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7th EMship cycle: September 2016 – February 2018

Master Thesis

Structural Design and Stability of a 6,000 ton Capacity Floating Dock as per DNVGL Rules

Supervisor: Dr. Zbigniew Sekulski, West Pomeranian University of Technology, Szczecin, Poland
Internship tutor: Mr. Szymon Chwalisz, Nelton Sp. z o.o., Szczecin, Poland
Reviewer: Dr. Thomas Lindemann, University of Rostock, Rostock, Germany

La Spezia, February 2018

Internship Company: Nelton Sp. z o.o., Szczecin

nelton

MODERN ENGINEERING COMPANY

- Founded in 1999
- Headquarters in Gdansk
- Subdivision in Szczecin
- More than 70 qualified engineers
- Expertise and vast experience in
  - Marine and Offshore Design
  - Mechanical Engineering
  - Special Tasks
- Design Softwares

AUTODESK AUTOCAD | FORAN | AVEVA | NUPAS CADMATIC
INVENTOR | SOLIDWORKS | MAXSURF | ANSYS
Rhinoceros | CATIA

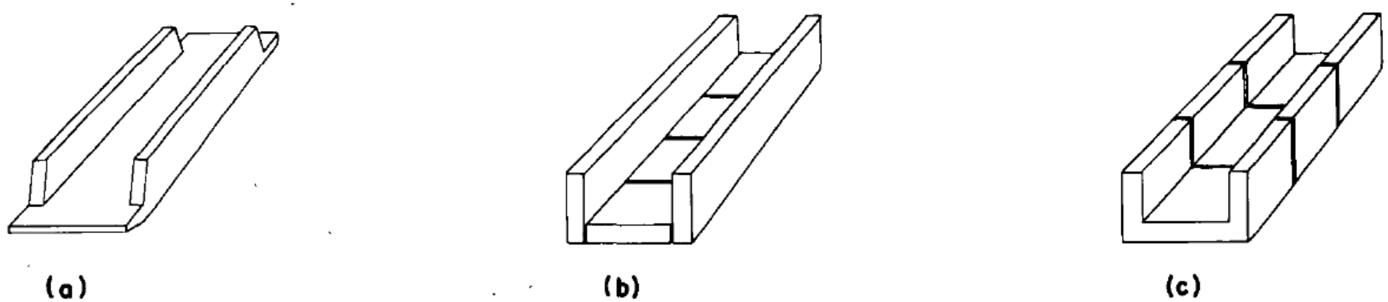
Ref: Nelton company presentation

Contents:

1. General Overview on Floating Docks

Purpose: Construction, repair, surveys, launching

Major Types: Unit dock (a), composite dock (b), sectional dock (c)



Materials of construction: Concrete, steel, wood

Advantages: Saves yard space, mobility, self-docking (composite dock)

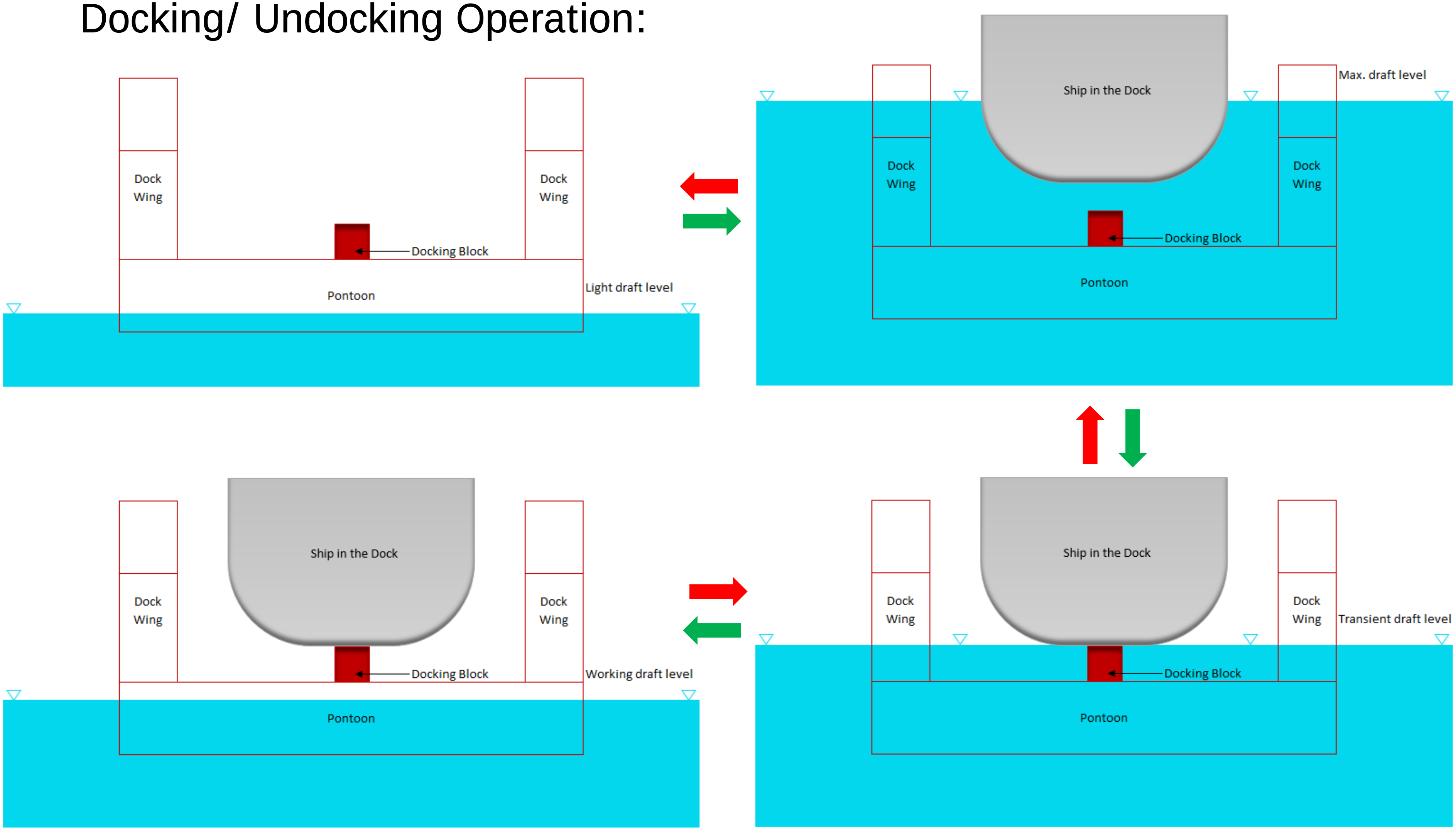
Disadvantages: Movement of materials and people

Construction standards: Various Class Rules (ABS, DNVGL, BV, etc.)

Ref: Analysis and Design of Floating Drydocks by Arsham Amirikian

1. General Overview on Floating Docks (contd...)

Docking/ Undocking Operation:



2. Objectives

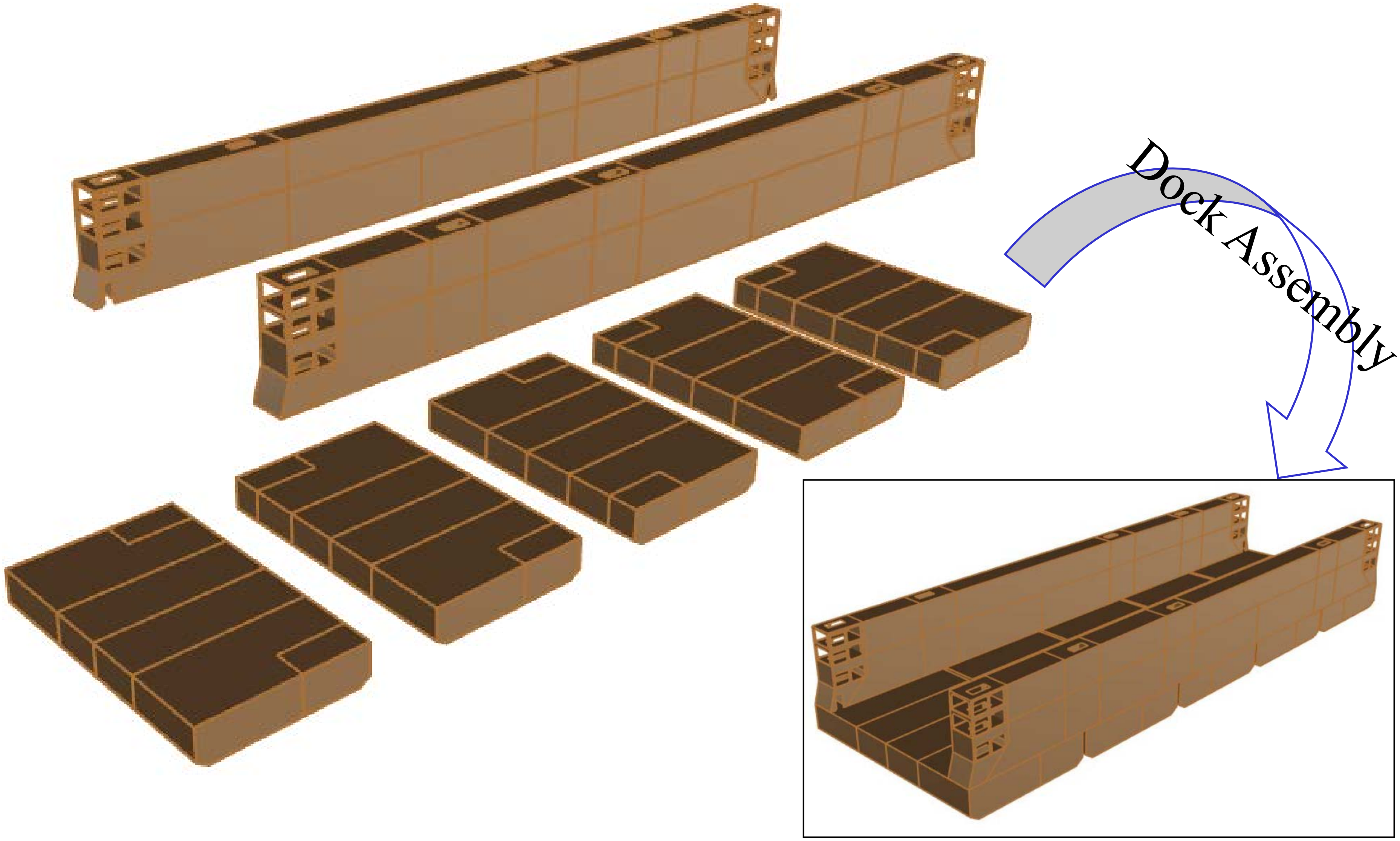
- Scantlings Design
- Weights and CoG Estimation
- Strength Analysis (FEA)
- Connection Concepts
- Intact Stability Check
- Feasibility Study for Submarines Construction

3. Main Particulars

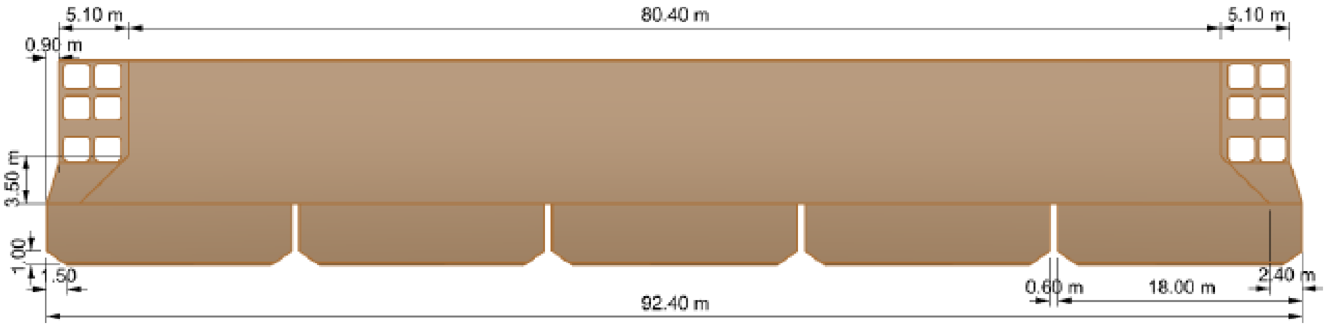
Design	Floating Dock
Type	Sectional Pontoon Type
Material	Steel
Capacity	6,000 tons
Length overall	92.4 m
Breadth overall	30 m
Breadth inside	23 m
Depth overall	15 m
Depth of pontoon	4.5 m
Minimum Draught	1.69 m
Maximum Loaded Draught	13.5 m
Height of Docking Block	1.2 m (from Pontoon Deck)
Class	DNV-GL

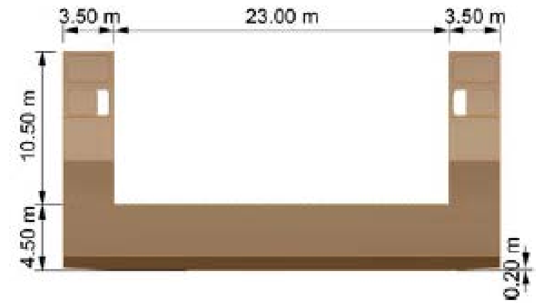
Ref: Drawings and Preliminary Stability Check document provided by Nelton

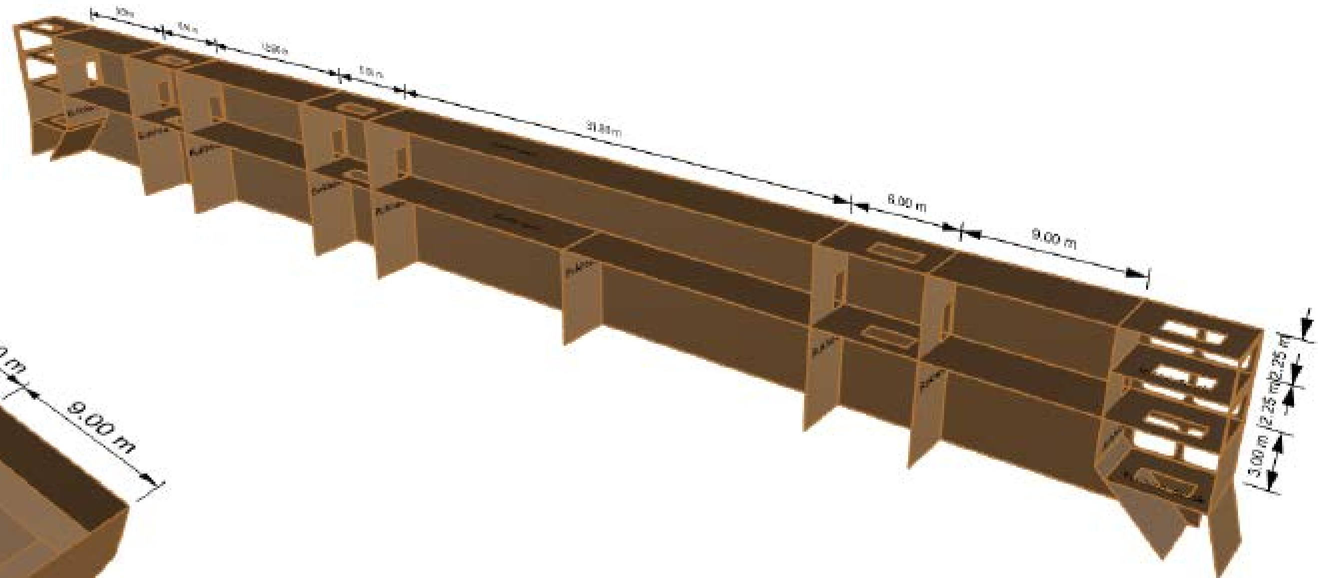
4. Geometry

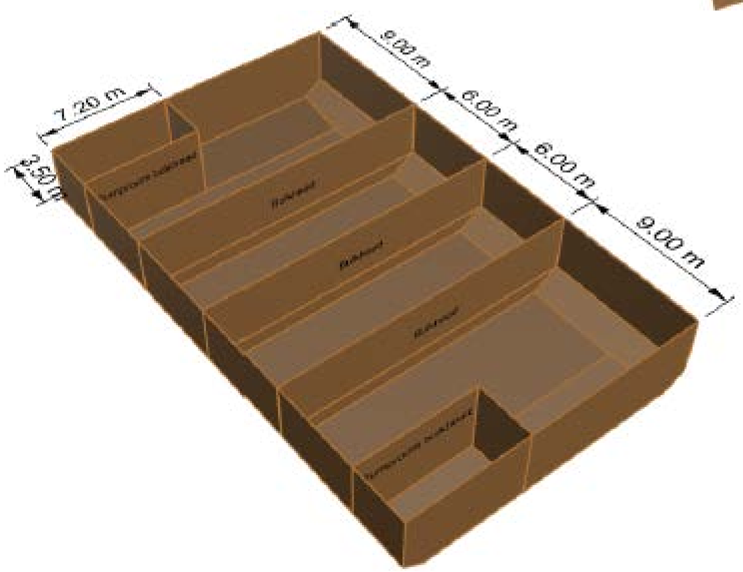


4. Geometry (contd...)









5. Scantlings Design

Based on DNVGL-RU-FD Edition 2015

Yield strength of steel considered: 235MPa or 355MPa

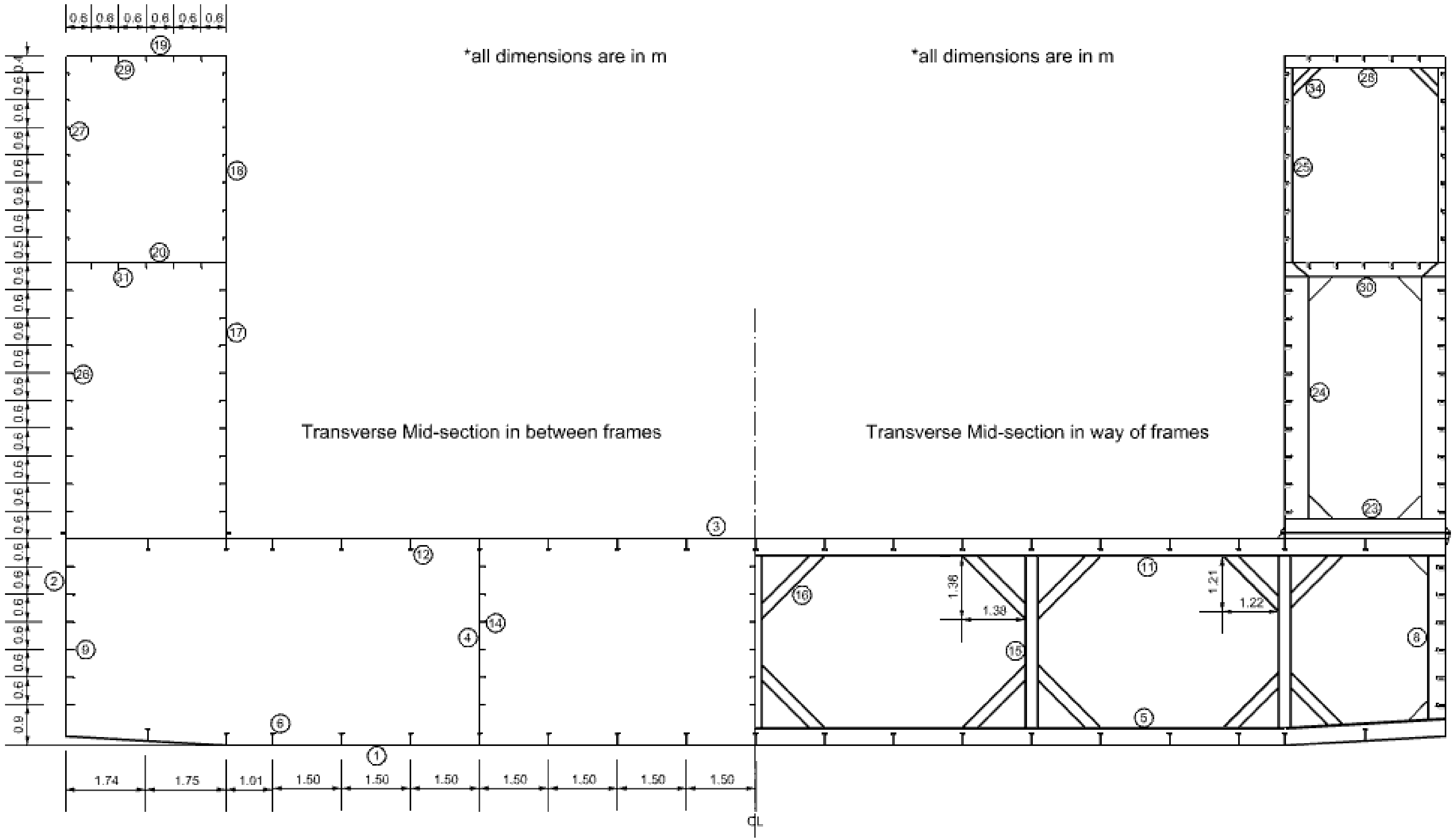
Design based on local pressures: Hydrostatic pressure due to maximum draft (13.5m) and tank fluid pressures

Built up T-sections/ standard I-sections used for longitudinal and transverse frames/ pillars

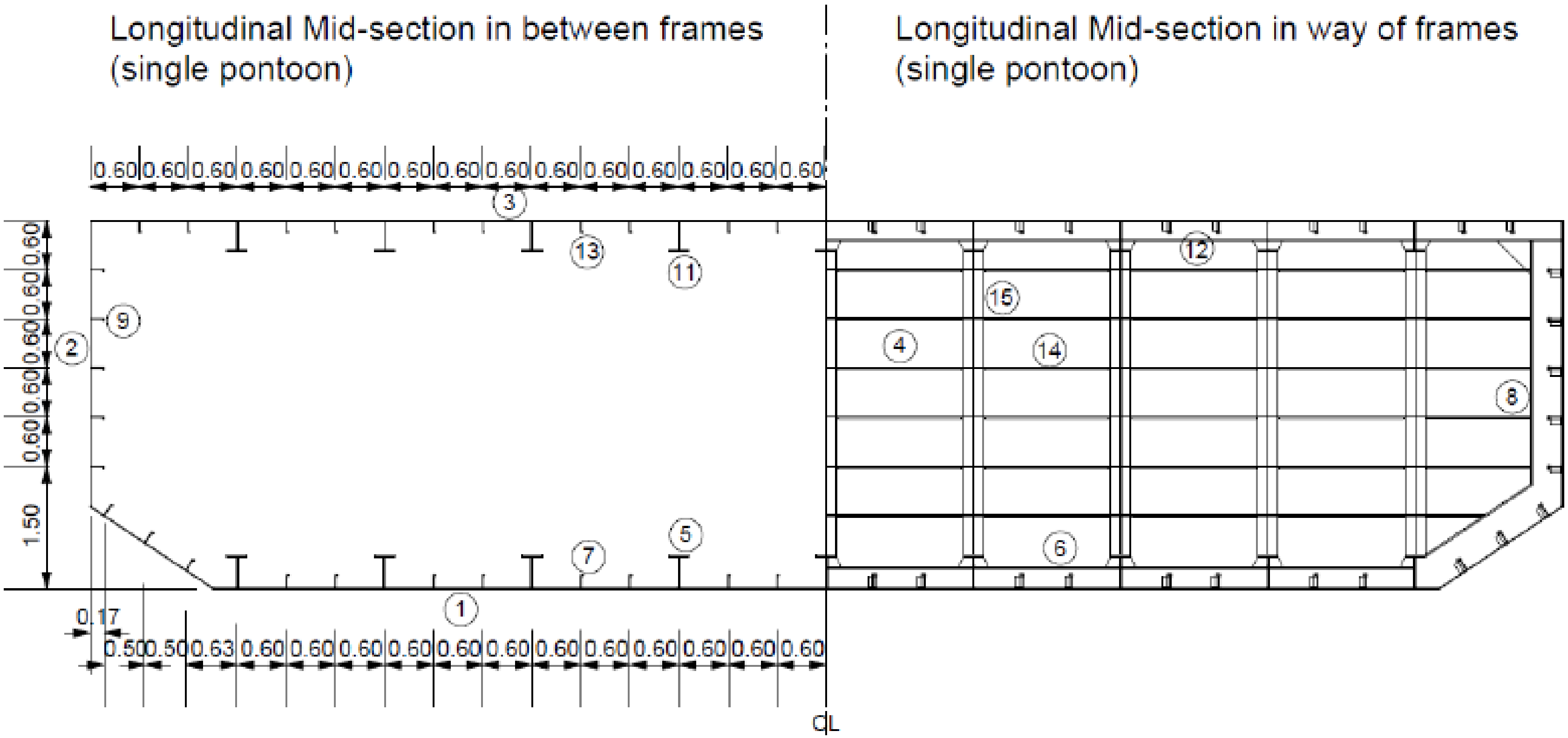
Standard bulb sections and angle sections for stiffeners

Framing System: Longitudinal for individual Pontoons (transverse in dock assembly) and Dock Wings

5. Scantlings Design (contd...)



5. Scantlings Design (contd...)



5. Scantlings Design (contd...)

Items list from the section drawings

Item no.	Item description	Scantlings in mm
	Pontoon	
1	Bottom plate	12 thick
2	Side Plate	12 thick
3	Deck plate	12 thick
4	Longitudinal bulkhead	10 thick
5	Bottom Girder	T section: W380x12 F250x20
6	Bottom Frame	T section: W240x12 F100x16
7	Bottom stiffeners	BP 160x11.5
8	Side frame	T section: W360x12 F250x16
9	Side stiffeners	BP 180x10
10	Side stiffeners	BP 160x9
11	Deck girder	T section: W350x12 F250x20
12	Deck frame	T section: W220x12 F100x16
13	Deck stiffeners	BP 140x10
14	Bulkhead stiffeners	BP 120x8
15	Pillars	UC 250x250x71.8 kg/m
16	Pillar brackets	UC 250x250x71.8 kg/m

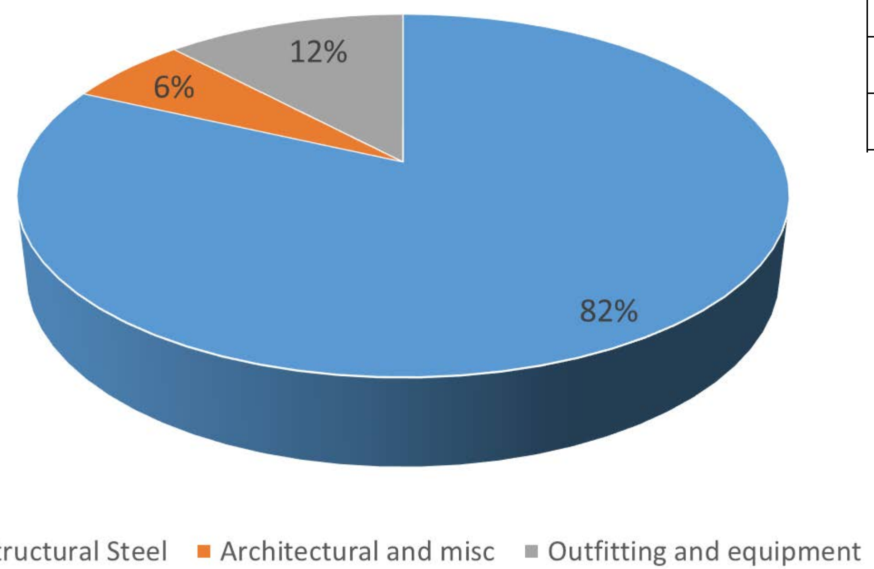
Item no.	Item description	Scantlings in mm
	Dockwing	
17	Side plate (below safety deck)	10 thick
18	Side plate (above safety deck)	8 thick
19	Upper deck plate	8 thick
20	Safety deck plate	8 thick
21	Transverse bulkhead (below safety deck)	8 thick
22	Transverse bulkhead (above safety deck)	6 thick
23	Bottom frame	UB 300x200x55.8 kg/m
24	Side frame (below safety deck)	T section: W500x10 F100x16
25	Side frame (above safety deck)	T section: W150x8 F100x12
26	Side stiffeners (below safety deck)	BP 140x8
27	Side stiffeners (above safety deck)	LP 75x50x8
28	Upper deck frame	T section: W250x8 F100x10
29	Upper deck stiffeners	BP 120x6
30	Safety deck frame	T section: W300x8 F150x10
31	Safety deck stiffeners	BP 120x6
32	Bulkhead stiffeners (below safety deck)	BP 200x8.5
33	Bulkhead stiffeners (above safety deck)	LP 100x65x8
34	Upper bracket	UB 150x100x20.7 kg/m

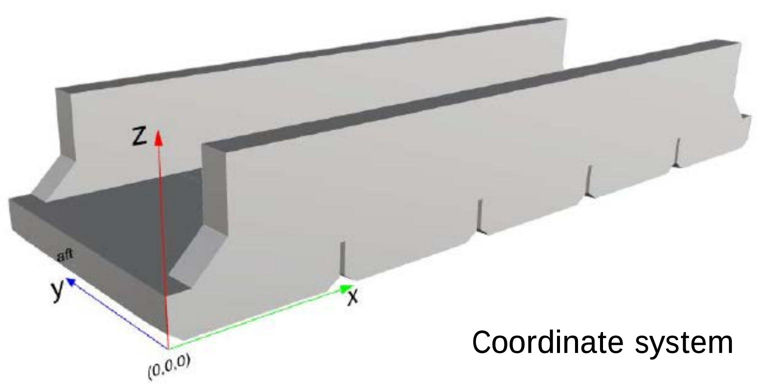
6. Weights and CoG Estimation

Summary of weights and CoG of the empty structure

Sl No	Item Description	Contingency	Total Weight (tons)	CoG X (m)	CoG Y (m)	CoG Z (m)	Moments M-x (t.m)	Moments M-y (t.m)	Moments M-z (t.m)
1	Structural Steel	10%	2207	46.34	15.00	4.36	102258	33100	9620
2	Architectural and misc	20%	165	45.68	15.40	10.13	7524	2536	1668
3	Outfitting and equipment	20%	323	48.45	14.33	7.86	15667	4634	2541

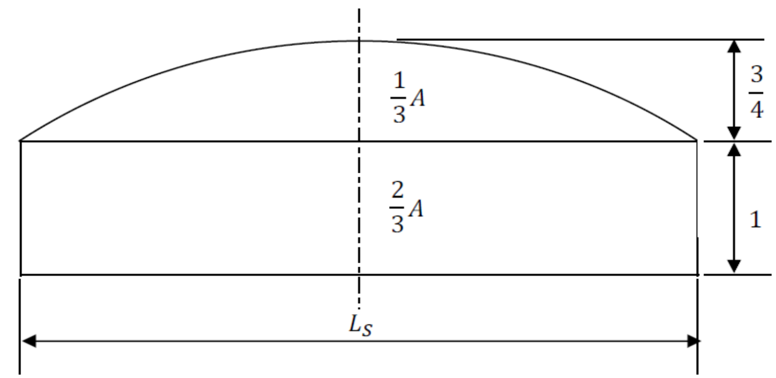
Total Weight (tons)	CoG X (m)	CoG Y (m)	CoG Z (m)	Moments M-x (t.m)	Moments M-y (t.m)	Moments M-z (t.m)
2695	**46.55**	**14.94**	**5.13**	**125449**	**40271**	**13829**



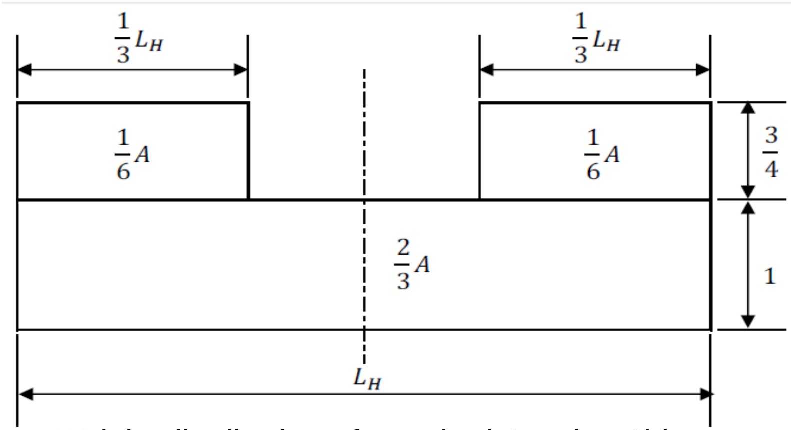


Coordinate system

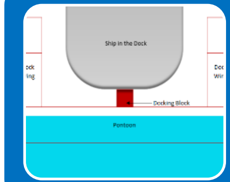
7. Strength Analysis



Weight distribution of standard Sagging Ship
Source: DNVGL-RU-FD Figure 1

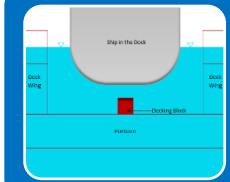


Weight distribution of standard Sagging Ship
Source: DNVGL-RU-FD Figure 2



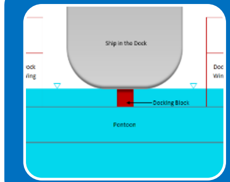
Working Draft Condition

- Sagging Ship
- Hogging Ship



Fully Submerged Condition

- -
- -

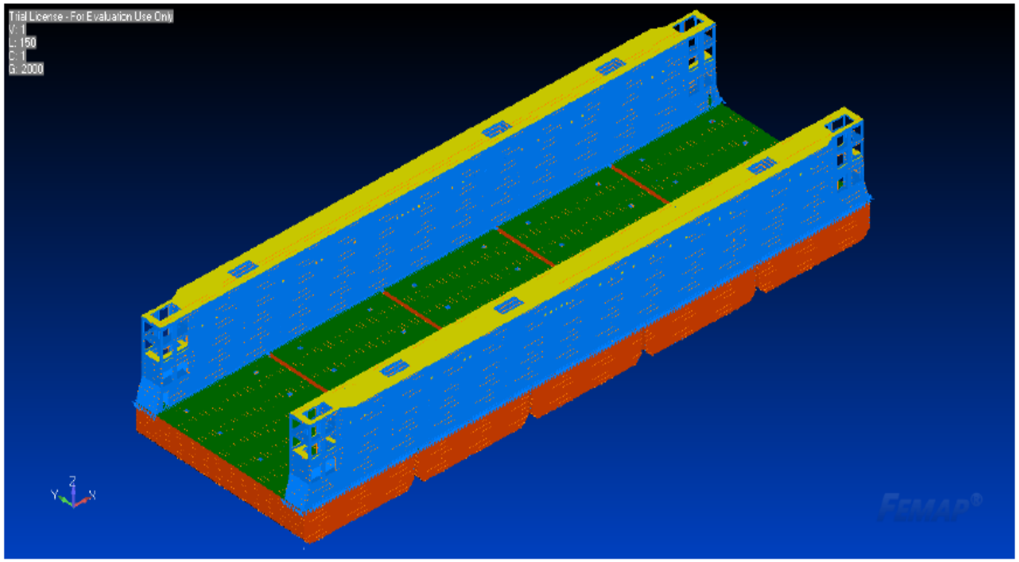


Docking or Undocking Condition

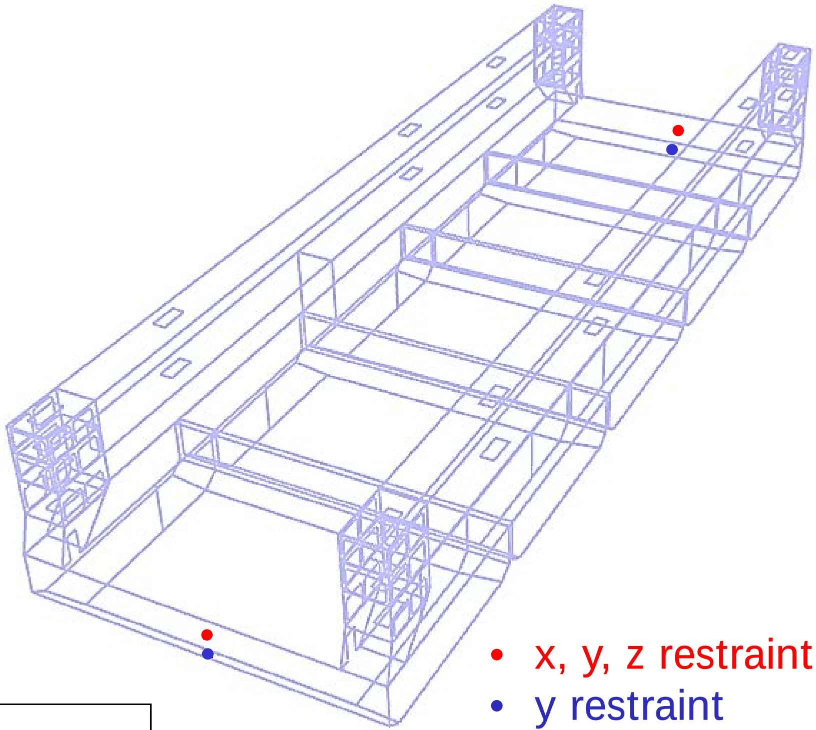
- Sagging Ship
- Hogging Ship

L_D = 92.4m (Length of Dock)
L_S = $0.8L_D$ (Length of Sagging Ship)
L_H = $1.2L_D$ (Length of Hogging Ship)

7. Strength Analysis (contd...)



FEMAP Model



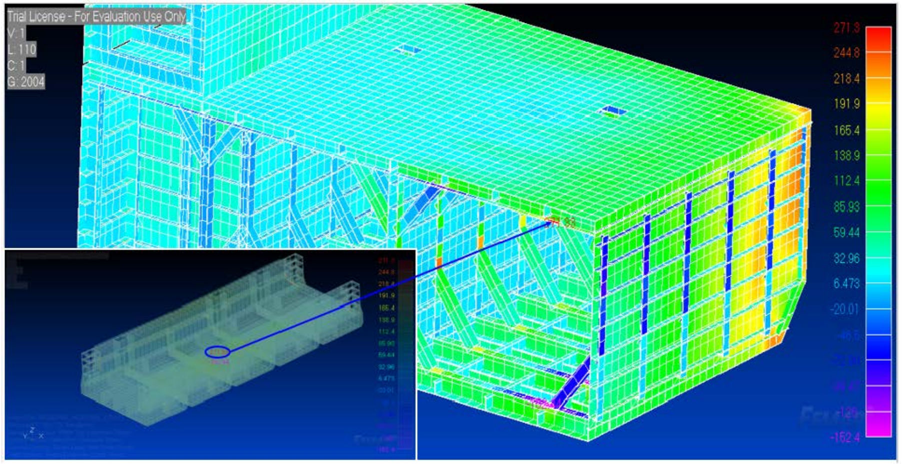
Boundary Conditions

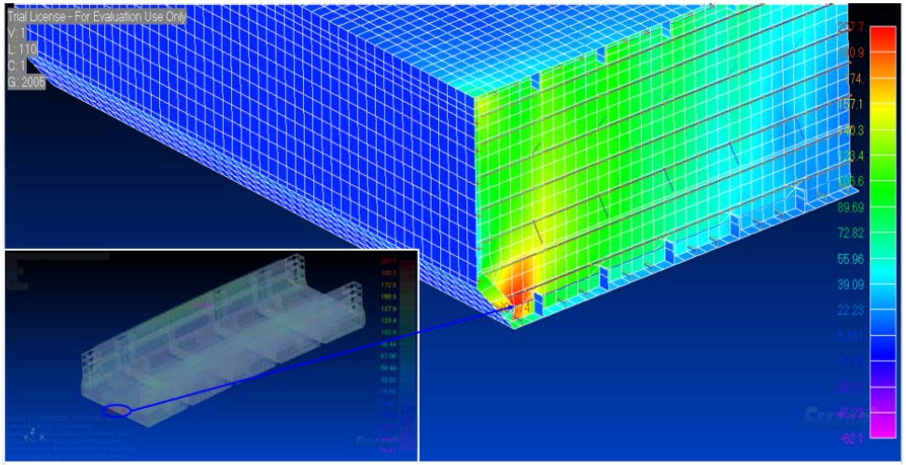
No. of nodes	234899
No. of elements	358705
Plate elements	Plates, girder and frame webs
Beam elements	Girder and frame flanges, stiffeners, pillars, brackets
Spring elements	Bolted connections

FEM Data

7. Strength Analysis (contd...)

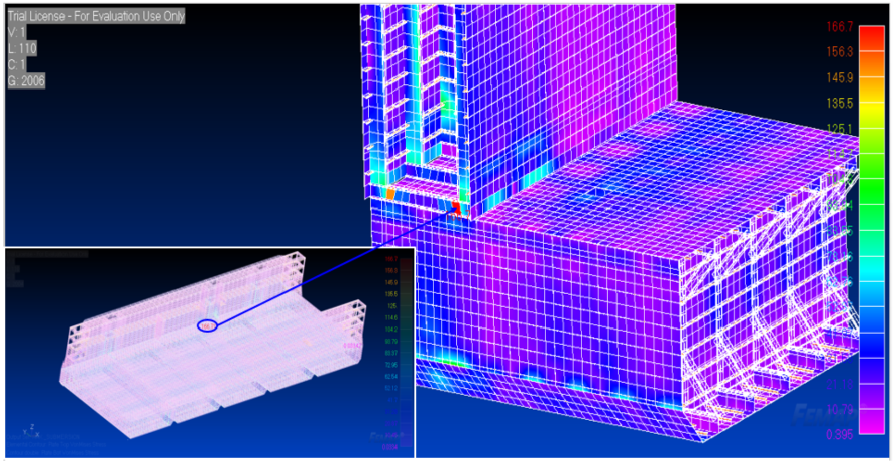
Working Draft Condition:





Sagging Ship (Max. Von Mises Stress Plot) Hogging Ship

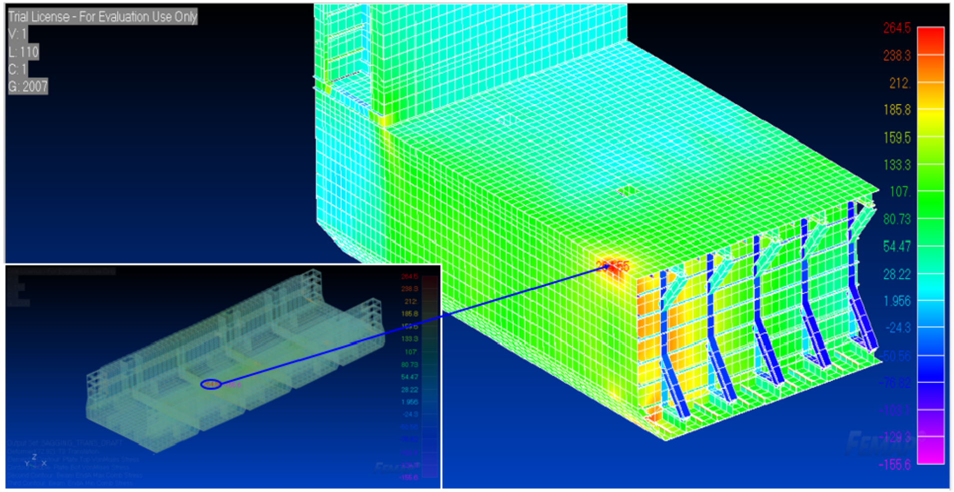
Fully Submerged Condition:

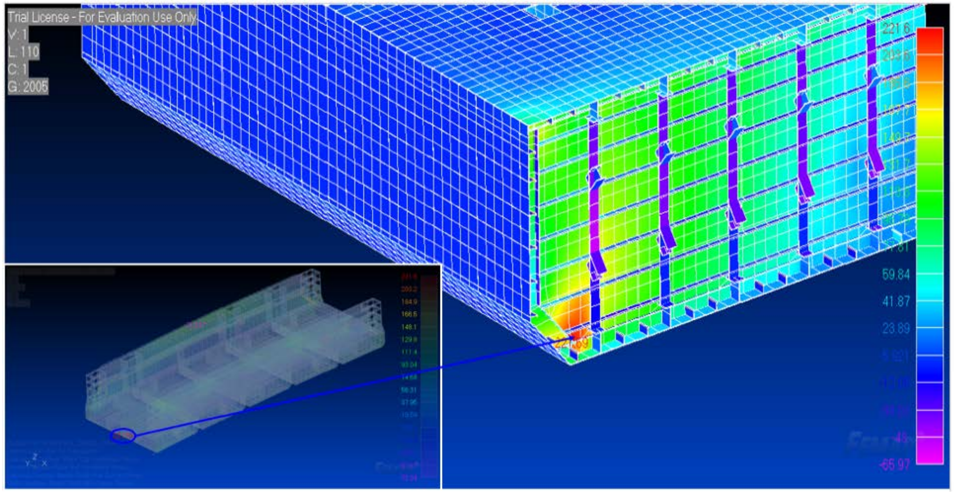


Max. Von Mises Stress Plot

7. Strength Analysis (contd...)

Docking or Undocking Condition (water level just below docking blocks):





Sagging Ship (Max. Von Mises Stress Plot) Hogging Ship

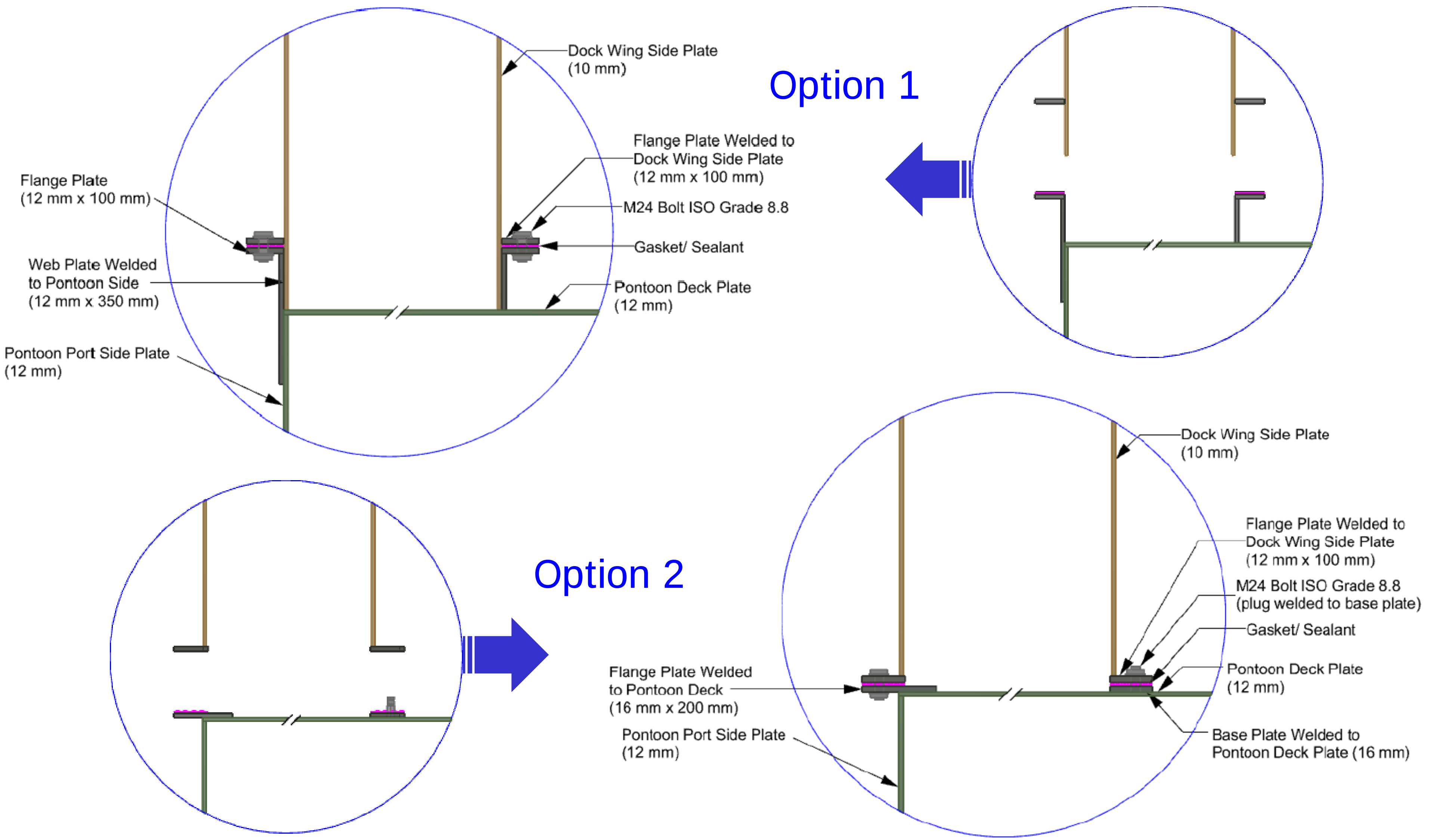
Results Summary:

Max. Von Mises Stress = 271MPa on Pontoon Deck Girder at Sagging Ship Working Condition

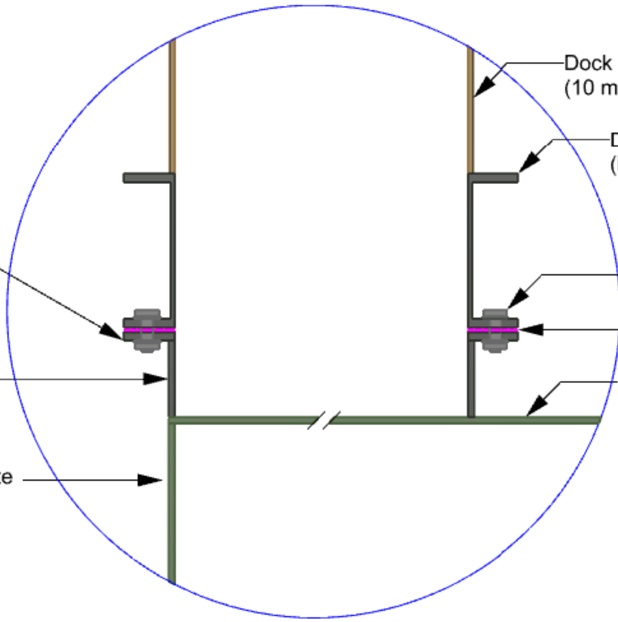
Maximum Vertical Deflection = 73mm at Sagging Ship Transient Draft Condition

High Stressed Normal Yield Strength Members = Pontoon Central Bulkhead, Pontoon Bottom, Side and Deck Plates at the connecting edges close to centreline (central and end pontoons)

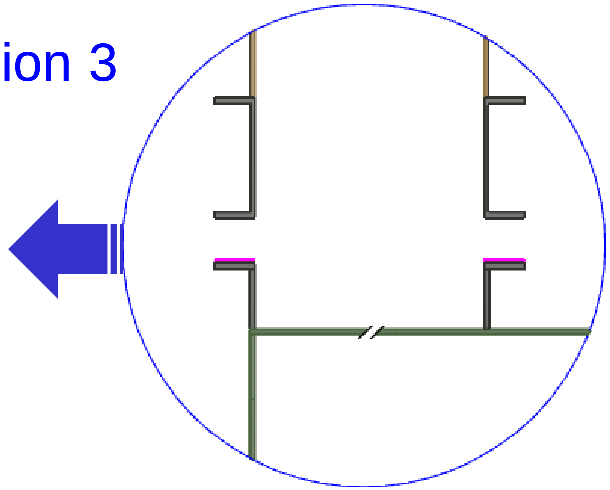
8. Connection Concepts



8. Connection Concepts (contd...)



Option 3



Bolt Loads- FEA Results:

Max. Tensile Load = 131kN; Resultant Shear Load = 71kN

Bolt Selected- M24 ISO Grade 8.8 Bolt:

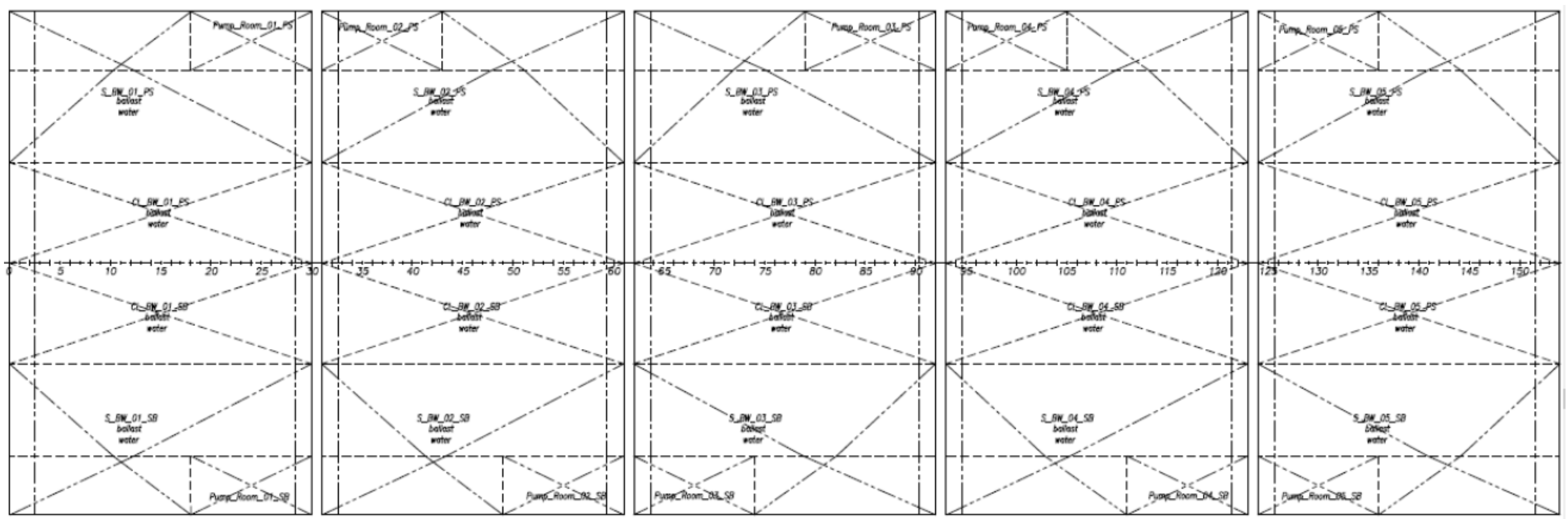
Allowable Tensile Strength = 146kN; Allowable Shear Strength = 105kN

Connecting Plates:

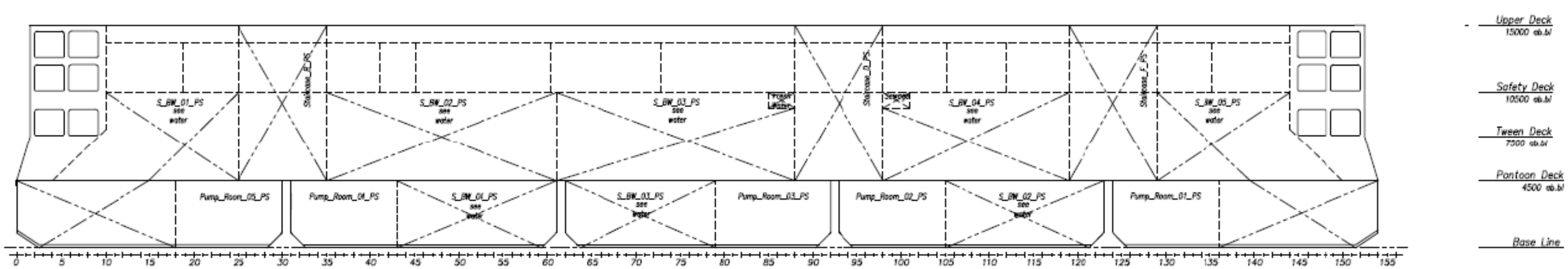
Min. Thickness = 12mm, Min. Yield Strength = 355MPa

9. Intact Stability Check

Empty structure weight ≈ 2700 tons; LCG and TCG ≈ at the centre of the dock; VCG ≈ 6m; Wind pressure ≈ 526 Pa (30m/s velocity)

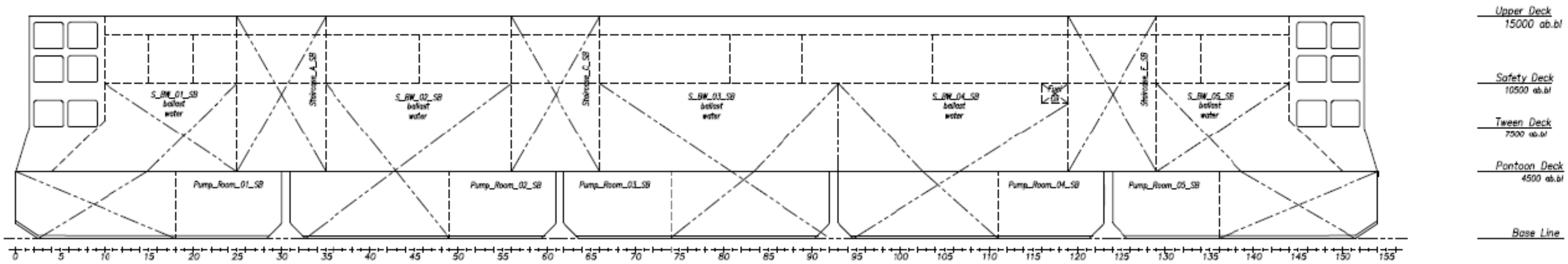


Tank Plan



View of Port Side (from CL)

9. Intact Stability Check (contd...)



View of Starboard Side

Stability Check:

1. Initial GMt after free surface correction (>1m)
2. Wind Criteria (Angle of steady heel ≤ 16 deg; Angle of steady heel/ Deck edge immersion angle ≤ 80%)
3. Lifting Criteria (Angle of steady heel < 10 deg; A1/A2 > 40%)
4. Freeboard (>0.3 m for pontoon deck; >1 m for upper deck)

9. Intact Stability Check (contd...)

Stability Cases:

1. Lightship Condition:

   Draft amidships = 1.59 m; Displacement = 4039 tons
2. Fully Submerged Condition:

   Draft amidships = 12.1 m; Displacement = 16518 tons
3. Docking Condition (water level just below docking blocks):

   Draft amidships = 5.7 m; Displacement = 12751 tons
4. Working Condition:

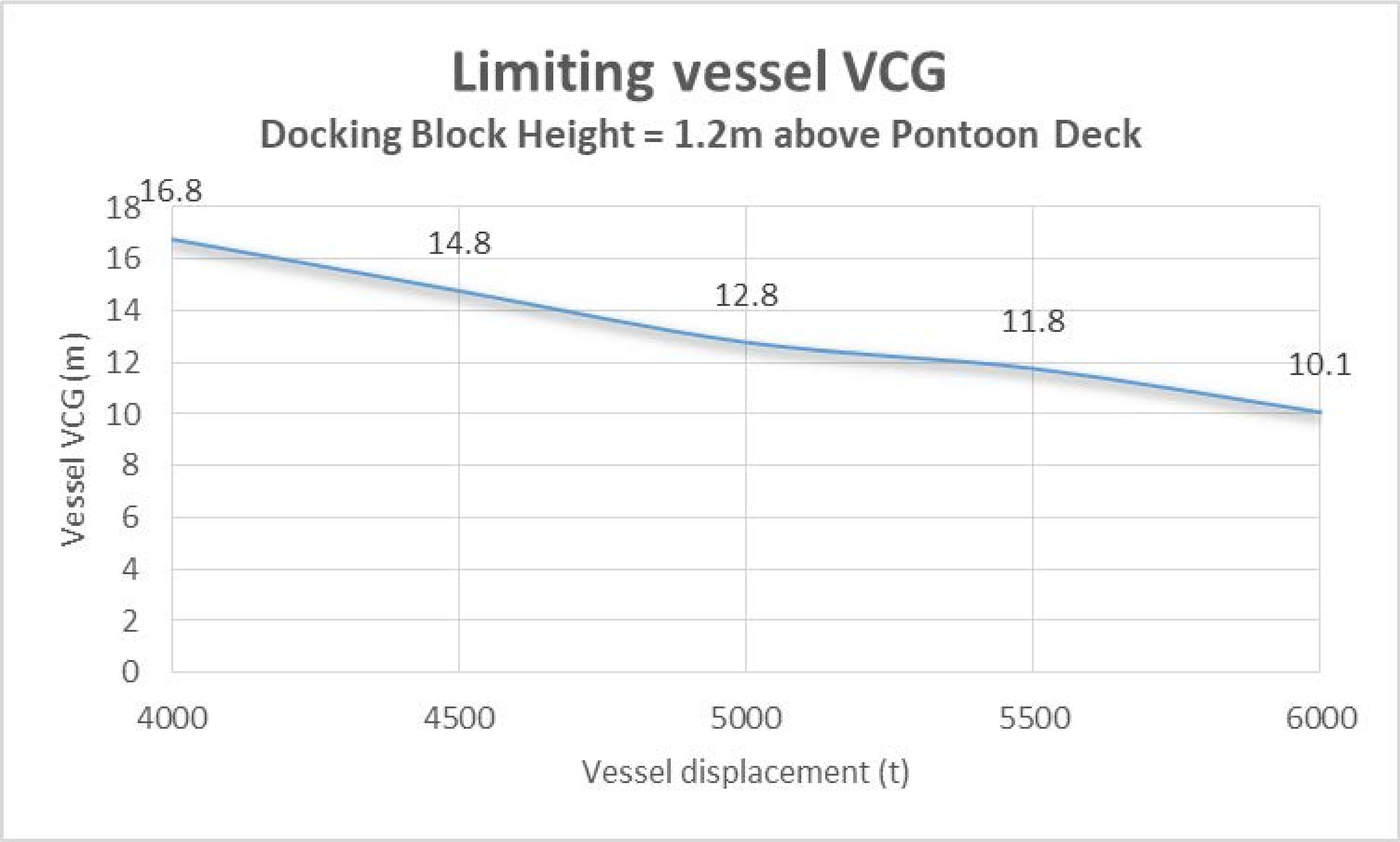
   Draft amidships = 3.7 m; Displacement = 10039 tons
5. Undocking Condition (water level just below docking blocks):

   Draft amidships = 5.7 m; Displacement = 12744 tons

Results:

All stability requirements satisfied except that the maximum submersion of 13.5 m not achieved (less by approx. 1.4 m)

9. Intact Stability Check (contd...)

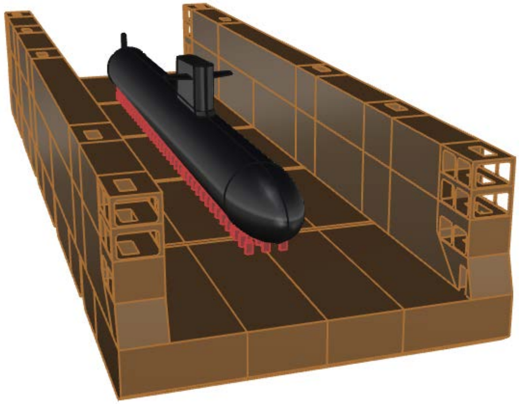


Limiting Vessel VCG-Displacement Curve

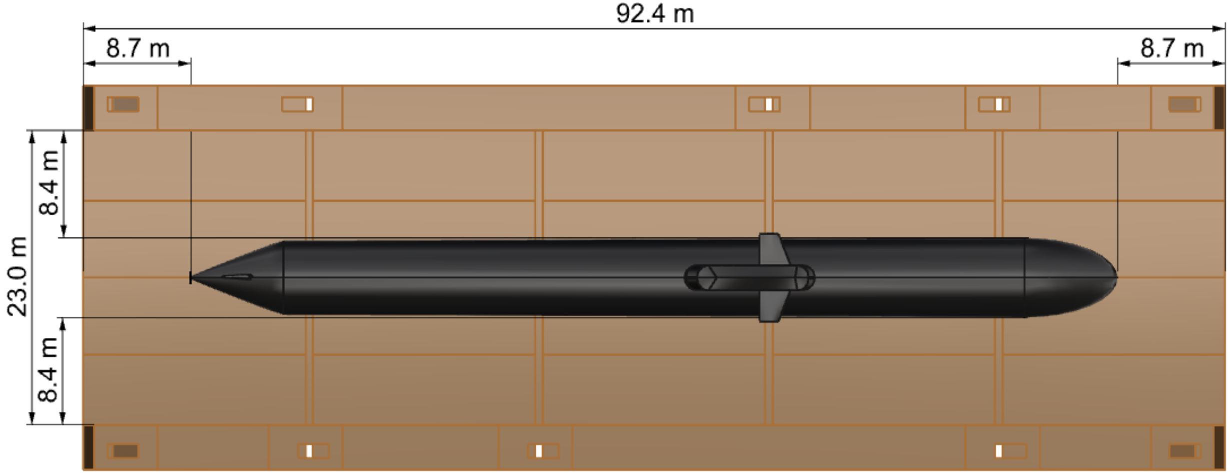
10. Feasibility Study for Submarines Construction

Polish Navy- Orca Submarine Program- Procurement of Submarines

Builder	Submarine Class	L (m)	B (m)	T (m)	Δ (ton)
Saab	A26	63	6.4	6	1930
DCNS	Scorpene	75	6.2	5.8	2000
TKMS	Type 212A	57.2	6.8	6.4	1830



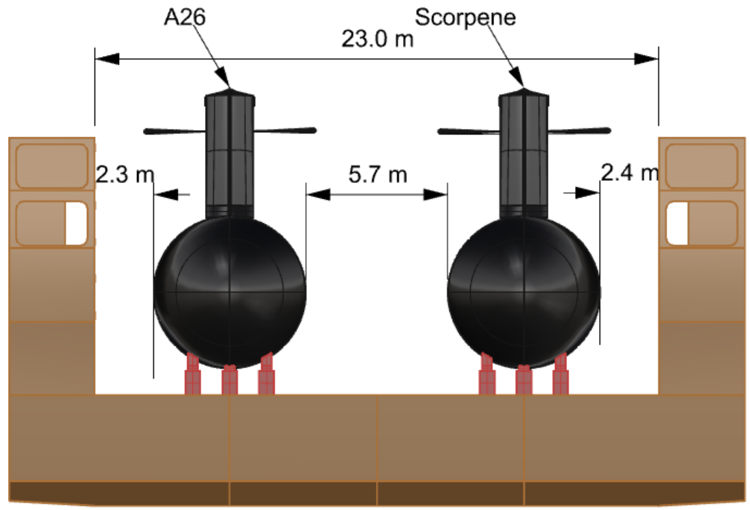
Submarine Data for Study



Dimensional Clearances for Scorpene Class Submarine (Top View)

Ref: www.navyrecognition.com; https://en.wikipedia.org/wiki/A26_submarine; https://en.wikipedia.org/wiki/Scorp%C3%A8ne-class_submarine; https://en.wikipedia.org/wiki/Type_212_submarine

10. Feasibility Study for Submarines Construction (contd...)



Side-by-Side Docking (End View)

Lifting Capacity Checks:

1. Strength_ ok
2. Clear Space requirements_ ok except for draft in case of Type 212A
3. Stability_ ok

11. Conclusions

1. High yield steel of strength 355MPa is considered for pontoon frames and girders so as to reduce the size of the sections used (section modulus requirement is approximately 39% lesser compared to low yield steel).
2. Pillars of high yield steel are used as they undergo higher stresses from axial loads and a buckling check is also carried out and found satisfactory.
3. Based on the FEA results, low yield plates of 235MPa considered in the scantlings design are replaced with high yield plates of strength 355MPa at specific locations like the plates of pontoon deck, side and bottom between the first frame to the port and to the starboard which are high stressed regions, then the pontoon central bulkhead and the dock wing upper deck plate.
4. From FEA we obtain the maximum deflection associated with the maximum stresses.

11. Conclusions

5. The considered case of loading is a conservative case where the docking load is distributed along the centreline as required by the Class. Actual case of docking may be supported from the sides too and hence less concentration of loads along the centreline.
6. More accurate weights calculation has to be carried out with concept designs for electrical, HVAC, outfitting and piping.
7. Ballast capacity needs to be increased to achieve maximum submersion (approx. 800 m^3 as per the calculated weight). An increase of pontoon height by 0.2m and moving safety deck up by 1m could give sufficient ballast space.
8. The dock design was checked for its feasibility in constructing submarines for the Polish Navy's Orca Submarine Program and found to be feasible except for the draft clearance for Type 212A class submarine being less by a small margin (0.3m). This correction of draft or submersion of the dock is intended in the considered design. So it can be assumed that the subject dock is able to perform the construction and launching of the submarines needed to be constructed.

http://www.wildoceanfilm.com/marketing/images/photos/marinelife/Big%20Ship.jpg