per 1 000 DWT of design ship at yield stress in the fenders 1·52 tonne-metre per 1 000 DWT as a normal maximum allied to approximately working stress in the fenders.

2) Fender reaction: A fender reaction of not more than 500 tonnes relative to 2·30 tonne-metre energy criteria. A fender reaction of the order of 300 tonne for the 1·52 tonne-metre energy criteria.

3) Distribution of thrust on ship — The thrust in (2) above to be distributed over a length of hull not less than the spacing between the transverse frames of the designship.

4) For protected harbour condition and for terminals where vessels berth in ballast, the design criteria to be adopted for the design of berthing structure is 62·5 percent of the vessels specified under (1) and (2).

5.2.1.1 *Approach velocities* — Normal components of approach velocities of berthing vessels are recommended to be taken as given in Table 2.

Berthing conditions will depend on alignment of the berth relative to currents, availability of tugs, physical layout of the harbour, winds and waves at time of berthing.

5.2.1.2 *Mass coefficient* — When a vessel approaches a berth and as its motion is suddenly checked, the force of impact which the vessel imparts comprises of the weight of the vessel and an effect from the water moving along with the moving vessel. Such an effect, expressed in terms of weight of water moving with the vessel, is called the additional weight

*Tanker Terminals Berthing Structures by G. E. Dent & B. F. Saurin.

TABLE 2 NORMAL VELOCITIES OF VESSELS

(*Clause* 5.2.1.1)

Sl No.	Site Condition	Berthing Condition	Berthing Velocity Normal to Berth in m/s			
			Up to 5 000 DT	Up to 10 000 DT	Up to 100 000 DT	More than 100 000 DT
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Strong wind and swells	Difficult	0·75	0·55	0·40	0·20
ii)	Strong wind and swells	Favourable	0·60	0·45	0·30	0·20
iii)	Moderate wind and swells	Moderate	0·45	0·35	0·20	0·15
iv)	Sheltered	Difficult	0·25	0·20	0·15	0·10
v)	Sheltered	Favourable	0·20	0·15	0·10	0·10

(W_A) of the vessel or the hydrodynamic weight of the vessel. Thus the effective weight in berthing is the sum of displacement tonnage of a vessel and its additional weight, which is known as virtual weight (W_V) of a vessel.

a) The mass coefficient C_m should be calculated as follows:

$$C_m = 1 + \frac{2D}{B}$$

where

D = draught of the vessel in m,

B = beam of the vessel in m.

b) Alternative to (a) in case of a vessel which has a length much greater than its beam or draught generally for vessels with displacement tonnage greater than 20 000 the additional weight may be approximated to the weight of a cylindrical column of water of height equal to the length of vessel and diameter equal to the draught of vessel, then

$$C_m = 1 + \frac{\pi/4\, D^2\, Lw}{W_D}$$

where

D = draught of the vessel in m,

L = length of the vessel in m,

w = unit weight of water (1·03 tonnes/m² for sea water), and

W_D = displacement tonnage of the vessel in tonnes.

NOTE — *Virtual weight* — The virtual weight of the vessel should be calculated as follows:

$$W_v = W_D \times C_m$$

where

W_v = virtual weight of the vessel in tonnes, and

W_D = displacement tonnage of the vessel in tonnes.

5.2.1.3 *Eccentricity coefficient* — A vessel generally approaches a berth at an angle, denoted by θ and touches it at a point either near the bow or stern of the vessel. In such eccentric cases the vessel is imparted a rotational force at the moment of contact, and the kinetic energy of the vessel is partially expended in its rotational motion.

a) The eccentricity coefficient (C_e) may then be derived as follows:

$$C_e = \frac{1 + (l/r)^2 \sin^2 \theta}{1 + (l/r)^2}$$

where

l = distance from the centre of gravity of the vessel to the point of contact projected along the water line of the berth in m, and

r = radius of gyration of rotational radius on the plane of the vessel from its centre of gravity in m (P-CG in Fig. 1).

Table 3 gives eccentricity coefficient values of l/r.

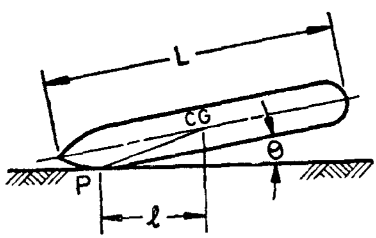


FIG. 1 VESSEL APPROACHING BERTH AT AN ANGLE

b) The approach angle θ unless otherwise known with accuracy should be taken as 10°. For smaller vessels approaching wharf structures, the approach angle should be taken as 20°.

c) The rotational radius of a vessel may be approximated to $L/4$ and, in normal case, the point of contact of the berthing vessel with the structure is at a point about $L/4$ from the bow or stern of the vessel, which is known as a quarter point contact. Also, if the approach angle θ is nearly 0°, then

For large tankers, $r = 0{\cdot}2\ L$

Then $C_e = 0{\cdot}4$.

TABLE 3 VALUES OF ECCENTRICITY COEFFICIENT

[*Clause* 5.2.1.3 (*a*)]

l/r	Angle θ		
	0°	10°	20°
1	0·50	0·51	0·56
1·25	0·39	0·41	0·46

5.2.1.4 *Softness coefficient* — This softness coefficient (C_s) indicates the relation between the rigidity of the vessel and that of the fender, and hence also that between the energy absorbed by the vessel and by the fender. Since the ship is relatively rigid compared with the usually yielding fendering systems, a value of 0·9 is generally applied for this factor, or 0·95 if higher safety margin is thought desirable.

5.2.2 High energy absorption is required during the mooring of very large vessels. However, the reaction force against the side of large vessels should not exceed 40 tonnes/m².

5.2.2.1 Deflection-reaction diagram should give the berthing energy which the fender system can absorb. A fender system includes fenders and the berthing structure. The reaction force for the fenders and the structures will be the same.

5.2.3 Berthing load and, therefore, the energy of impact is to be considered for pier, dolphin and the like, with no backfill. In the case of continuous structures with backfill this may not form a governing criterion for design, because of the enormous passive pressure likely to be mobilized. However, short lengths of gravity type, sheet pile type or relieving platform type berths may have to be checked for impact of vessels.

5.3 Mooring Loads

5.3.1 The mooring loads are the lateral loads caused by the mooring lines when they pull the ship into or along the dock or hold it against the forces of wind or current.

5.3.2 The maximum mooring loads are due to the wind forces on exposed area on the broad side of the ship in light condition:

$$F = C_w\ A_w\ P$$

where

F = force due to wind in kg,

C_w = shape factor = 1·3 to 1·6,

A_w = windage area in m² (*see* **5.3.2.1**), and

P = wind pressure in kg/m² to be taken in accordance with IS : 875-1964*.

5.3.2.1 The windage area (A_w) can be estimated as follows:

$$A_w = 1{\cdot}175\ L_p\ (D_M - D_L)$$

where

L_p = length between perpendicular in m,

D_M = mould depth in m, and

D_L = average light draft in m.

5.3.3 When the ships are berthed on both sides of a pier, the total wind force acting on the pier, should be increased by 50 percent to allow for wind against the second ship.

5.3.4 The appropriate load on the bollard shall then be calculated, which depends upon the layout of harbour, and position of bow line, stern line, spring line and breasting lines; for guidance the bollard pulls independent of the number of laid-on hawsers, may be taken as given in Table 4 since the hawsers are not fully stressed simultaneously.

TABLE 4 BOLLARD PULLS

(*Clauses* 5.3.4 *and* 6.1)

Displacement (Tons)	Line Pull (Tonnes)
(1)	(2)
2 000	10
10 000	30
20 000	60
50 000	80
100 000	100
200 000	150
Greater than 200 000	200

Note 1 — For ships of displacement tonnage 50 000 and over the value of line pulls given above should be increased by 25 percent at quays and berths where there is a strong current.

Note 2 — Main bollards at the ends of individual large vessel berths at river structures should be designed for a line pull of 250 tons for ships up to 100 000 tons displacement and for double the values given above for larger ships.

*Code of practice for structural safety of buildings: Loading standards (*revised*).

5.3.5 The line pull will be towards the water and may make any angle to the longitudinal direction of the structure and is usually assumed to act horizontally.

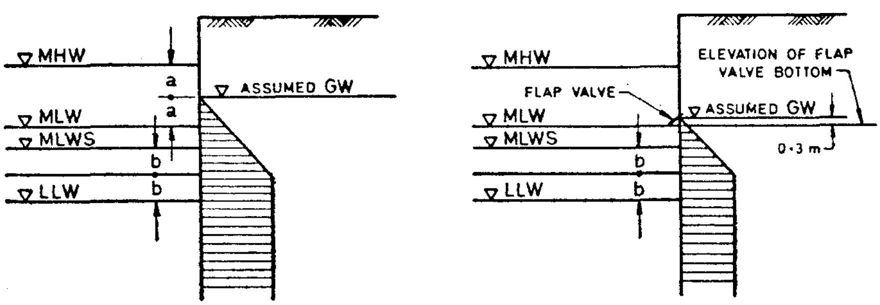
5.3.6 In the design calculations of the bollard itself and its connections to the structure, line pull up to 30° and above the horizontal should be considered.

5.3.7 Pressure on the vessel as well as the structure due to the current should be taken into account, especially with a strong current and where the berth alignment deviates from the direction of the current. Determination of these forces is dealt with in **5.6**.

5.4 Differential Water Pressure

5.4.1 In the case of waterfront structures with backfill, the pressure caused by difference in water levels at the fillside and the waterside has to be taken into account in design. The magnitude of this hydrostatic pressure is influenced by the tidal range, free water fluctuations, the ground water influx, the permeability of the foundation soil and the structure as well as the efficiency of available backfill drainage.

5.4.2 In the case of good and poor drainage conditions of the backfill the differential water pressure may be calculated on the guidelines given in Fig. 2. The level between MLWS and LLW is 'assumed LLW'.



2A Poor Drainage Condition 2B Good Drainage Condition

MHW = Mean high water
MLW = Mean low water
MLWS = Mean low water springs
LLW = Lowest low water
GW = Ground water

Fig. 2 Guide for Calculating Differential Water Pressure

5.5 Earthquake Forces — In areas susceptible to seismic disturbance, horizontal force equal to a fraction of the acceleration of gravity times the weight applied as its centre of gravity should be taken. The fraction will depend upon the likely seismic intensity of the area, and shall be taken in accordance with IS : 1893-1970*. The weight to be used is the total dead load plus one-half of the live load.

5.6 Forces due to Current — Pressure due to current will be applied to the area of the vessel below the water line when fully loaded. It is approximately equal to $w\ v^2/2\ g$ per square metre of area, where v is the velocity in m/s and w is the unit weight of water in tonnes/m^3. The ship is generally berthed parallel to the current. With strong currents and where berth alignment materially deviates from the direction of the current, the likely force should be calculated by any recognized method and taken into account.

5.7 Wave Forces

5.7.1 As far as analysis and computation of forces exerted by waves on structures are concerned, there are three distinct types of waves, namely:

a) Non-breaking waves,

b) Breaking waves, and

c) Broken waves.

5.7.2 *Non-breaking Waves*

5.7.2.1 Generally, when the depth of water against the structure is greater than about $1\frac{1}{2}$ times the maximum expected wave height non-breaking wave conditions occur.

5.7.2.2 Forces due to non-breaking waves are essentially hydrostatic. ' Sainflou Method ' may be used for the determination of pressure due to non-breaking waves. The method of computation using Sainflou Method is outlined in Appendix B.

5.7.3 *Breaking Waves*

5.7.3.1 Breaking waves cause both static and dynamic pressures.

5.7.3.2 Determination of the design wave for breaking wave conditions may be based on depth of water about seven breaker heights H_b, seaward of the structure, instead of the water depth at which the structure is located.

5.7.3.3 The actual pressures caused by a breaking wave is obtained by following the method suggested by Minikin. The method of computation using Minikin's Method is outlined in Appendix C.

5.7.4 *Broken Waves*

5.7.4.1 Locations of certain structures like protective structure will be such that waves will break before striking them. In such cases, no exact formulae have been developed so far to evaluate the forces due to broken waves, but only approximate methods based on certain simplifying assumptions are available and these are given in Appendix D.

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*Criteria for earthquake resistant design of structures.

5.7.5 *Wave Forces on Vertical Cylindrical Structures, such as Piles*

5.7.5.1 The total force '*F*' exerted by non-breaking waves on a cylindrical pile can be divided into two components:

a) Force due to drag, and

b) Force due to inertia.

In many of the cases it may be sufficient to know the maximum crest elevation, wavelength and maximum total force and overturning moments.

A set of generalized graphs which are available in accepted publications *together with the following formulae may be used to compute these:

$$F_{DM} = \tfrac{1}{2} C_D \rho D H^2 K_{DM}$$

$$F_{IM} = \tfrac{1}{2} C_M \rho D^2 H K_{IM}$$

$$F_M = \frac{F_M}{F_{DM}} F_{DM}$$

$$M_{DM} = S_D F_{DM}$$

$$M_{IM} = S_I F_{IM}$$

$$M_M = \frac{F_M}{F_{DM}} M_{DM}$$

where

F_{DM} = total drag force on a vertical pile from the sea bottom to the surface crest elevation and this occurs at the crest positions, in kg;

C_D = drag coefficient — value of 0·53 is suggested for design purposes;

ρ = mass density of sea water = $\left(\frac{w}{g}\right)$ = 104·99 kg·s²/m;

D = diameter of pile, in m;

H = wave height, in m;

K_{DM} = drag force factor, in m/s²;

F_{IM} = total inertial force on a vertical pile from the seabed to the free surface elevation, in kg (occurs at some phase position between the crest and one-quarter of the wavelength);

C_M = inertial coefficient, usually taken as 2·0 for vertical circular pile;

K_{IM} = inertial force factor, in m/s²;

F_M = maximum value of the combined drag and inertial force, in kg;

*Reference may be made to 'Shore Protection, Planning and Design', Technical Report No. 4 (Third Edition), U. S. Army Coastal Engineering Research Centre.

M_{DM} = moment on pile about bottom associated with maximum drag force, in kg·m;

S_D = effective lever arm for F_{DM} from the bottom of pile, in m;

M_{IM} = moment on pile about bottom associated with maximum inertial force, in kg·m;

S_I = effective lever arm for F_{IM} from the bottom of pile in m; and

M_M = maximum total moment, in kg·m.

5.7.5.2 The wave forces are smallest for piles of cylindrical cross section. For piles with flat or irregular surfaces, such as concrete and H pipes, very little is known of the effect of shape on drag and inertial forces.

5.7.5.3 Tests have indicated that the wave forces are smallest for a cylindrical section, increasing about 25 percent for a flat plate of the same projected width, between 42 and 158 percent for H sections perpendicular to the wave and between 122 and 258 percent when oriented at 45°. These figures have been indicated for guidance purposes.

5.8 Wind Forces — Wind forces on structures shall be taken in accordance with IS : 875-1964* as applicable.

6. COMBINED LOADS

6.1 The combination of loadings for design is dead load, vertical live loads, plus either berthing load, or line pull, or earthquake or wave pressure. If the current and alignment of the berth are likely to give rise to line pull in excess of that given in Table 4, provisions for such extra pull in combination of likely wind should be made. The worst combination should be taken for design.

APPENDIX A

(*Clause* 3.2)

DIMENSIONS OF SHIPS

A-1. BULK CARRIERS

Dead Weight Tonnage	*Overall Length*	*Width*	*Height*	*Fully Laden Draught*
Tons	m	m	m	m
4 000	100·0	15·4	7·0	6·3
6 000	118·0	16·6	8·3	6·9
8 000	130·0	17·6	9·5	7·4

*Code of practice for structural safety of buildings: Loading standards (*revised*).

Dead Weight Tonnage Tons	*Overall Length* m	*Width* m	*Height* m	*Fully Laden Draught* m
10 000	140·0	18·5	10·5	7·9
12 000	150·0	19·4	11·2	8·5
15 000	163·0	20·7	12·0	9·0
20 000	180·0	22·8	13·0	9·7
25 000	194·0	24·7	13·8	10·3
30 000	205·0	26·5	14·3	10·7
40 000	223·0	29·7	15·4	11·1
50 000	235·0	32·5	16·2	11·3
60 000	245·0	35·0	17·1	12·0
80 000	259·0	39·2	18·8	12·6
100 000	268·0	42·5	20·4	13·0

A-2. TANKERS

Dead Weight Tonnage Tons	*Length* m	*Width* m	*Height* m	*Fully Laden Draught* m
700	48·0	8·6	4·2	3·8
1 000	53·0	9·1	4·7	4·1
2 000	68·0	10·2	5·5	4·8
3 000	81·0	11·3	6·3	5·4
4 000	92·0	12·3	6·9	5·9
5 000	102·0	13·3	7·5	6·3
6 000	111·0	14·1	8·1	6·7
8 000	126·0	15·7	9·0	7·4
10 000	140·0	17·2	9·8	7·9
12 000	150·0	18·4	10·4	8·3
15 000	163·0	20·0	11·2	8·8
17 000	170·0	21·0	11·7	9·1
20 000	178·0	22·4	12·3	9·5
25 000	190·0	24·2	13·0	10·0
30 000	200·0	25·8	13·6	10·3
35 000	208·0	27·4	14·2	10·6
40 000	215·0	29·0	14·7	10·9
45 000	223·0	30·5	15·2	11·2
50 000	230·0	32·0	15·7	11·4
65 000	250·0	34·0	18·0	13·3
85 000	260·0	38·1	18·7	14·0
100 000	285·0	41·2	20·6	14·6
200 000	310·0	47·1	26·3	18·9
300 000	339·0	53·2	30·7	21·9
400 000	370·0	57·0	36·5	26·7
500 000	398·0	69·0	39·4	26·0

A-3. COMBINATION BULK/ORE CARRIERS (100 000 DWT NOMINAL)

Dead Weight Tonnage Tons	*Overall Length* m	*Breadth (Moulded)* m	*Depth (Moulded)* m	*Draught (Loaded)* m	*Draught (Ballast)* m
119 190	270	42·00	21·20	15·60	8·4
112 900	261	40·20	21·40	15·50	10·62 (*Max*)
113 180	261	40·60	24·00	16·00	10·69 ,,
102 824	259	41·30	20·40	14·20	8·29 ,,
118 000	261	42·00	22·80	16·13	9·0 ,,
104 330	259·7	38·00	21·30	15·52	9·37
111 120	261	40·60	23·00	16·00	9·36
98 720	255	40·20	23·90	14·63	9·00
113 180	261	40·60	23·00	16·00	9·74

A-4. MIXED CARGO FREIGHTERS

Gross Registered Tonnage Tons	*Dead Weight Tonnage* Tons	*Displacement Tonnage* Tons	*Overall Length* m	*Length Between Perpendiculars* m	*Width* m	*Draught* m
(1)	(2)	(3)	(4)	(5)	(6)	(7)
10 000	15 000	20 000	165	155	21·5	9·5
7 500	11 000	15 000	150	140	20·0	9·0
5 000	7 500	10 000	135	125	17·5	8·0
4 000	6 000	8 000	120	110	16·0	7·5
3 000	4 500	6 000	105	100	14·5	7·0
2 000	3 000	4 000	95	90	13·0	6·0
1 500	2 200	3 000	90	85	12·0	3·5
1 000	1 500	2 000	75	70	10·5	4·5
500	700	1 000	60	55	8·5	3·5

A-5. PASSENGER SHIPS

Gross Registered Tonnage	*Displacement Tonnage*	*Overall Length*	*Length Between Perpendiculars*	*Width*	*Draught*
Tons	Tons	m	m	m	m
(1)	(2)	(3)	(4)	(5)	(6)
80 000	75 000	315	295	35·5	11·5
70 000	65 000	315	295	34·0	11·0
60 000	55 000	310	290	32·5	10·5
50 000	45 000	300	280	31·0	10·5
40 000	35 000	265	245	29·5	10·0
30 000	30 000	230	210	28·0	10·0
20 000	—	200	180	23·0	9·0
10 000	—	155	145	19·0	8·5
5 000	—	125	115	16·0	7·0

A-6. FISHING VESSELS

Gross Registered Tonnage	*Displacement Tonnage*	*Overall Length*	*Length Between Perpendiculars*	*Width*	*Draught*
Tons	Tons	m	m	m	m
(1)	(2)	(3)	(4)	(5)	(6)
3 225	4 279	95	89	15·5	7·3
2 500	2 800	90	80	14·0	5·9
2 000	2 500	85	75	13·0	5·6
1 500	2 100	80	70	12·0	5·3
1 000	1 750	75	65	11·0	5·0
800	1 550	70	60	10·5	4·8
600	1 200	65	55	10·0	4·5
400	800	55	45	8·5	4·0
200	400	40	35	7·0	3·5
96	113	23	21	5·7	2·7
20	15·07	15	12	4·6	2·25
10	11	10	8·9	3·1	1·1

A-7. INLAND WATER WAY VESSELS

Capacity Tons	*Overall Length* m	*Overall Breadth* m	*Overall Depth* m	*Draught Light* m	*Draught Loaded* m
(1)	(2)	(3)	(4)	(5)	(6)
600	57	11·58	3·05	0·91	2·29
500	49·1	8·75	2·50	0·40	1·85
400	41	8·76	1·94	0·76	1·85
300	37·3	7·60	2·44	0·91	2·13
300	42	7·80	2·70	0·57	1·82
200	35·2	7·05	2·25	1·63	0·75
125	22	5·85	2·20	0·76	1·83

APPENDIX B

(*Clause* 5.7.2.2)

SAINFLOU METHOD

B-1. FORMATION OF CLAPOTIS

B-1.1 Suppose a wave of length L and height H strikes the vertical AC, a standing wave or clapotis is formed, features of which are given in Fig. 3:

$$h_o = \frac{\pi H^2}{L} \coth \frac{2 \pi d}{L}$$

$$P_1 = \frac{w H}{\cosh \frac{2 \pi d}{L}}$$

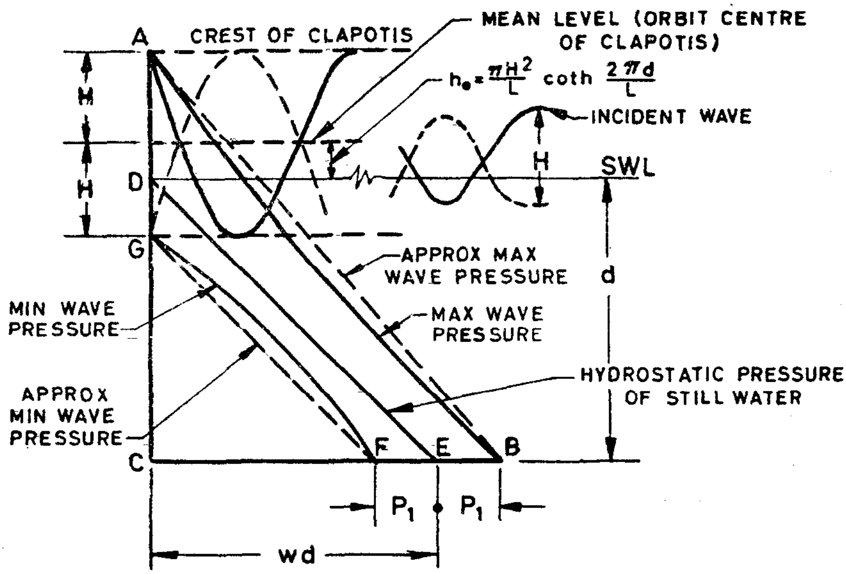
Symbols are explained in Fig. 3.

NOTE — Plotted graphs are available giving values of Lh_o and P_1 corresponding to various values of d/L ratio, from which values of h_o and P_1 can be readily obtained.

B-1.2 Assuming the same still water level on both sides of the wall, the pressure diagram will be as given in Fig. 4.

B-2. OTHER CASES

B-2.1 When there is no water on the landward side of the wall, then the total pressure on the wall will be represented by the triangle ACB (Fig. 3) when the clapotis crest is at A.



d = depth from stillwater level

H = height of original free wave

L = length of wave

w = weight per m^3 of water

P_1 = pressure the clapotis adds to or subtracts from still water pressure

h_o = height of orbit centre (on mean level) above still water level

$$P_1 = \frac{w\,H}{\text{Cosh}\,\frac{2\pi d}{L}}$$

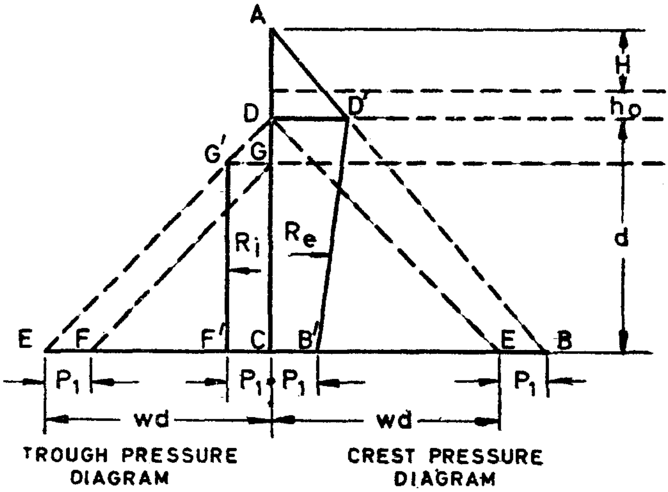
Fig. 3 Clapotis on Vertical Wall

B-2.2 If there is wave action on the landward side also, then the condition of crest of clapotis on the seaside and trough of the wave on the harbour side will produce maximum pressure from the seaside.

The maximum pressure from the harbour side will be produced when the trough of the clapotis on the seaside and the crest of wave on the land-side are at the structure.

B-2.3 Wall of Low Height — If the height of the wall is less than the predicted wave height at the wall, forces may be approximated by drawing the force polygon as if the wall were higher than the impinging waves then analyzing only that portion below the wall crest.

Forces due to a wave crest at the wall are computed from the area *AFBSC*, as shown in Fig. 5.



Considering unit length of wall,

$$R_e = \frac{(d+H+h_o)(wd+P_1)}{2} - \frac{wd^2}{2}$$

$$M_e = \frac{(d+H+h_o)^2(wd+P_1)}{6} - \frac{wd^3}{6}$$

$$R_i = \frac{wd^2}{2} - \frac{(d+h_o-H)(wd-P_1)}{2}$$

$$M_i = \frac{wd^3}{6} - \frac{(d+h_o-H)^2(wd-P_1)}{6}$$

where

R_e = the resultant pressure with maximum crest level,
M_e = the moment due to R_e about the base,
R_i = the resultant pressure with minimum trough level, and
M_i = the moment due to R_i about the base.

FIG. 4 SAINFLOU WAVE PRESSURE DIAGRAM

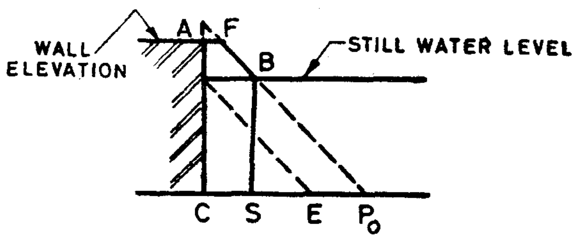


FIG. 5 PRESSURE ON WALLS OF LOW HEIGHT

APPENDIX C

(*Clause* 5.7.3.3)

MINIKIN'S METHOD

C-1. FORCE DUE TO BREAKING WAVES

C-1.1 Pressure caused by breaking waves is due to a combination of dynamic and hydrostatic pressures as given below:

a) The dynamic pressure is concentrated at still water level and is given by

$$P_m = 101 \frac{H_b\, w\, d}{L_D\, D} \, (D + d)$$

where

P_m = dynamic pressure, in kg/m²;
H_b = height of wave just breaking on the structures, in m;
w = unit weight of the water, in kg/m³;
d = depth of water at the structure, in m;
D = deeper water depth, in m; and
L_D = deeper water length, in m.

Values of L_D and D may be computed by accepted methods*.

b) The hydrostatic pressure P_s on the seaward side at still water level and the pressure P_d at the depth, d, are given by

$$P_s = \frac{w\, H_b}{2}$$

$$P_d = w\left(\frac{d + H_b}{2}\right)$$

For explanation of symbols, *see* Fig. 6.

C-2. CALCULATION OF FORCE AND MOMENT

C-2.1 The Minikin Wave Pressure diagram is given in Fig. 6.

C-2.1.1 *With Water on Land Side*

The resultant wave thrust R on structure per linear metre of structure is determined from the area of pressure diagram and is

$$R = \frac{P_m\, H_b}{3} + P_s\left(d + \frac{H_b}{4}\right)$$

*Reference may be made to 'Shore Protection, Planning and Design', Technical Report No. 4 (Third Edition), U. S. Army Coastal Engineering Research Centre.

The resultant overturning moment M about the ground line before the wall is the sum of the moments of the individual areas and is given by

$$M = \frac{P_m H_b}{3} d + \frac{P_s d^2}{2} + \frac{P_s H_b}{4}\left(d + \frac{H_b}{6}\right)$$

For explanation of symbols, *see* Fig. 6.

C-2.1.2 *With No Water on Land Side*

Thrust R per linear metre is

$$R = \frac{P_m H_b}{3} + \frac{P_d}{2}\left(d + \frac{H_b}{2}\right)$$

Moment M about the ground line is

$$M = \frac{P_m H_b}{3} d + \frac{P_d}{6}\left(d + \frac{H_b}{2}\right)^2$$

For explanation of symbols, *see* Fig. 6.

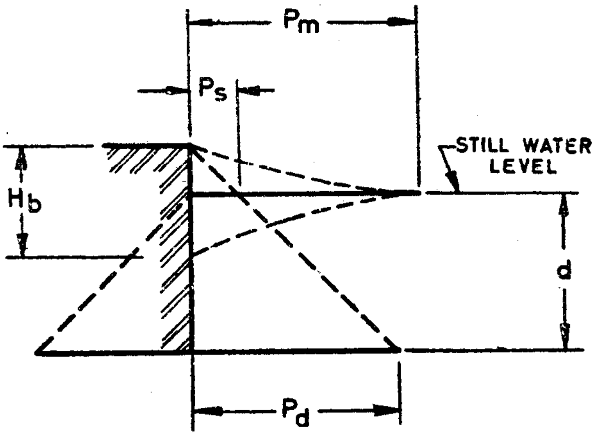


FIG. 6 MINIKIN WAVE PRESSURE DIAGRAM

APPENDIX D

(*Clause* 5.7.4.1)

BROKEN WAVES

D-1. WALL SEAWARD OF SHORELINE

D-1.1 Such walls are subjected to wave pressures which are partly dynamic and partly static (*see* Fig. 7).

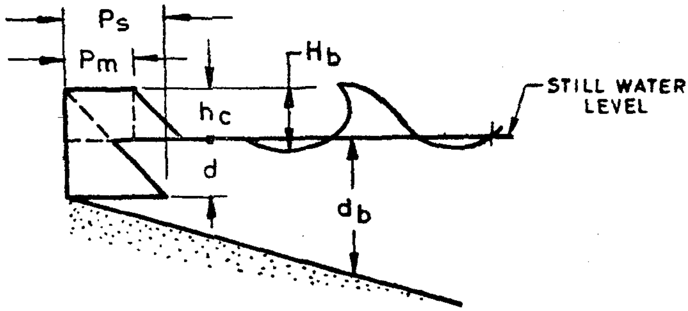


FIG. 7 WAVE PRESSURES FROM BROKEN WAVES; WALL SEAWARD OF SHORELINE

Dynamic part of the pressure P_m will be

$$P_m = \frac{wd_b}{2}$$

where

w = unit weight of water, in kg/m³; and

d_b = breaking wave depth, in m.

The static part will vary from zero at a height h_c, where h_c is the height of that portion of the breaking wave above still water level which is given by

$$h_c = 0{\cdot}7\ H_b$$

to the maximum static pressure at the wall base and this maximum pressure P_s will be given by

$$P_s = w\ (\ d + h_c\ )$$

where

d = depth of water at structure, in m.

Assuming that the dynamic pressure is uniformly distributed from the still water level to a height, h_c, above the still water level, the total wave thrust R will be

$$\begin{aligned} R &= R_m + R_s \\ &= P_m\ h_c + P_s \left(\frac{d + h_c}{2} \right) \\ &= \frac{wd_b\ h_c}{2} + \frac{w}{2}\ (\ d + h_c\ )^2 \end{aligned}$$

The overturning moment M, about the ground line at the seaward face of the structure will be

$$M = M_m + M_s$$

$$= R_m \left(d + \frac{h_c}{2} \right) + R_s \left(\frac{d + h_c}{3} \right)$$

$$= \frac{w d_b h_c}{2} \left(d + \frac{h_c}{2} \right) + \frac{w}{6} (d + h_c)^3$$

where

w = unit weight of water, in kg/m².

For explanation of other symbols, *see* Fig. 7.

D-2. WALL LANDWARD OF SHORELINE

D-2.1 Wave pressure diagram in this case will be as given in Fig. 8.

$$\text{Dynamic pressure } P_m = \frac{w d_b}{2} \left[1 - \frac{X}{X_2} \right]^2$$

$$\text{Static pressure } P_S = wh' = wh_c \left[1 - \frac{X_1}{X_2} \right]$$

$$\text{Wave thrust} = R = R_m + R_s$$

$$= P_m h' + P_s h'$$

$$= \frac{w d_b h_c}{2} \left[1 - \frac{X_1}{X_2} \right]^3 + \frac{w h_c^2}{2} \left[1 - \frac{X_1}{X_2} \right]^2$$

$$\text{Moment } M = M_m + M_s$$

$$= R_m \frac{h'}{2} + R_s \frac{h'}{3}$$

$$= \frac{w d_b h_c^2}{4} \left[1 - \frac{X_1}{X_2} \right]^4 + \frac{w h_c^3}{6} \left[1 - \frac{X_1}{X_2} \right]^3$$

where

w = unit weight of water.

For explanation of symbols, *see* Fig. 8.

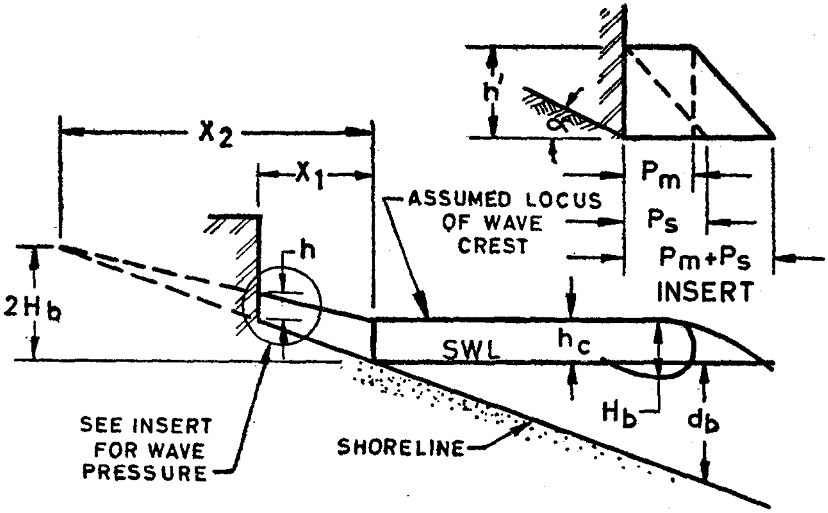


FIG. 8 WAVE PRESSURES FROM BROKEN WAVES: WALL LANDWARD OF SHORELINE