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Design of Catamaran Ship Main Deck and Bulkhead to Withstand the Crane Load

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Abstract:- Catamaran is a dual hull ship which has many advantages then the mono hull ship. Some of the advantages are excellent stability, Cruise in shallow water, large wide deck areas, large load carrying capacity, faster and Motion comfort etc. In this paper work, design of main or strength deck and Bulkhead structural member calculations for Catamaran ship used for transport for the crane (Mantis® 10010mx 46 ton tele-boom crawler crane) to its place of work. Ship's main deck or Strength deck hull structural scantlings or calculations play a very vital role in carrying the deck loads such as crane load safely against the external pressures which are acting on the deck. This can done by designing the suitable deck and hull plate thickness, and it's strengthening stiffening. The design of main deck involves determination of scantlings of deck plate, deck plate stiffeners, girders, pillars, Bulkhead and its stiffeners against the wheel load. Scantlings of deck and Bulkhead plates, stiffeners and girders to meet the local strength requirements are to be determined in accordance with the general principles of the rules. Scantlings of hull members should contribute the longitudinal strength of the ship and to be subjected to compressive stresses. The design calculations are carried out according to Indian Register of shipping (IRS) Rules and Regulations, Construction & Classification of steel ships July 2013. This design process gives the effective & efficient solutions to the new generation ships.

Keywords: Catamaran, Strength or Main deck, Bulkhead, Hull design, Structural members, Design loads, IRS rules 2013.

I. INTRODUCTION

Catamaran is a dual hull ship which has many advantages then the mono hull ship. Some of the advantages are excellent stability, Cruise in shallow water, large wide deck areas, large load carrying capacity, faster and Motion comfort etc.

In this project work, design of main deck for Catamaran ship used for transport for the crane (Mantis® 10010mx 46 ton tele-boom crawler crane) to its place of work in overseas. Decks contribute to structural strength and preserve watertight integrity. It's stiffened by the beams and longitudinal girders. The beams and girders are generally rolled steel tee bars, toe welded, the beams being slotted to enable the girders to be worked continuously. Comparing all decks the uppermost continuous deck, being farthest from the neutral axis of the ship's section and therefore the most highly stressed, is worked as a strength deck and the scantlings suitably increased. Only really essential openings are permitted to be cut in this deck, such openings have to be carefully disposed to avoid lines of weakness and the corners of each opening are radiused to reduce the concentration of stress which occurs there.

In this paper, Ship designing Rules like IRS (Indian Register of shipping July 2013) rules are used for calculating the scantlings of structural members of main deck and Bulkhead, where it can with stand crane loads acting upon the ship. The ship building materials which are approved by the classification society and amount of corrosion additions are added to actual design calculations are considered and demonstrate the model main deck calculations, Model outputs and Cad drawings.

Materials Of Construction

The Rules relate, in general, to the construction of steel ships.

STEEL GRADES

Ordinary hull structural steel is a hull structural steel with a minimum yield stress of 235 [N/mm2] and a tensile strength generally in the range of 400-490 [N/mm2]. For ordinary hull structural steel, the **material factor `k' is to be taken as 1.0 ----------** (5.1.a)

Steels having a yield stress of 265 [N/mm2] and higher, are regarded as higher tensile steels. Where higher tensile steel is used, the hull girder section modulus and the local scantlings may be reduced in accordance with the relevant requirement of the Rules. For this purpose, a material factor 'k', is to be taken as follows:
k = 0.78 for steel with a minimum yield stress of 315 [N/mm2]
k = 0.72 for steel with minimum yield stress of 355 [N/mm2]
k = 0.68 for steel with minimum yield stress of 390 [N/mm2].

1.1 CORROSION ADDITIONS:

The thickness of plates, stiffeners and girders in tanks for water ballast and/or cargo oil and in holds of dry bulk cargo carriers is to be increased by a corrosion addition 'tc'
The required corrosion addition 'Zc' to the section modulus of stiffeners and girders due to the thickness addition 'tc' mentioned above may be approximated as:

$$Z_c = \frac{t_c h_w (b_f + 0.3h_w)}{1000} \; [cm^3]$$

Where
Zc = corrosion addition [cm3]
t_C =thickness addition
hw = height of the web
bf =breadth of the flange

1.2 PRINCIPAL PARTICULARS CATAMARAN SHIP:

Length Over All (L.O.A)	19.5m
Length between Perpendiculars (L)	18.5m
Breadth	9.00m
Depth	2.0m
Draft	1.0m

II. FRAME SPACING

The normal frame spacing between aft peak and 0.2L from F.P. may be taken as:
450 + 2L [mm] for transverse framing,
550 + 2L [mm] for longitudinal framing
However, it is generally not to exceed 1000 [mm].
Elsewhere, the frame spacing is generally not to exceed the following:
- In peaks and cruiser sterns:
600 [mm] or as in (1), whichever is lesser.
- Between collision bulkhead and 0.2L from F.P.:
700 [mm] or as in (1), whichever is lesser.
Where the actual frame spacing is higher than that mentioned above, the minimum thicknesses of various structural members as given in the Rules may require to be increased.

Frame Spacing:

Frame spacing (s) = 550 + 2L [mm] for longitudinal framing.

= 550 + (2x18.5)
= 587mm

Let us consider Frame spacing is (s) = 500 mm

III. DECKS FOR WHEEL LOADING

Where it is proposed either to stow wheeled vehicles on the deck or to use wheeled vehicles for cargo handling, the requirements of this section are to be complied with in addition to those given in the preceding sections.

The requirements given below are based on the assumption that the considered element (Deck plating and/or stiffener) is subjected to one load area only, and that the element is continuous over several evenly spaced supports. The requirements for other loads and/or boundary conditions will be specially considered.
A "load area" is the tyre print area of individual wheels; for closely spaced wheels it may be taken as the enveloped area of the wheel group. These details are to include the proposed arrangement and dimensions of tyre prints, axle and wheel spacings, maximum axle load and tyre pressure.

Wheel load on deck

The pressure 'p' from the wheels on deck is to be taken as:

$$p = \frac{W}{n.a.b}.(9.81 + 0.5\,a_v).10^3 \;\; [N/mm^2]$$

where,

W = maximum axle load, [t]. For fork lift trucks, the total weight is to be taken as the axle load.
n = number of "load areas" per axle
a = extent [mm], of the load area parallel to the stiffener [Fig 3.0]
b = extent [mm], of the load area perpendicular to the stiffener [Fig 3.0]

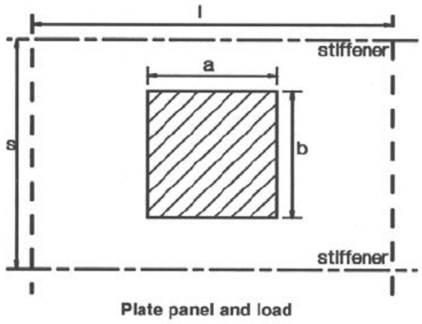


Fig. 3.0

a_v = vertical acceleration [m/s2], as follows:

for stowed vehicles, in sea going condition

$$a_v = \frac{9.81.k_v\,a_o}{C_b} \;\; [m/s^2]$$

for cargo handling vehicles in harbour condition

$$a_v = \frac{6}{\sqrt{W}} \;\; [m/s^2]$$

kv = 1.3 aft of A.P.
= 0.7 between 0.3L and 0.6L from A.P.
= 1.5 forward of F.P.
ao = common acceleration parameter

$$a_o = \frac{3C_w}{L} + \frac{C_v V}{\sqrt{L}}$$

Cv =√L/50, for L 100[m]

= 0.2 for L ≥ 100 [m]

3.1 Deck Pressure for Wheel Loading

P =	Pressure = W / n a b (9.81+0.5 a_v) 10^3	**0.065**	N/mm^2
W =	Maximum axial load (Crane load)	**46.00**	T
n =	Number of "load areas" per axle	**2.00**	
a =	Extent of the load area parallel to the stiffener	**800**	mm
b =	Extent of the load area perpendicular to the stiffener	**5100**	mm
a_v =	Vertical acceleration		

	$9.81\ k_v\ a_o / C_b$ (For stowed vehicle in sea going condition)	**3.58**	
	6/√W--------(For cargo handing vehicles in harbour condition)	1.90	
L =	Length	**18.50**	m
C_w =	0.0856 x L	**1.58**	
C_b =	Block coefficient	**0.80**	
k_v =		**0.70**	
a_o =	common acceleration parameter $3C_w / L + C_v V / \sqrt{L}$	**0.42**	N/mm^2
C_v =	$\sqrt{L}/50$	**0.09**	
V =	Speed	**8**	

3.2 Deck plating

The thickness't' of deck plating subjected to wheel loadings is not to be less than;t [mm]

$$t = c_1 f_a \sqrt{\frac{c_2\, b\, s\, p\, k}{m}} + t_c \ [\text{mm}]$$

Where,

fa = (1.1 - 0.25 s/l) for s ≤ l,

However need not be taken as greater than 1.0

a,b,s,l = deck panel dimensions [mm]

c1 = 0.137 in general for seagoing conditions

= 0.127 in general for harbour conditions

= As per Table 4.7.a for upper deck within 0.4L amidships.

c_1 values for upper deck plating within 0.4Lamidships		
Framing system	c_1-seagoing conditions	c_1-harbour conditions
Longitudinal	0.145	0.130
Transverse	0.180	0.145

Table 3.2.a

For upper deck plating between 0.4L amidships and 0.1[illegible] 1 is to be varied linearly. However, need not be taken as greater than 1.0

$$c_2 = 1.3 - \frac{4.2}{(a/s + 1.8)^2},$$

$$m = \frac{38}{(b/s)^2 - 4.7(b/s) + 6.5} \quad \text{for } b \le s.$$

DECK PLATING THICKNESS:

t =	Thickness of deck plate = (c1 fa √ (c2 b s p k / m)) + tc	**6.03**	mm
p =	Pressure	**0.065**	N/mm^2
a =	Extent of the load area parallel to the stiffener	**1000**	mm

b =	Extent of the load area perpendicular to the stiffener	**500**	mm
s =	Spacing of the stiffeners	**500**	mm
l =	Span of the stiffener	**1000**	mm
fa =	(1.1-0.25.s/l)	0.975	
	Let 'fa' be	1	
c_1 =	For Sea going condition	**0.137**	
	General habour condition	0.145	
c_2 =	$1.3 - (4.2/(a/s+1.8)^2)$	**1.009**	
m =	$38/((b/s)^2 -4.7 (b/s)+6.5$	**13.57**	
k =	Material Factor	**1**	
tc =	Corrosion addition to thickness	**1.5**	mm

3.3 DECK STIFFENERS OR BEAMS

The section modulus 'Z' of deck beams and longitudinals subjected to wheel loadings is not to be less than:

$$Z = \frac{c_3 .a.b.l.p}{m\sigma} 10^{-3} + Z_c \quad [cm^3]$$

C_3 = (1.15 0.25 b/s) for b ≤ s,
however need not be taken as greater than 1.0

$$m = \frac{r}{(a/l)^2 - 4.7\, a/l + 6.5}$$

r = 29 for continuous stiffeners supported at girders
= 38 when the continuous stiffeners can be considered as rigidly supported at girders against rotation.
σ = 160/k [N/mm2] in general, for seagoing conditions
= 180/k [N/mm2] in general, for harbour conditions
= As per Table 4.8.a for deck longitudinals within 0.4L amidships, but not exceeding the above general values.
For deck longitudinals between 0.4L amidships and 0.1L from ends is to be varied linearly.

σ Values for longitudinals within 0.4L amidships	
Condition	σ [N/mm^2]
Seagoing	$(215-135f_D.f_z)/k$
Harbour	$(225-85\, f_D.f_z)/k$

Table : 3.3

DECK BEAMS OR STIFFENERS:

Corrosion addition (Zc) for Stiffeners (L 60x60x6)			
Zc=	Section Modulus = tc.hw (bf+0.3.hw)/1000	9.36	cm^3
tc=	Corrosion addition = tn x 0.2	1.2	mm
	From [table 6.a] Let us take 'tc'	2	mm
tn=	Net thickness of member	6	mm
hw=	Height of the web	60	mm
bf=	Breath of the flage	60	mm

Z =	Section Modulus = $(((c_3\ a\ b\ l\ p)\ /(\ m\ \sigma))\ 10^{-3}) + Z_c$	**17.75+9.36= 27.11**	cm^3
c_3 =	(1.15-0.25 b/s)	**0.9**	
m =	$r/\{(a/l)^2-4.7\ (a/l) + 6.5\}$	**10.35**	
r =	For continuous stiffeners supported at girders	**29**	
	When the continuous stiffeners can be considered as rigidly supported at girders against rotation	38	
σ =	For seagoing conditions	**160**	N/mm^2
	For harbour conditions	180	N/mm^2
p =	Pressure	**0.065**	N/mm^2
a =	Extent of the load area parallel to the stiffener---	**1000**	mm
b =	Extent of the load area perpendicular to the stiffener	**500**	mm
s =	Spacing of the stiffeners	**500**	mm
l =	Span of the stiffener	**1000**	mm

3.4 DECK GIRDERS

Deck girders and transverses are to be arranged in line with vertical members of scantlings sufficient to provide adequate support.

The scantlings of simple girders and transverses are to be calculated by following formula. The section modulus 'Z' of deck girders is not to be less than:

$$Z = \frac{b\,p\,S^2\,.10^6}{m\sigma} + Z_c\ [cm^3]$$

Where,
p = applicable design pressure [N/mm2]
m = 12 for continuous longitudinal girders with end ---- (4.9.b)
m = 10 for other girders with end attachments ----------- (4.9.c)

$$\sigma = (190\text{-}135 f_D . f_z)/k$$

max. σ = 160/k [N/mm2] for continuous longitudinal girders within 0.4L amidships.
σ = 160/k [N/mm2] for longitudinal girders within 0.1L from ends and for transverse girders in general, Elsewhere, `σ' may be obtained by linear interpolation.

DECK LONGITUDINAL GIRDERS:

Corrosion addition (Zc) for Long. Girders (Web 180x6+80x6 FP)			
Zc=	Section Modulus = tc.hw (bf+0.3.hw)/1000	48.24	cm^3
tc=	Corrosion addition = tn x 0.2	1.6	mm
	From [table 6.a Let us take 'tc'	2	mm
tn=	Net thickness of member	8	mm
hw=	Height of the web	180	mm
bf=	Breath of the flage	80	mm

Z =	Section Modulus = $((b\ p\ S^2\ 10^6\ /\ (m\ \sigma)) + Zc$	**136.2+48.24 = 184.44**	cm^3
b =	Spacing of girders	**1**	m
p =	Pressure	**0.065**	N/mm^2
S =	Span of girder	**2**	m

m =	For continuous longitudinal girders	**12**	
	For other girders	10	
σ =	Allowable Bending stress	**160**	N/mm^2

DECK TRANSVERSE WEBS:

Corrosion addition (Zc) for Trans. Girders (Web 180x6+50x8 FP)			
Zc=	Section Modulus = tc.hw (bf+0.3.hw)/1000	37.44	cm^3
tc=	Corrosion addition = tn x 0.2	1.6	mm
	[From table 6.a] Let us take 'tc'	2	mm
tn=	Net thickness of member	8	mm
hw=	Height of the web	180	mm
bf=	Breadth of the flage	50	mm

Z =	Section Modulus = $(b\ p\ S^2\ 10^6 / m\ \sigma) + Zc$	**81.73+37.44= 119.17**	cm^3
b =	Spacing of girder	**2**	m
p =	Pressure	**0.065**	N/mm^2
S =	Span of girder	**1**	m
m =	For continuous longitudinal girders	12	
	For other girders	**10**	
σ =	Allowable Bending stress	**160**	N/mm^2

3.5 DECK PILLARS:

Pillars are to be fitted in the same vertical line wherever possible, and arrangements are to be made to effectively distribute the load at the heads and heels. Where pillars support eccentric loads, they are to be strengthened for the additional bending moments imposed upon them. Doubling or insert plates are generally to be fitted at the head and heel of hollow pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding.

Sectional area of the pillar 'A' is not to be less than

$$\mathbf{A = 70.A_L.p}\ [cm2]$$

Where,
p = design pressure as given in Sec.3, causing the tensile stress in pillar
A_L = load area of deck [m2], being supported by the pillar.

DECK SUPPORTED PILLARS:

Deck Pillar			
A =	Sectional Area = **70 A_L p**	**9.1539971**	cm^2
A_L =	Deck Area Supported by Pillar	2	m^2
p =	Design pressure	0.0653857	N/mm^2

3.6 Pressure for watertight bulkhead:

The design pressure 'p', for ordinary watertight bulkheads is given by:
p = 0.01 h [N/mm2]
where,
h = the vertical distance [m] from the center of loading to the freeboard deck.

PRESSURE FOR WATERTIGHT BULKHEAD:

P=	applicable design pressure	0.01*h	0.010	N/mm 2
h=	height from load point to freeboard deck		1	m

3.7 Transverse Bulkhead plating:

The thickness 't' of the bulkhead plating is not to be less than the minimum thickness given in 3.8 nor less than

$$t = \frac{s\sqrt{p}}{2\sqrt{\sigma}} + t_c \text{ [mm]}$$

where, p = applicable design pressure as given in 3.6.

σ = 160/k for transverse tank bulkheads and collision bulkhead;

= 220/k for ordinary transverse watertight bulkheads.

= 190/k for transverse dry bulk cargo bulkheads

BULKHEAD PLATING THICKNESS:

t=	Thickness of Bulkhead	{(s √p) / (2 √ σ)) }+ t_c	1.98	mm
s=	stiffener spacing		500	mm
σ =	allowable bending stress		160	N/mm2
K=	Material factor		1	

3.8 Minimum bulkhead thickness:

The minimum thickness requirement of the bulkhead plating is given by

t = (5.0 + c*L) √k + tc [mm]

where,

c = 0.02 for longitudinal bulkheads and bulkheads in cargo tank area and in peak tanks

= 0.01 for other bulkheads.

MINIMUM BULKHEAD TICKNESS:

t=	Thickness of Bulkhead	((5+c*L) √k)+tc	5.87	mm
$t_{c=}$	Corrosional addition of plate thickness		0.5	mm
L=	Length		18.5	m
k=	Material factor		1	mm
c=			0.02	

3.9 Vertical and transverse stiffeners on tank bulkheads, collision bulkheads, dry bulk cargo bulkheads and wash bulkheads:

The section modulus of bulkhead stiffeners is not to be less than:

$$Z = \frac{spl^2}{m\sigma} \times 10^3 + Z_c \text{ [cm}^3\text{]}$$

where,

p = applicable design pressure given in 3.6

m = 10 for transverse stiffeners and vertical stiffeners which may be considered fixed at both ends

= 7.5 for vertical stiffeners simply supported at one or both ends

BULKHEAD VERTICAL STIFFENERS:

Z=	section modulus	(spl^2 * 10^3/m σ) +Zc	16.4325	cm^3
$z_{c=}$	corrosion addition to section modulus	t_c*h_w(bf + 0.3 hw)/1000	3.9325	cm^3
s=	stiffener spacing		500	mm
l=	span of stiffener		2	m

P=	applicable design pressure		0.010	N/mm 2
hw=	height of web		55	mm
bf=	width of flange		55	mm
$t_{c=}$	Corrosional addition of plate thickness		1	mm
m=	for trans. & vertical stiffeners		10	

MODEL OUTPUTS AND CAD DRAWINGS

IV. DECK PLATE THICKNESS

S.No.	Description	Required Thk.(mm)	Provided Thk.(mm)
1	Deck plate	5.53 mm thk plate	6mm thk. Plate

4.1 Deck Beams or Stiffeners and Girders

S.No.	Description	Required Section Modulus (cm3)	Provided member Section Modulus(cm3)	Size of the member
1	Deck Beams or Stiffeners	27.11	29.23	L-60x60x6
2	Deck Longitudinal Girders	184.44	184.83	Web180x8+80x8FP
3	Deck Transverse Girders	119.17	127.74	Web180x6+50x8 FP

4.2 Deck Supported Pillars:

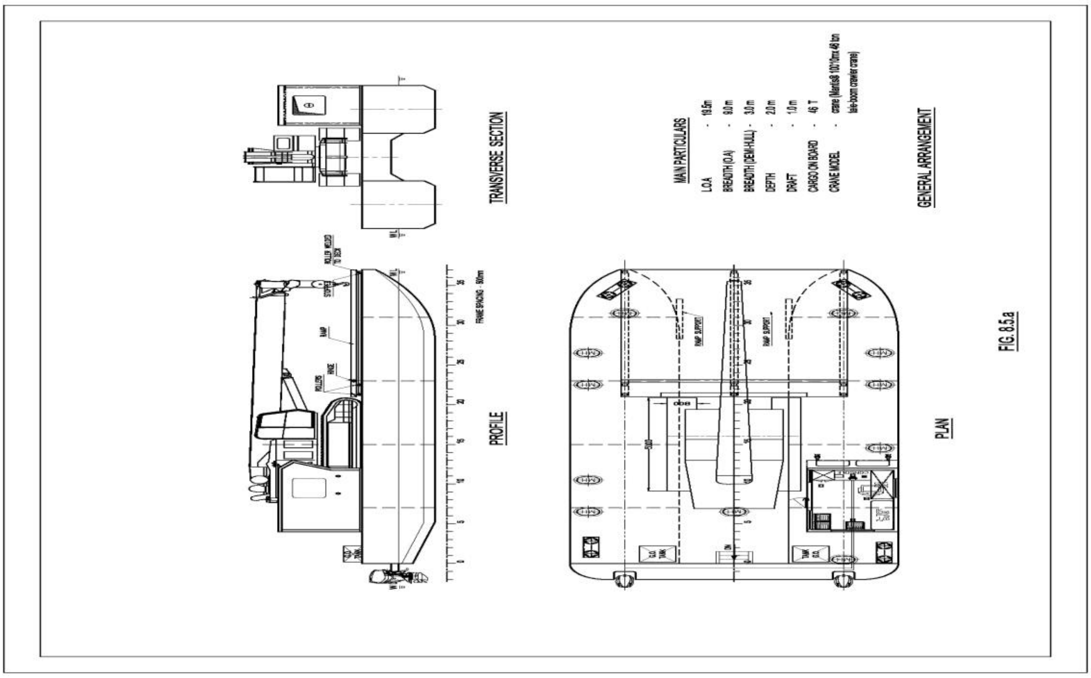
S.No.	Description	Required C/S Area (cm^2)	Provided Pipe size & C/S Area (cm^2)
1	Deck Supported Pillars	**9.1539**	Pipe 50.NB SCH.80, (O.D. 60.5, 5.5 THK) C/S area – 9.5 (cm^2)

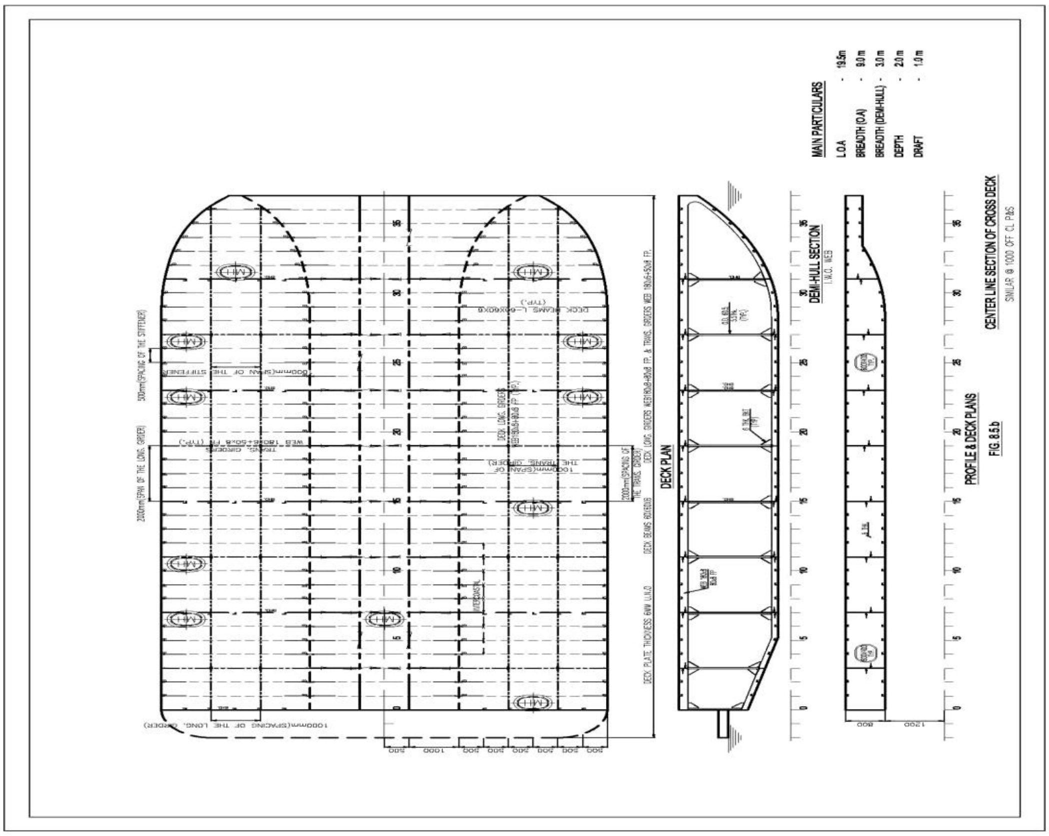
4.3 Bulkhead plate thickness:

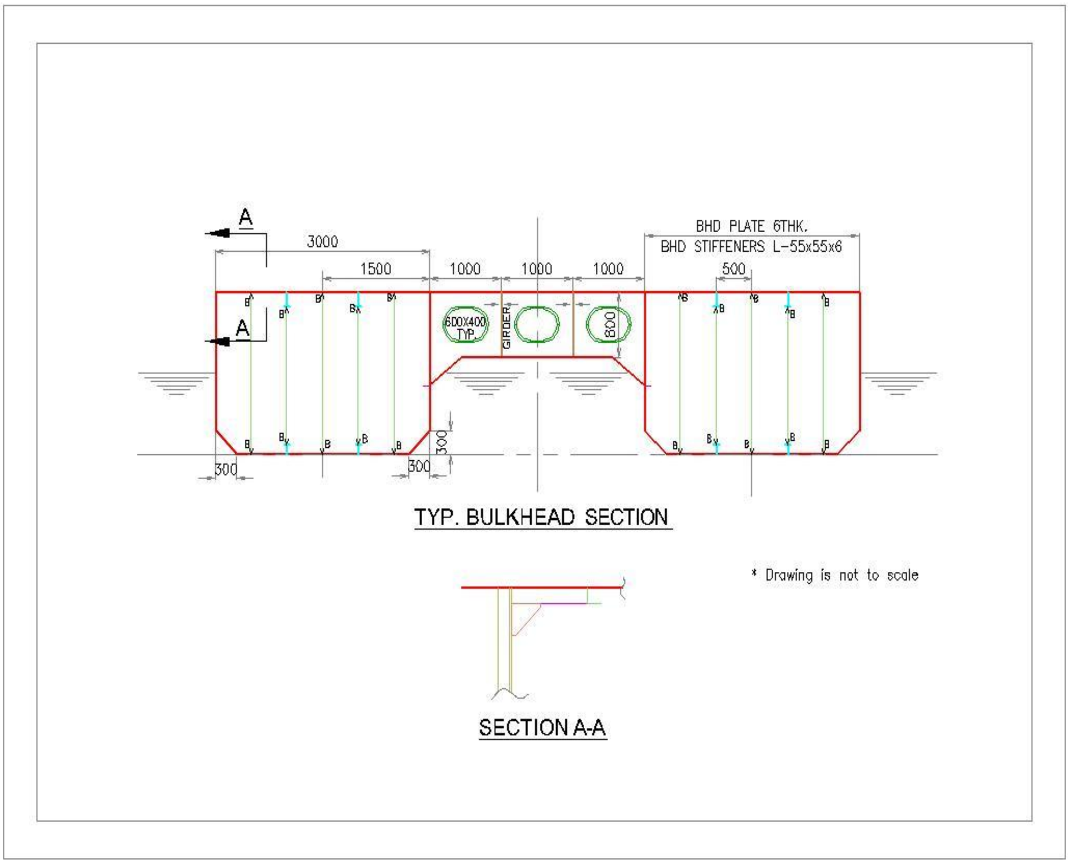
S.No.	Description	Required Thk.(mm)	Provided Thk.(mm)
1	Bulkhead plate	5.87 mm thk. plate	6mm thk. Plate

4.4 Bulkhead vertical Stiffeners:

S.No.	Description	Required Section Modulus (cm3)	Provided member Section Modulus(cm3)	Size of the member
1	Bulkhead vertical Stiffeners	16.43	24.47	L-55x55x6


TRANSVERSE SECTION
PROFILE
PLAN
MAIN PARTICULARS
L.O.A - 19.5m
BREADTH (O.A) - 9.0 m
BREADTH (DEMI-HULL) - 3.0 m
DEPTH - 2.0 m
DRAFT - 1.0 m
CARGO ON BOARD - 46 T
GENERAL ARRANGEMENT
FIG. 8.5.a


MAIN PARTICULARS
L.O.A - 19.5m
BREADTH (O.A) - 9.0 m
BREADTH (DEMI-HULL) - 3.0 m
DEPTH - 2.0 m
DRAFT - 1.0 m
DECK PLAN
DEMI-HULL SECTION
CENTER LINE SECTION OF CROSS DECK
PROFILE & DECK PLANS
FIG. 8.5.b



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