Structural design of a containership approximately 3100 TEU according to the concept of general ship design B-178

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Master Thesis

presented in partial fulfillment
of the requirements for the double degree:
“Advanced Master in Naval Architecture” conferred by University of Liege
"Master of Sciences in Applied Mechanics, specialization in Hydrodynamics, Energetics and Propulsion” conferred by Ecole Centrale de Nantes

Devepled in West Pomeranian University of Technology, Szczecin
Germanischer Llyod Office, Szczecin

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2010-2012

Outlines of the presentation

1. Introduction.
2. Concept of the Hull Structure, Material and Topology
3. Modelling and Scantling Calculation of Hull Structure According to GL Rules.
4. Strength Analysis Using Finite Element Method.
5. Three-D Visualisation of a Part of the Hull Structure Using Tribon Software.
6. Technical Description of the Developed Ship Hull Structure.
7. Conclusion.

Objective of the Master Thesis

The hull structural design based on the functional requirements of the containership.

The design was developed according to the Rules and Regulations of Germanischer Lloyd.

Initial data and assumption

Main dimensions, general arrangement, and hull form of the containership B 178-1.

General Description of the Containership B178.

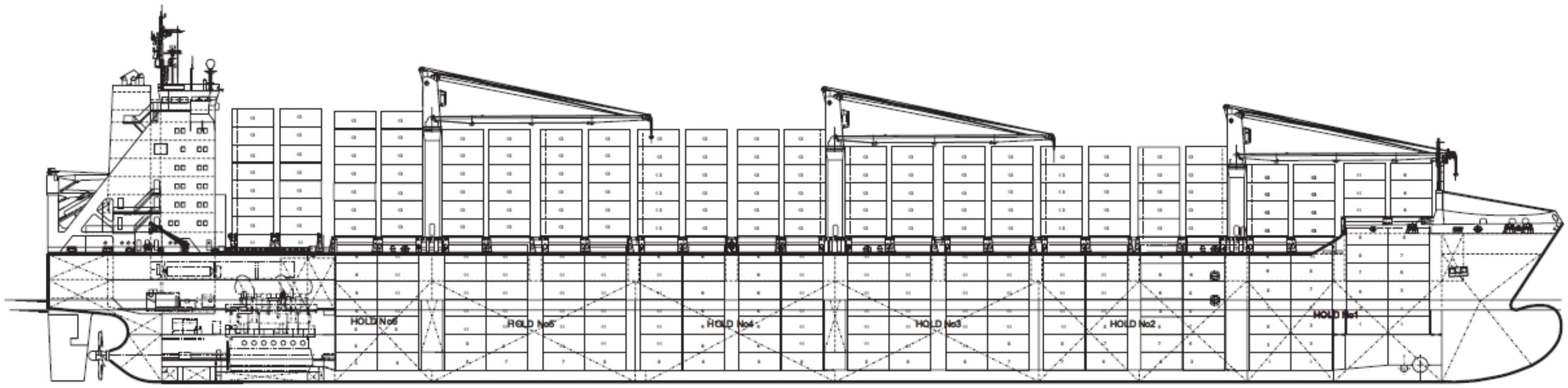
Type and destination of the ship

Cellular, geared container vessel intended for the carriage of:

- 20 and 40ft ISO containers in holds and on deck ;
- 45 and 49 ft containers on deck,
- Dangerous cargo containers in holds No 1-6
- Reefer containers (self-contained air cooled type) on deck and in hold No 2- 5
- Break bulk cargoes in hold No 2-5.

Built in the Stocznia Szczecińska Nowa

Classified by GL



Main characteristics

Tonnage 35 881 GT 14 444 NT

Deadweight 41 850 t

Length O.A. 220.50 m

Length B.P. 210.20 m

Breadth moulded 32.24 m

Depth to main deck 18.70 m

Freeboard draught 12.15 m

Speed (service) at 10,50 draught 22.30 kn

2.1. Material Selection

2.2. Factors Influencing the Selection of the Ship Hull Structure Topology

2.3. Structural Topology Selection

2.4. Midship Section Concept Sketch

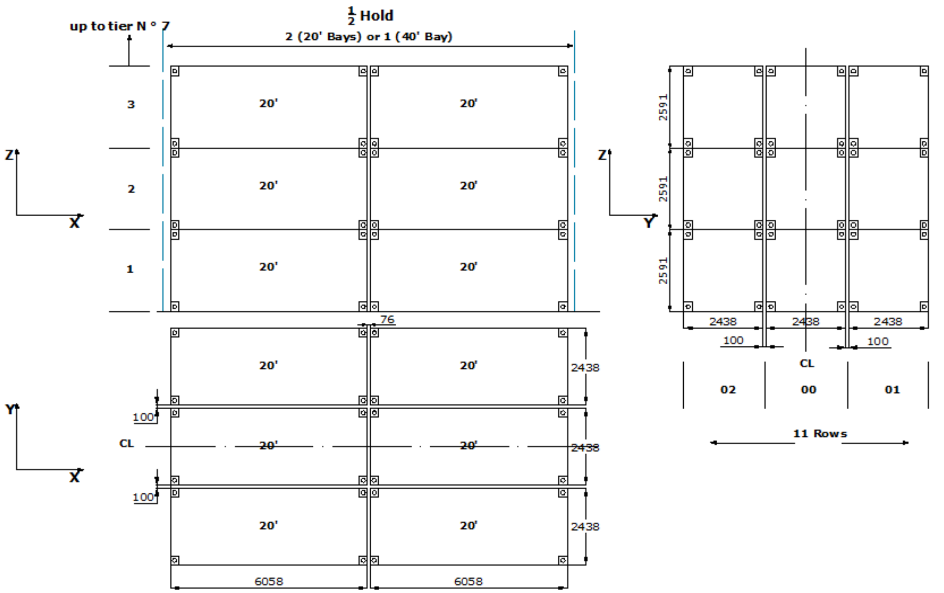
2.1. Material Selection

Application of the mild steel and high tensile steel :

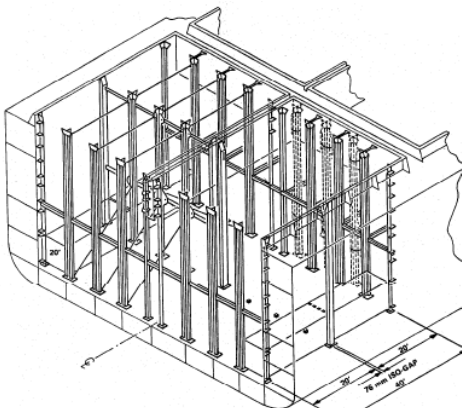
Steel	R_{eH} , N/mm²	Structural members
AH	355	Shell plating ,including keel, outer bottom and side plates; Inner bottom, deck plates, and longitudinal bulkhead strakes; Bottom longitudinal girders; Longitudinal hatch coamings including their longitudinal stiffeners.
A	235	Transverse members, including floors, web frames, and plates forming transverse bulkheads; Longitudinal stringers in the side shell as well as transverse bulkheads structures; Longitudinal stiffeners for the whole structure.

2.2. Factors Influencing the Selection of the Ship Hull Structure Topology

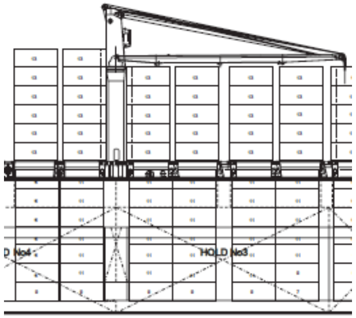
- Containers' size and the number of bays, rows, and tiers which may to be stowed inside the holds



- Container securing devises such as cell guides



- Handling containers equipment such as cranes

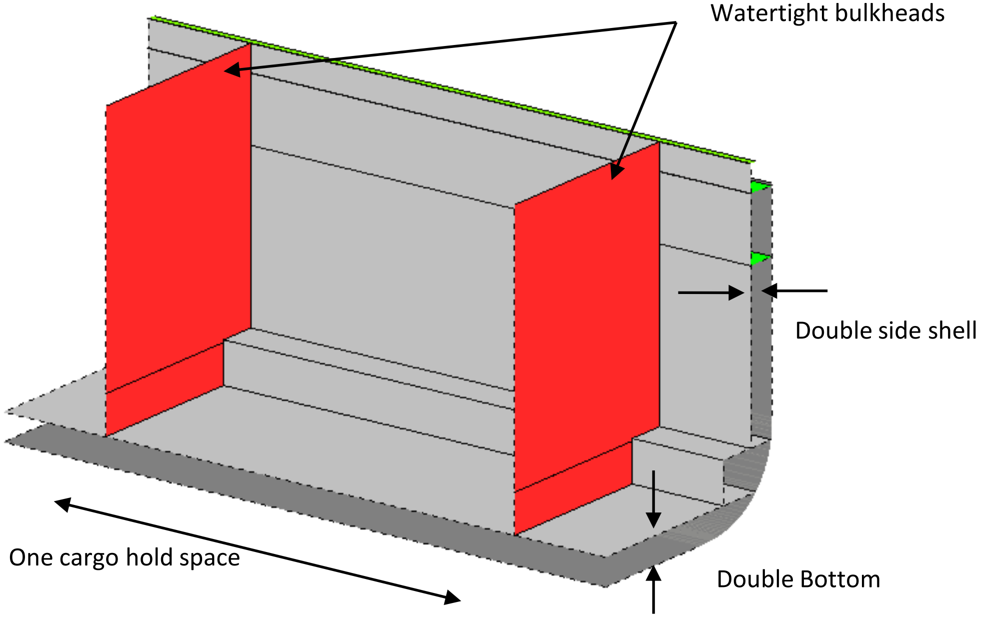


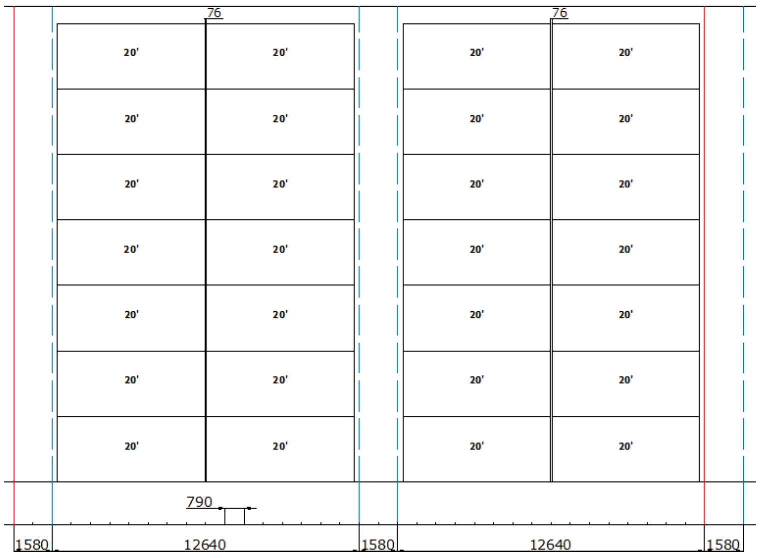
2.3. Structural Topology Selection

Longitudinal framing system is adopted

Longitudinal frame spacing equal to 790 mm

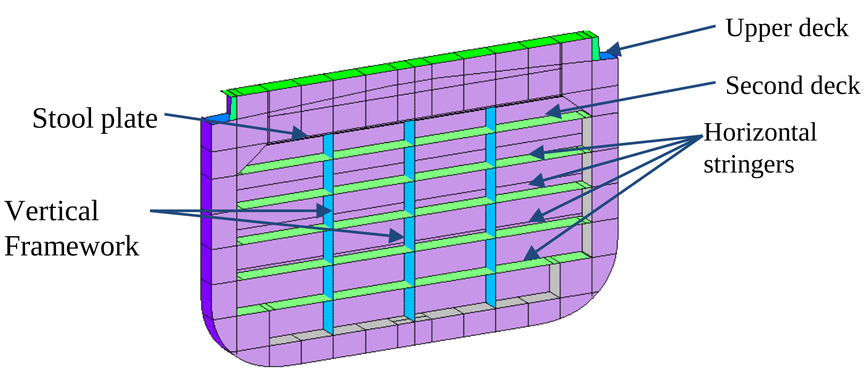
Initial structural topology of one cargo hold





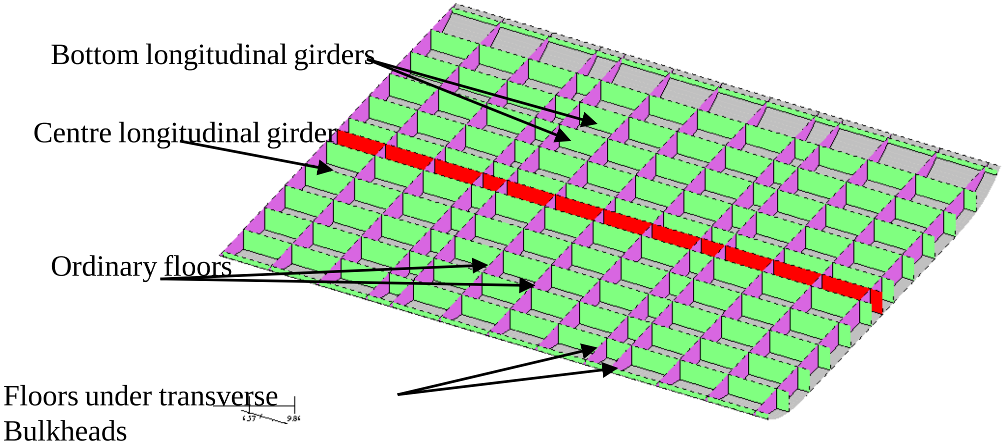
Transverse bulkhead structure

The structure of each bulkhead is extended over two frames.
The spacing between the transverse bulkheads is equivalent to the length of 40 ft container.



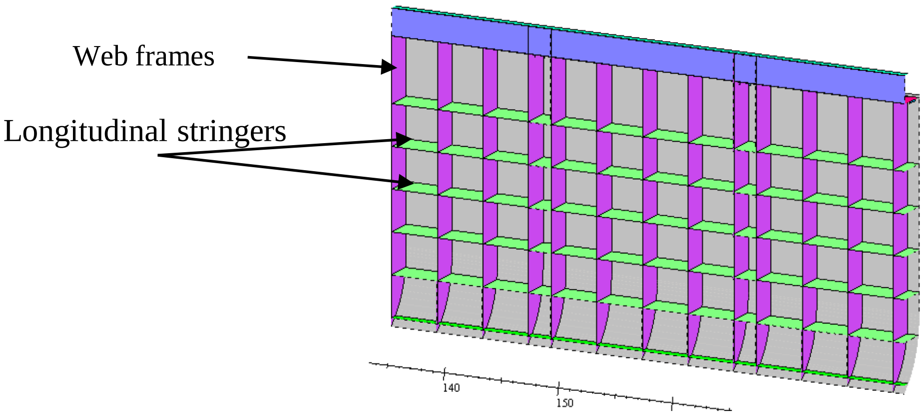
Double bottom structure:

side longitudinal girder and floors form rigid support for the containers' seat.

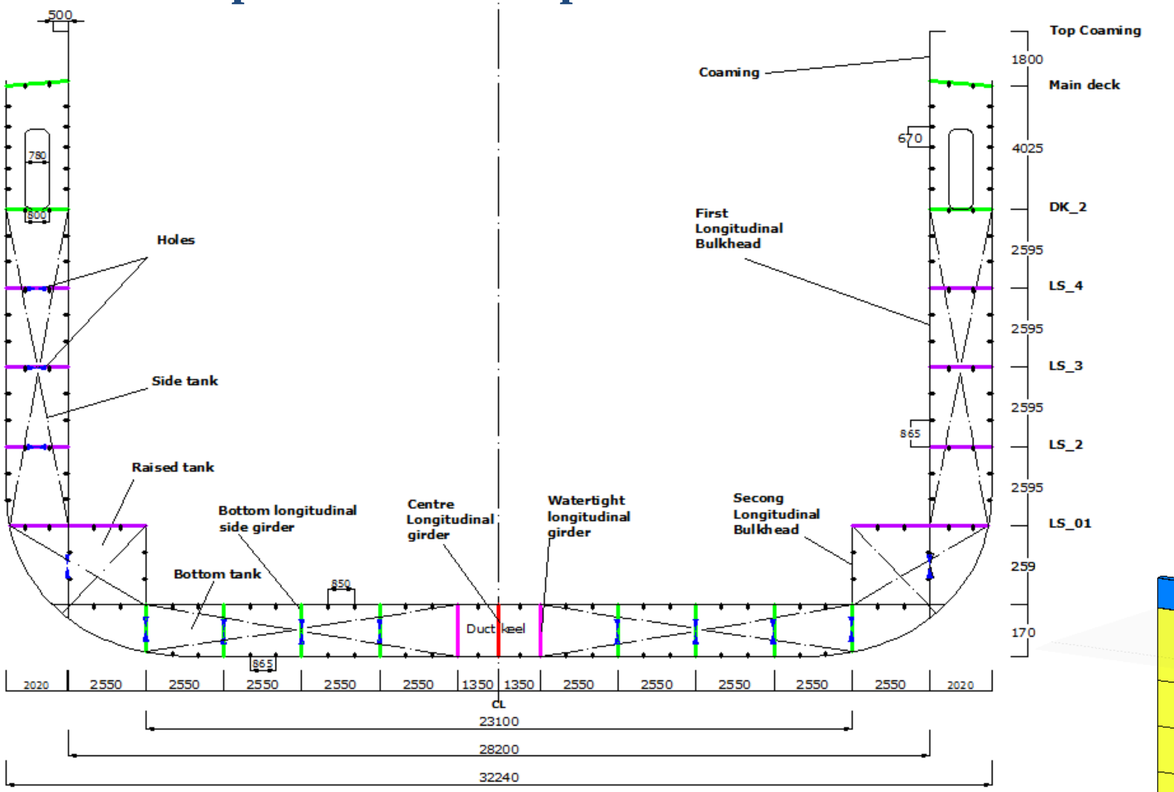


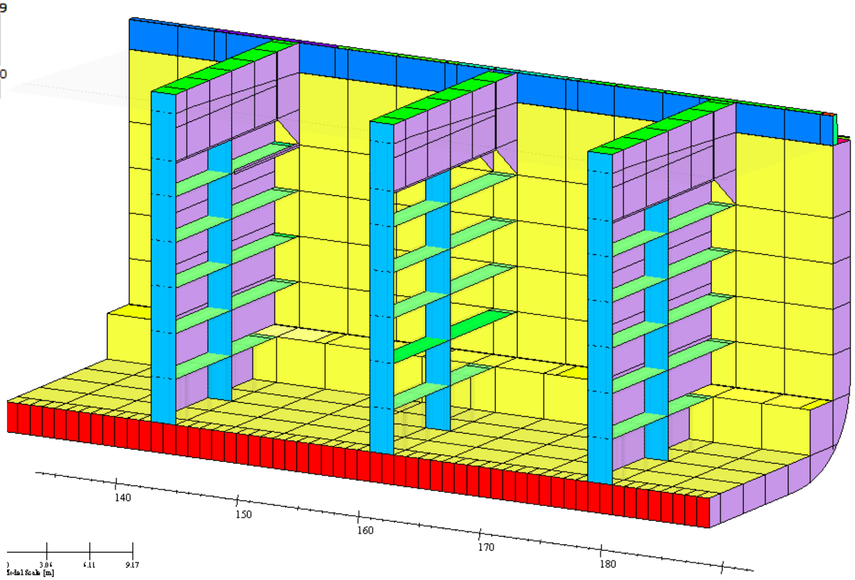
Double side structure

longitudinal stringers and web frames form a rigid support for ship's sides structure between transversal bulkheads.



2.4. Midship Section Concept Sketch

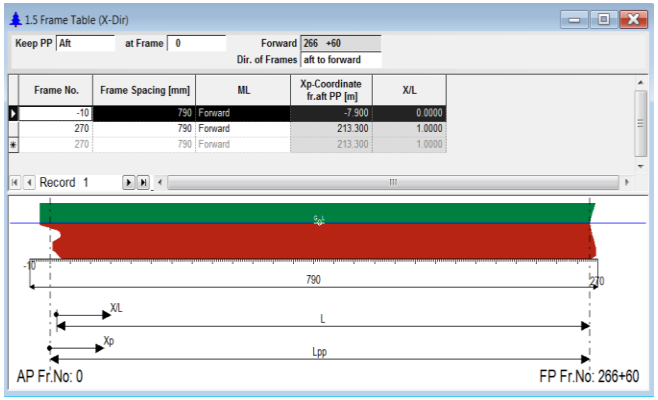


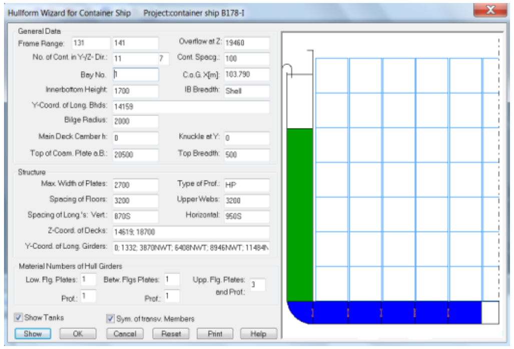


3.1. Ship Hull Structural Modelling According to Poseidon Computer Code

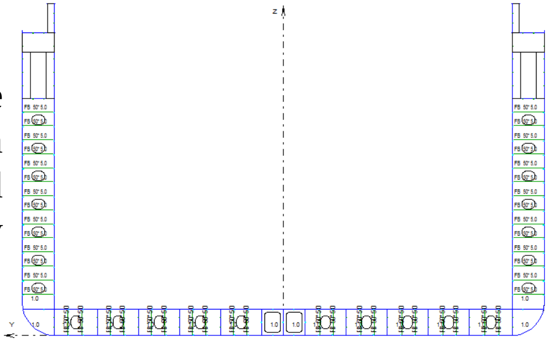
The modelling process is subdivided into the following steps

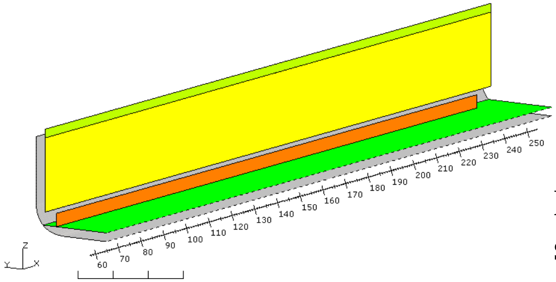
Input the ship characteristic data.





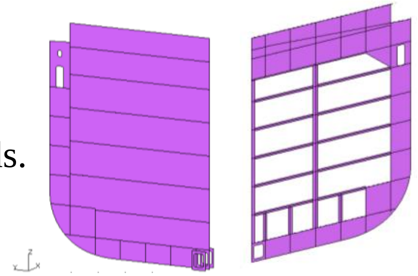
Generation of the typical cross section of the developed containership by Wizard-Poseidon.

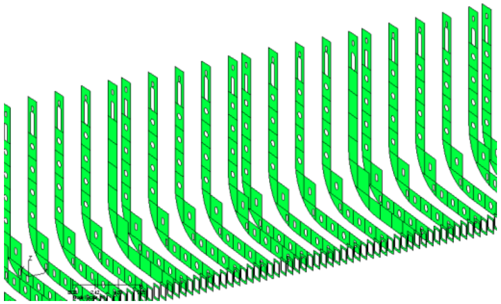




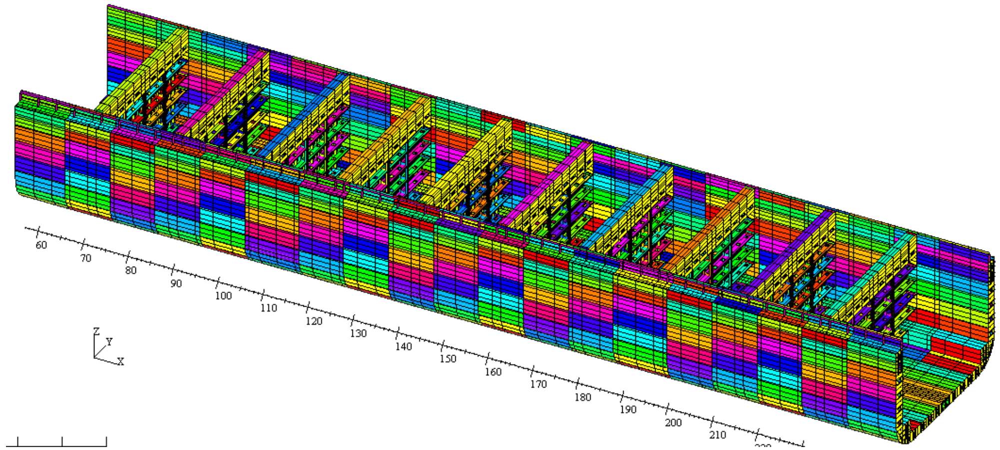
Extending of the structural elements over the cylindrical part of the ship.

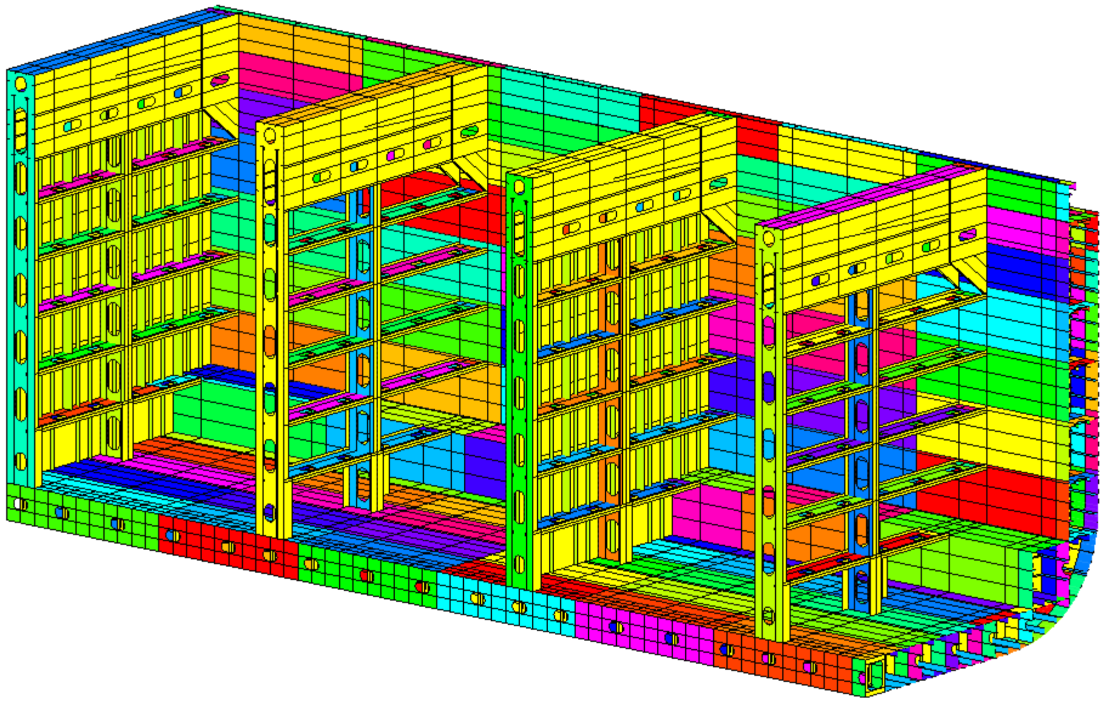
Arrangement of the transversal bulkheads.



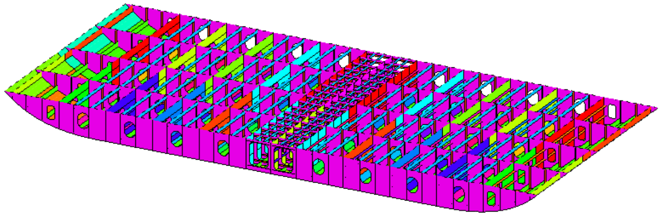


The developed hull structural model resulted from the structural modelling process

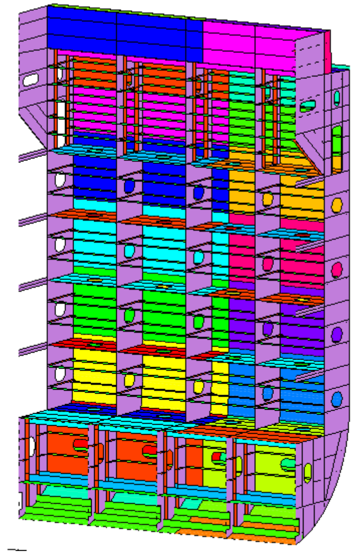




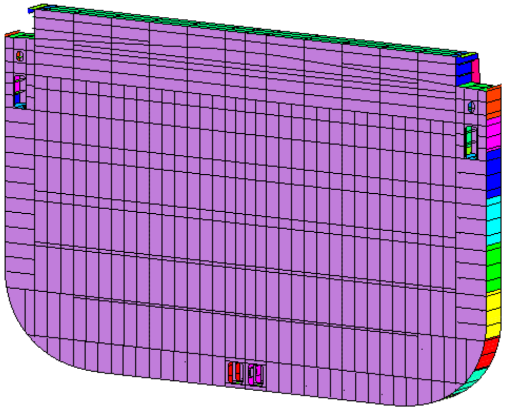
Double bottom structure



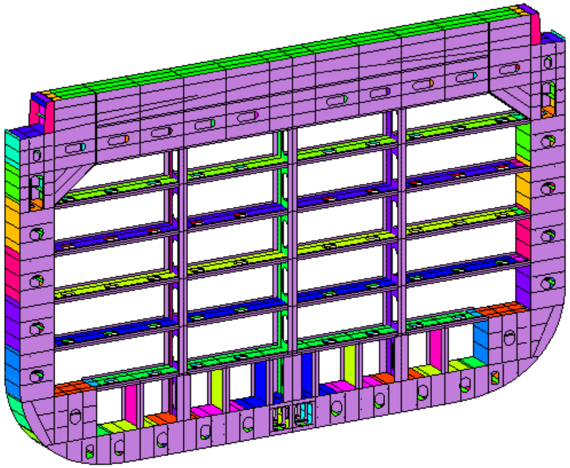
Side structure



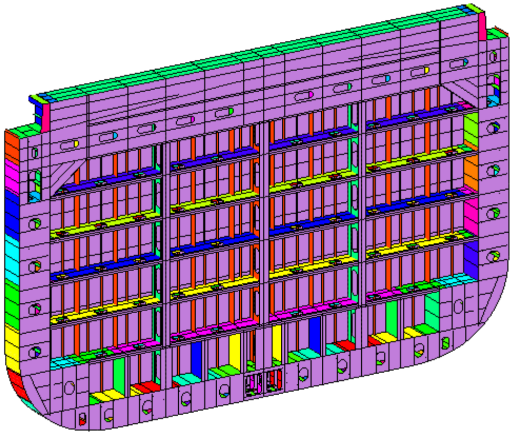
Watertight bulkhead



Non watertight bulkhead

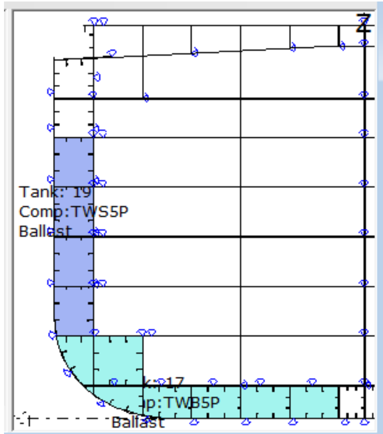


Open side of watertight bulkhead

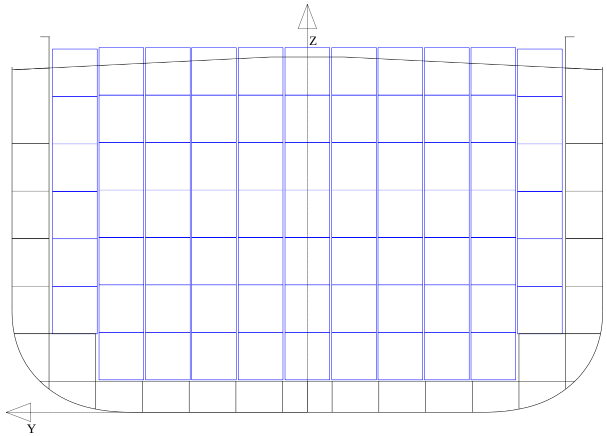


3.2. Design criteria load

Compartments load



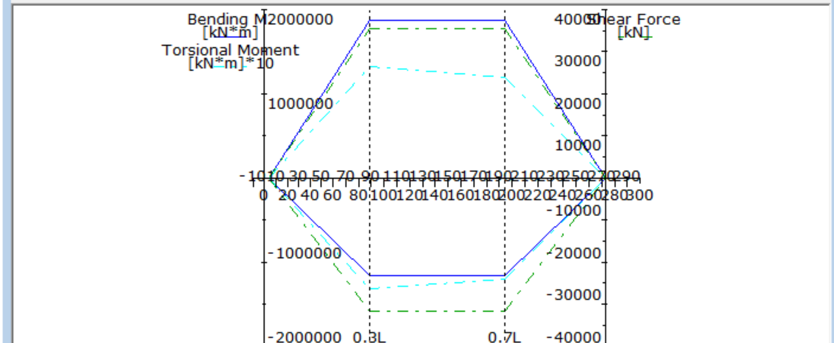
Containers load



Stillwater Bending Moments and Shear Forces

	Bending Moments BM		Shear Forces SF		Tors.Moment
Frame No.	Max [kN*m]	Min [kN*m]	Max [kN]	Min [kN]	+/- [kN*m]
0L	0	0	0	0	0
0.3L	1875894	-1154759	35431	-31641	131872
0.7L	1875894	-1154759	35431	-31641	120295
1.0L	0	0	0	0	0

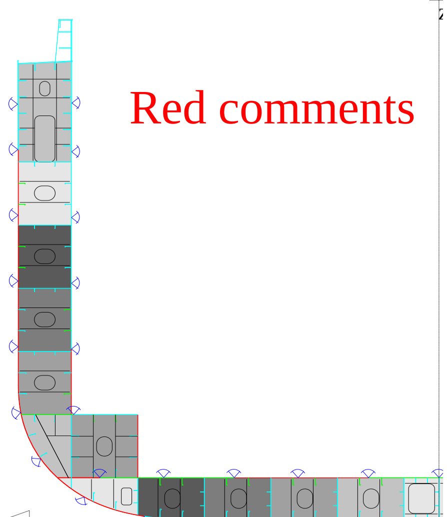
Record 2



Design Stillwater Bending Moments and Shear Forces

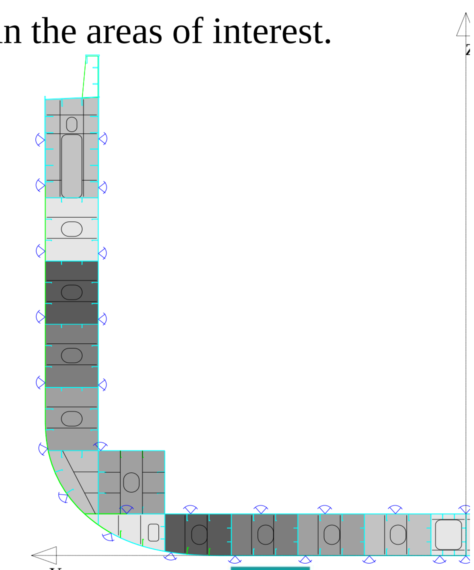
3.3. Scantling of structural elements

- Checking of the first scantling

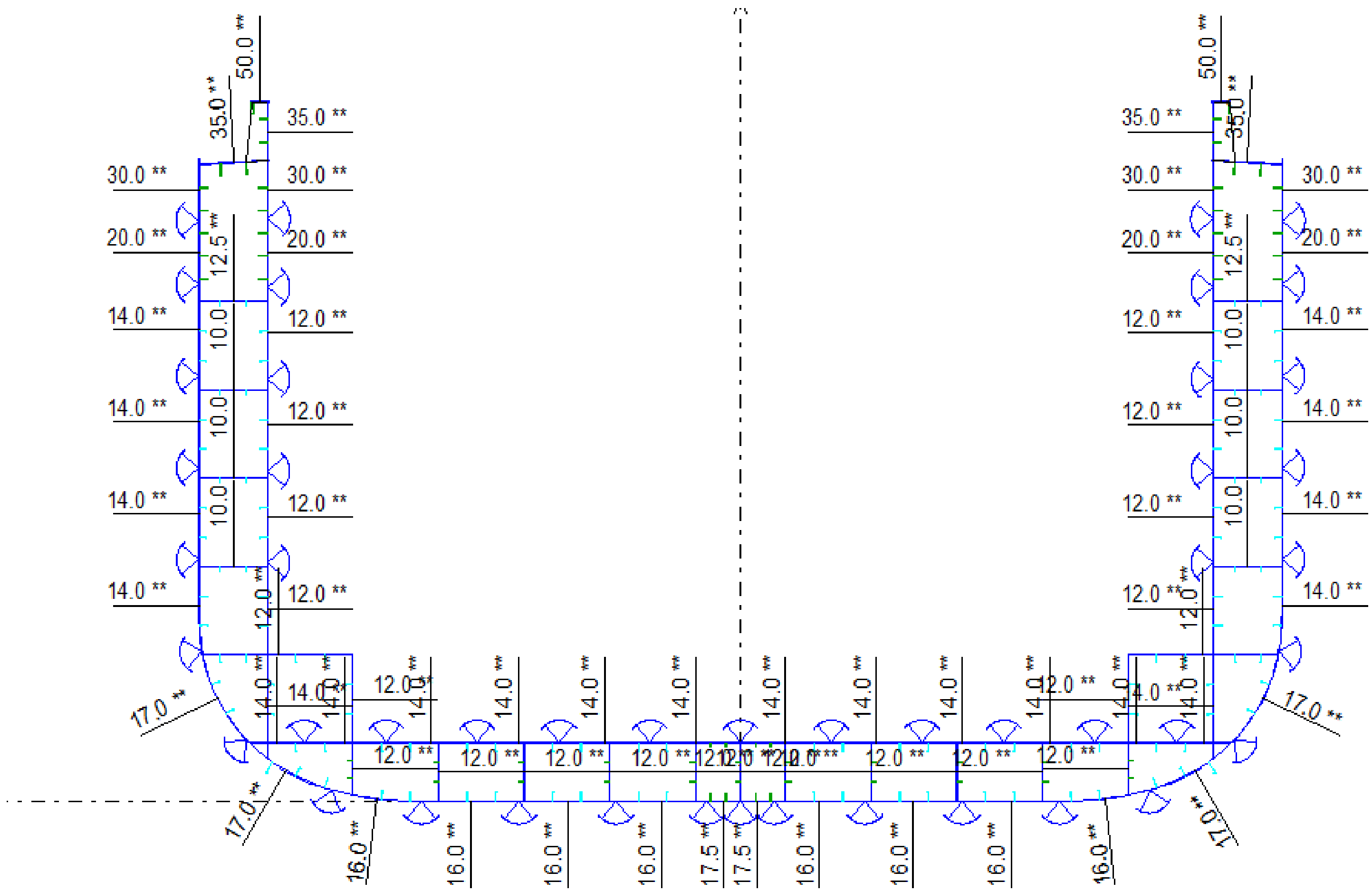


- Correction, change of material in the areas of interest.

Remove red comments, increasing the dimensions of profiles, increasing thickness of plates, and change the material where is necessary.



Resulted scantling fulfils the requirement of GL

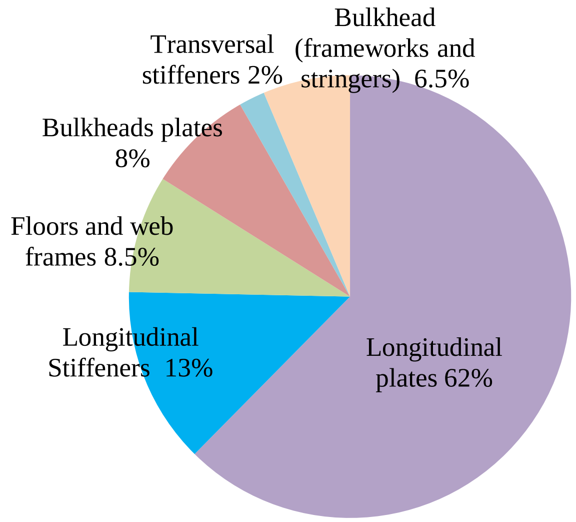


EMship Advanced Design

Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

Hull Steel Mass Estimation

	M, t	M, % M_t
Longitudinal plates	654.3	62.4
Longitudinal Stiffeners	135.5	12.9
transverse plates (floors and web frames)	90.0	8.5
Bulkheads plates	81.7	7.7
transversal stiffeners	20	1.9
Bulkhead (frameworks and stringers)	66.8	6.3
Total mass in one cargo hold, W_t	**1048.5**	

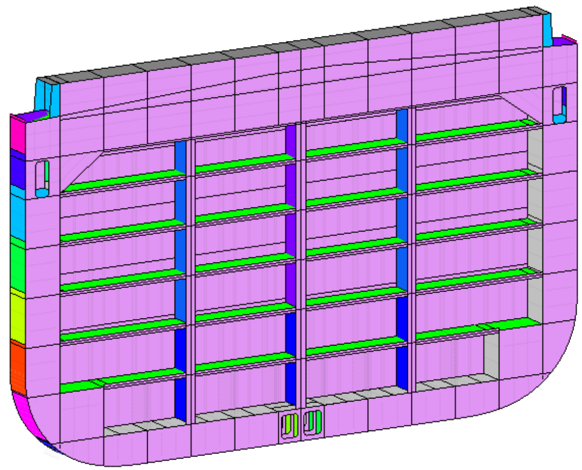


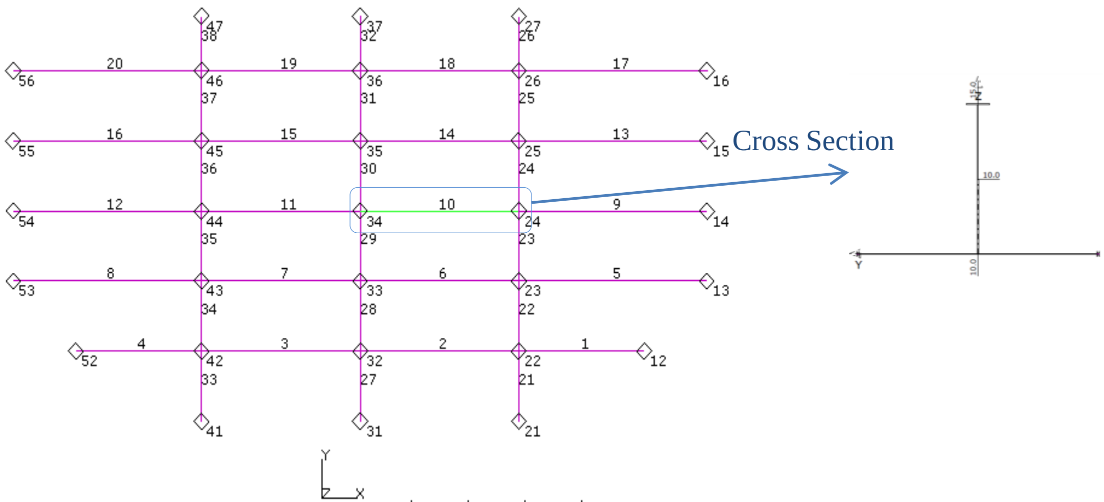
The mass of the ship hull steel is estimated equal to 3453 t which represent 6 % of the total displacement of the ship **(56996 t).**

4.1. Bulkhead Analysis Using Finite Element Method

Checking of the dimensions of bulkhead's primary structural members, against flooding load condition.

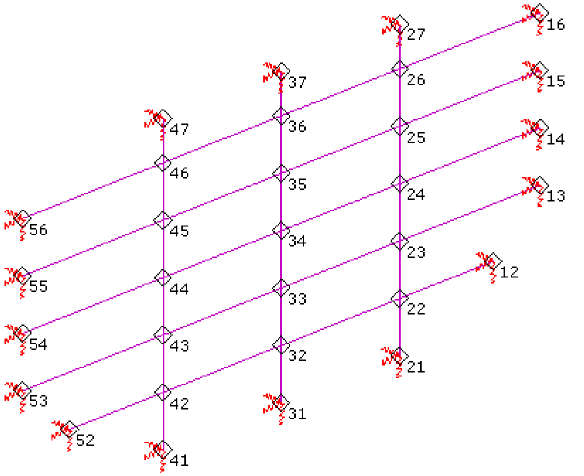
Build the structural model of one complete bulkhead





Boundary condition

Node No.	Spring Stiffness of boundary Elements in global direction					
	X	Y	Z	XX	YY	ZZ
	[kN/m]			[kN*m/rad]		
12	1.00000e+008	1.00000e+008	1.00000e+008	1.00000e+008	1.00000e+008	0.0
13	1.00000e+008	1.00000e+008	1.00000e+008	1.00000e+008	1.00000e+008	0.0
14	1.00000e+008	1.00000e+008	1.00000e+008	1.00000e+008	1.00000e+008	0.0



Load input

A damage water line has been taken at the level of the bulkhead deck h=18.7 m.

	Hi [m]	qi [KN/m]
IB	1.7	1102.558
LS_01	4.295	934.2559
LS_02	6.89	765.9536
LS_03	9.485	597.6514
LS_04	12.08	429.3491
DK_02	14.675	261.0469
DK_st	16.69	130.3613

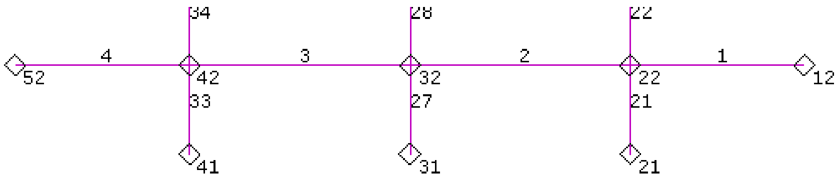
Input load for each vertical beam

Results evaluation

According to GL rules, the allowable stresses of the primary structural members, in the case of flooded hold is referred to nominal yield stress Re.

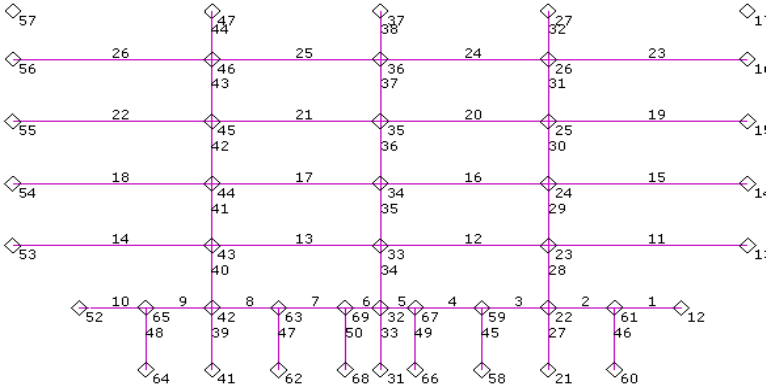
Re=235 N/mm²

Higher stresses at the level of the flanges of the lower vertical beams 21; 27; 33.



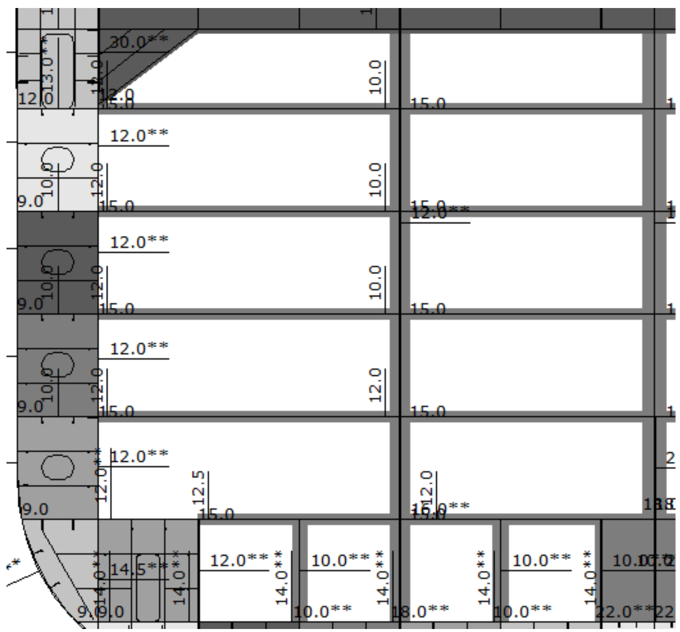
Add additional beams between Inner bottom and the first longitudinal stringer;

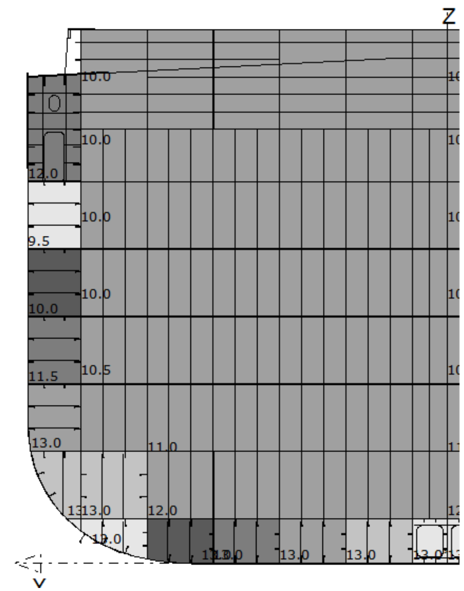
Increase the thickness of webs and flanges of the lower vertical beams.



Final scantling

Higher tensile steel is adopted for :
Flanges and lower web plates of vertical beams;
Normal steel for:
Bulkhead Plates and the rest of the bulkhead structure.





4.2. Cargo Hold Analysis

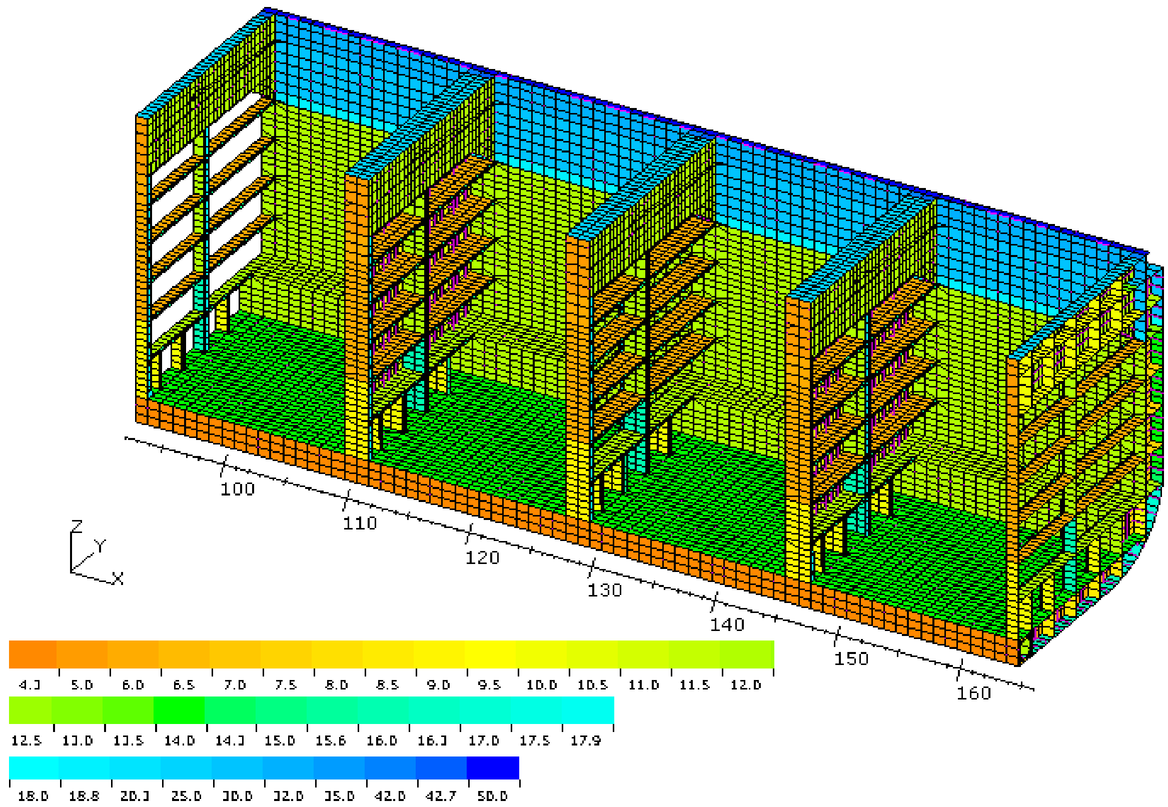
Description of the Model

Cargo hold from frame 93 to frame 165.

The model is built using mode 3:

Plates are modeled as Shell elements;

Stiffeners are modeled as beam element.



Load cases

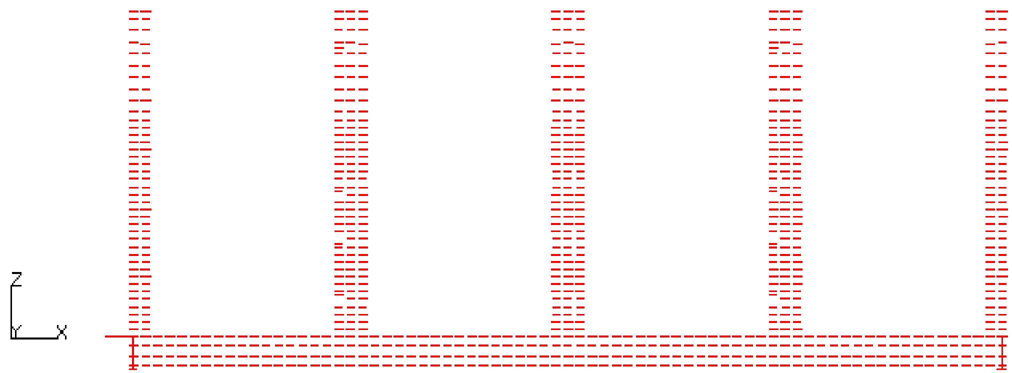
Two standard load cases are adopted :

- **homogeneous 40 ft;**
- **heavy Loading 20 ft.**

		LC 1		LC 2	
Load component		**Homo-geneous 40 FT**		**Heavy Loading 20 FT**	
Static Water Pressure Draught		scantling		scantling	
Dynamic Water Pressure		wave crest		wave trough	
Vertical Bending Moment Stillwater Wave		Max [3] Hogging		Min Sagging	
Vertical Acceleration		$(1 - a_V)$ g		$(1 + a_V)$ g	
Transverse Acceleration		0		0	
Longitudinal Acceleration of all masses		0		0	
Deck	Bay A	40'	20 t/FEU [4]	40'	30 t/FEU [4]
	Bay B	40'		40'	
	Bay C	40'		40'	
	Bay D	40'		40'	
Hold	Bay A	40'	20 t/FEU [4]	20'	15 t/TEU [4]
	Bay B	40'		20'	
	Bay C	40'		20'	
	Bay D	40'		20'	

Boundary condition

Two supports in the vertical direction at the fore and aft ends;
one support in the longitudinal direction at only the aft boundary;
In the transverse direction the symmetry conditions was applied



7.3 Boundary Conditon

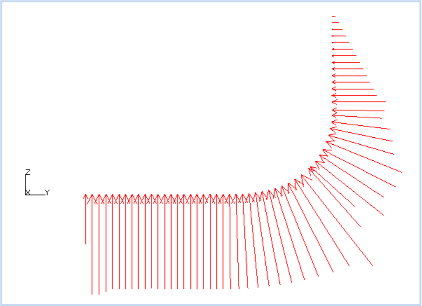
Model No: 1   Item: cargo hold analysis

Kind of Section	Location of Section					Support Condition						Boundary Value
	X-Start	X-End	Y-Z Start	Y-Z End	Sym	X	Y	Z	XX	YY	ZZ	
y-z-plane with CE	93					2	0	2	0	2	0	1.00000e+008
y-z-plane with CE	165					2	0	2	0	2	0	1.00000e+008
x-z-plane			0.0 mm			0	1	0	1	0	1	1.00000e+008
LG_00	93	93	IB	IB	P+S	1	0	1	0	0	0	1.00000e+008
LG_00	165	165	IB	IB	P+S	0	0	1	0	0	0	1.00000e+008

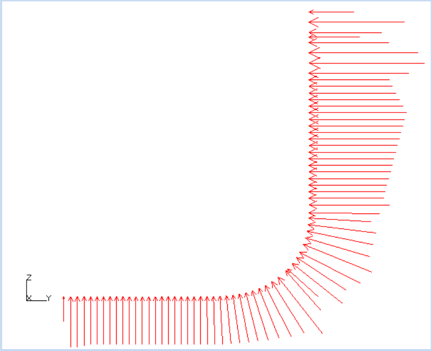
Record 4

Load input

Still water bending moment, Shear force



Static pressure Tmax



Dynamic water pressure

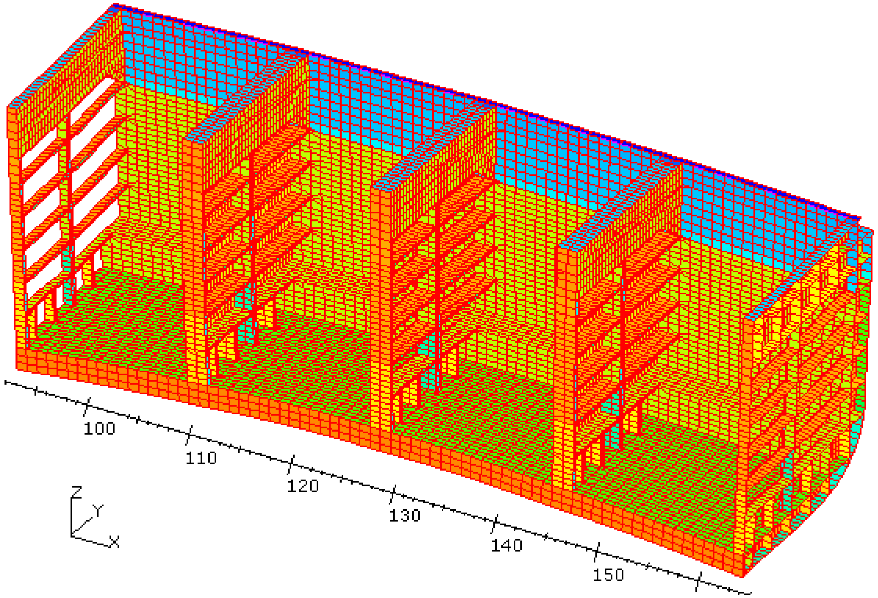
Vertical acceleration; Container load

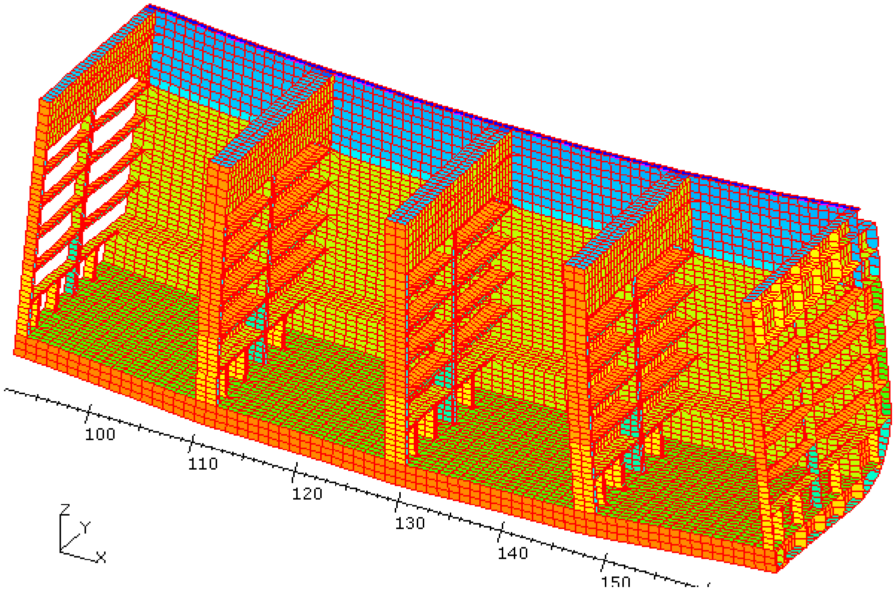
Load adjustment

	Bending moment Hogging, KN.m	Bending moment Sagging, KN.m
Still water	1875894.00	-1154759.00
Waves	1759584.34	-2144119.25
Target value	3635478.34	-3298878.25

Results evaluation: Deformation

Homogeneous 40 ft load case





Heavy 20 ft load case

Load case	Maximum deflection in *Z* direction, mm
Homogeneous 40 ft;	92
Heavy Loading 20 ft;	-33

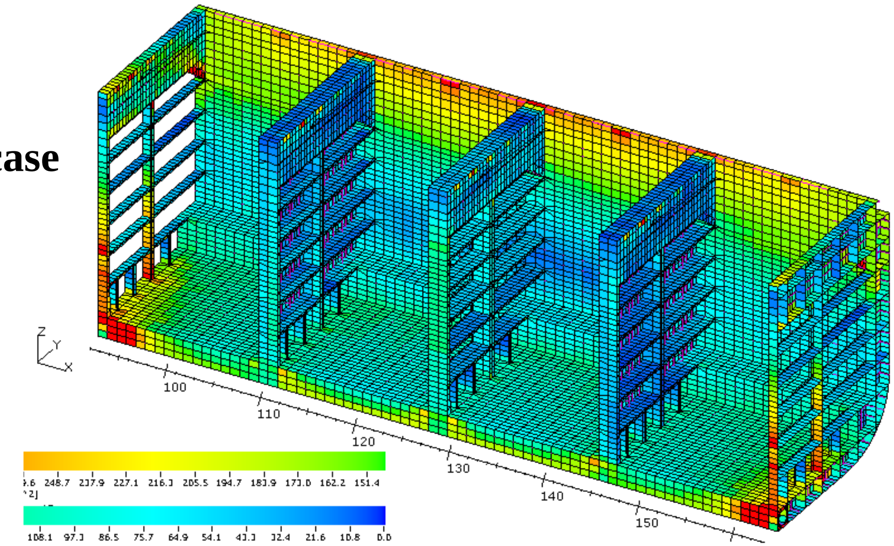
4. Strength Analysis Using Finite Element Method

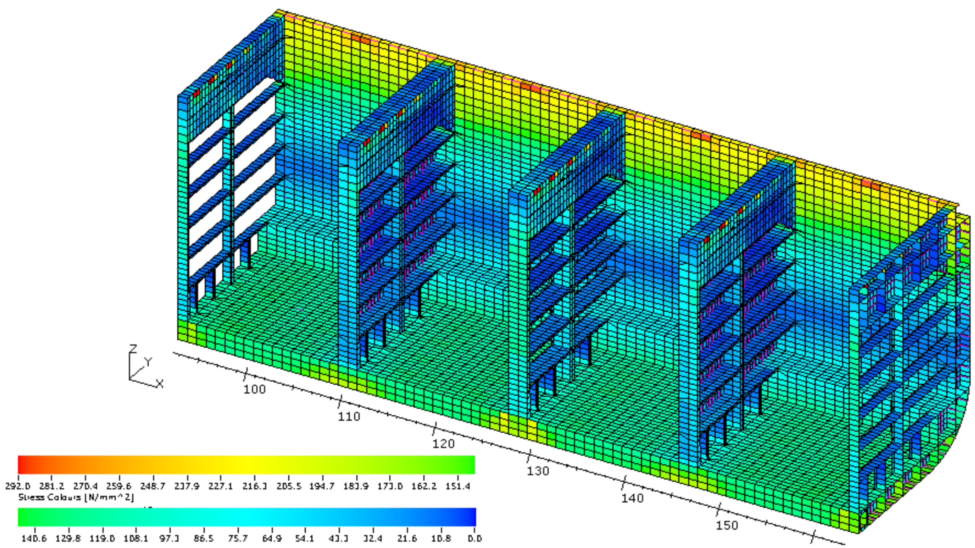
Results evaluation : permissible stress values

	k	Normal stress $\boldsymbol{\sigma_N}$, N/mm²	Shear stress $\boldsymbol{\tau}$, N/mm²	Equivalent stress $\boldsymbol{\sigma_v}$ N/mm²
Longitudinal members	0.72	264	138	292
Transverse members	1	150	100	180

Results evaluation: Von Mises stress

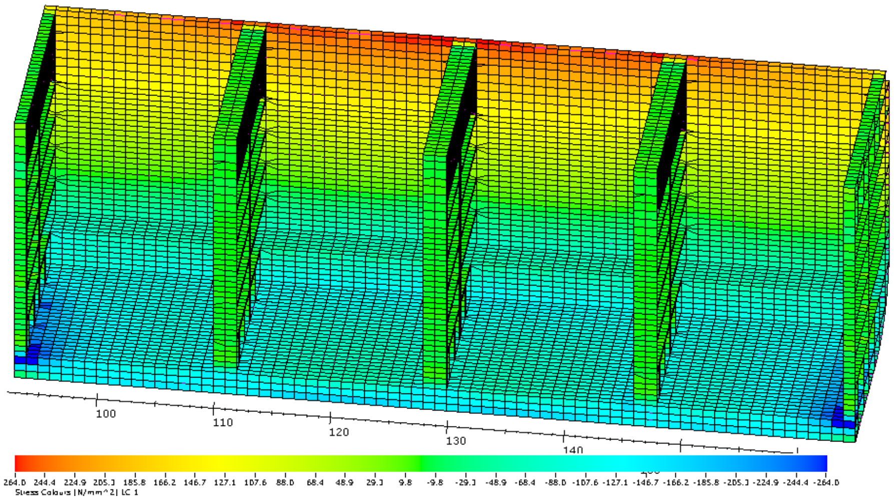
Homogeneous 40 ft load case



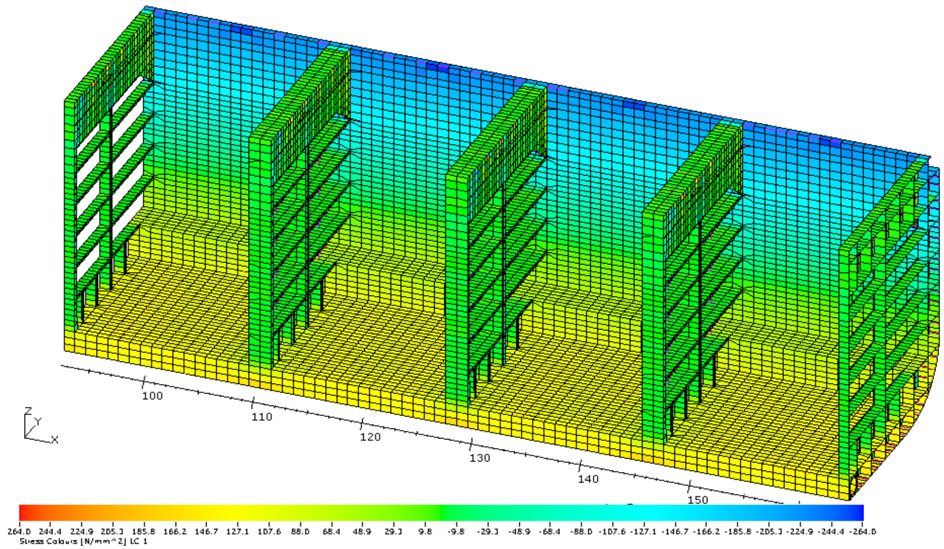


Heavy 20 ft load case

Results evaluation: Normal stress

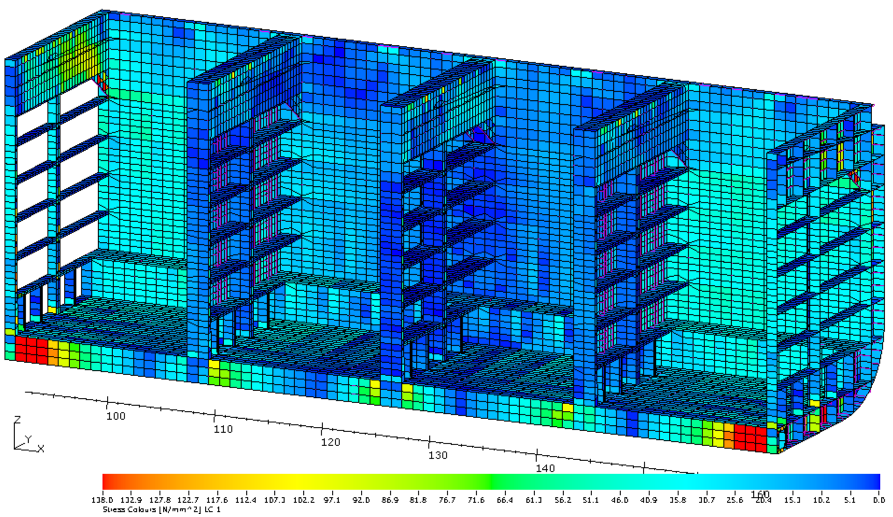


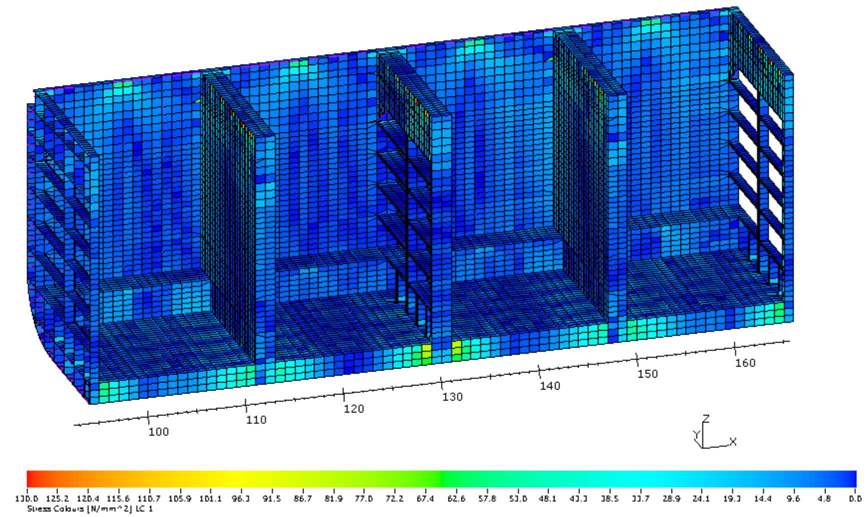
Homogeneous 40 ft load case



Heavy 20 ft load case

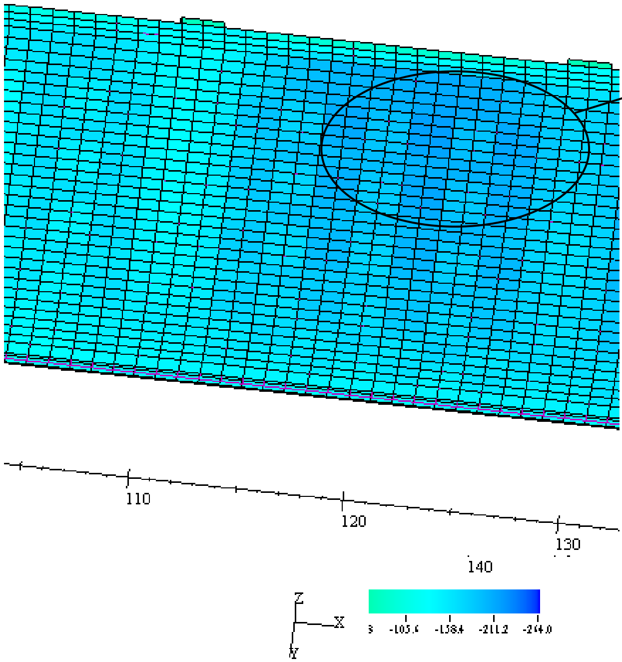
Results evaluation: Shear stress





4. Strength Analysis Using Finite Element Method

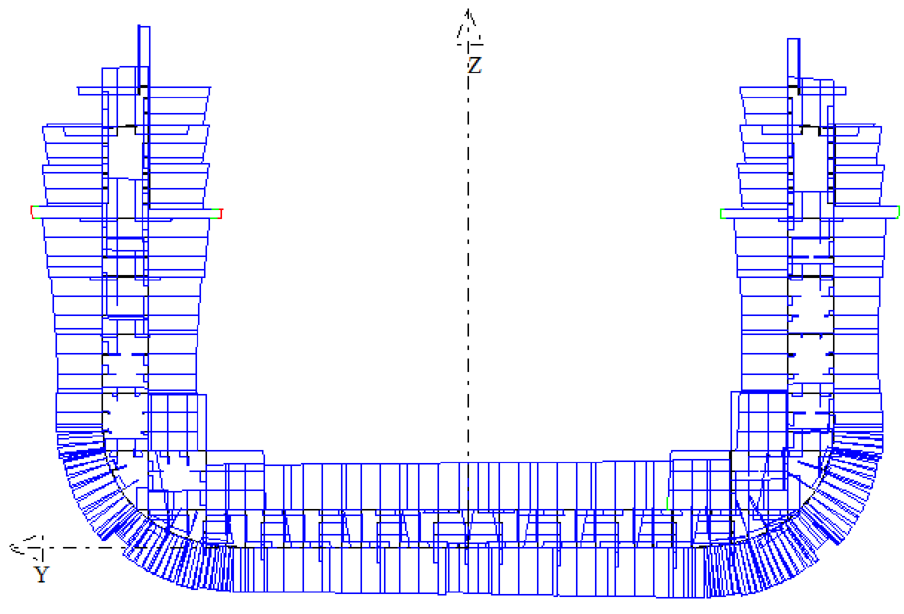
The buckling strength is checked for compliance with Section 3, Design principle of the GL rules which corresponding to the plate field evaluation in Poseidon software.



Plates Critical to buckling

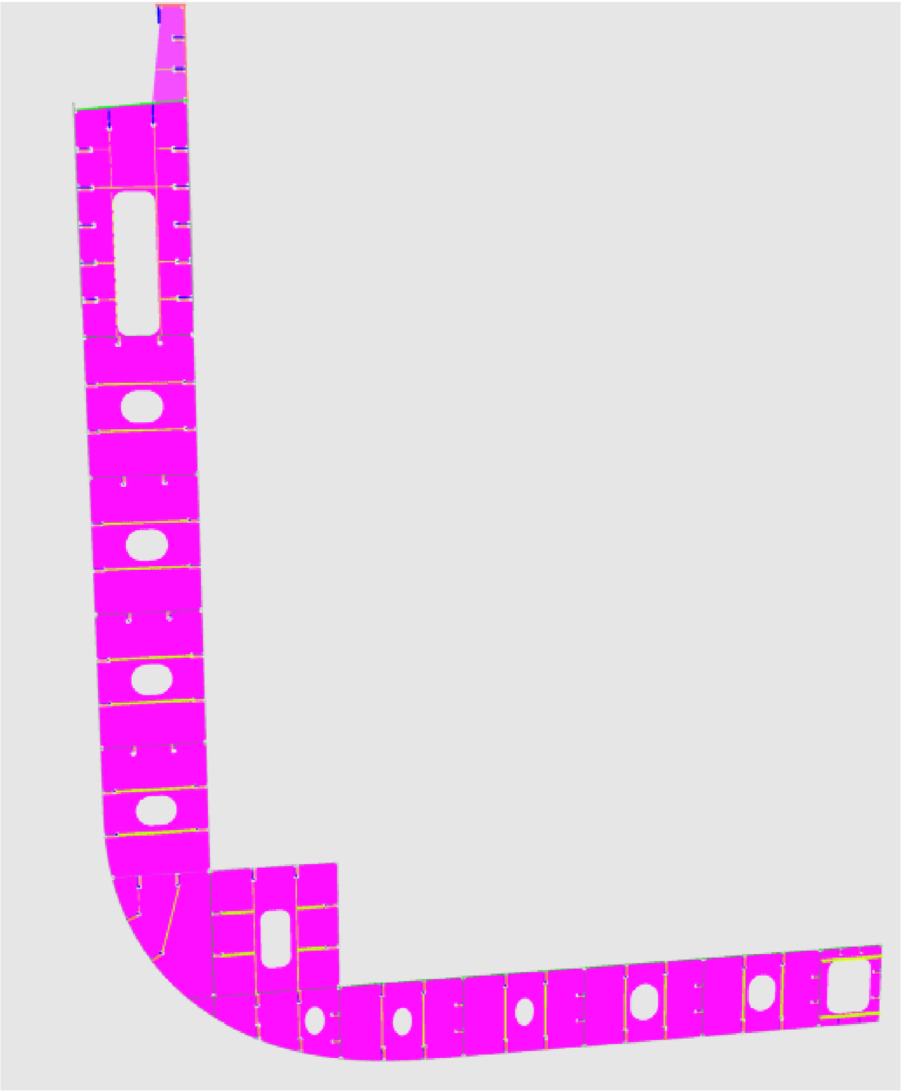
σ_x =-218 MPa

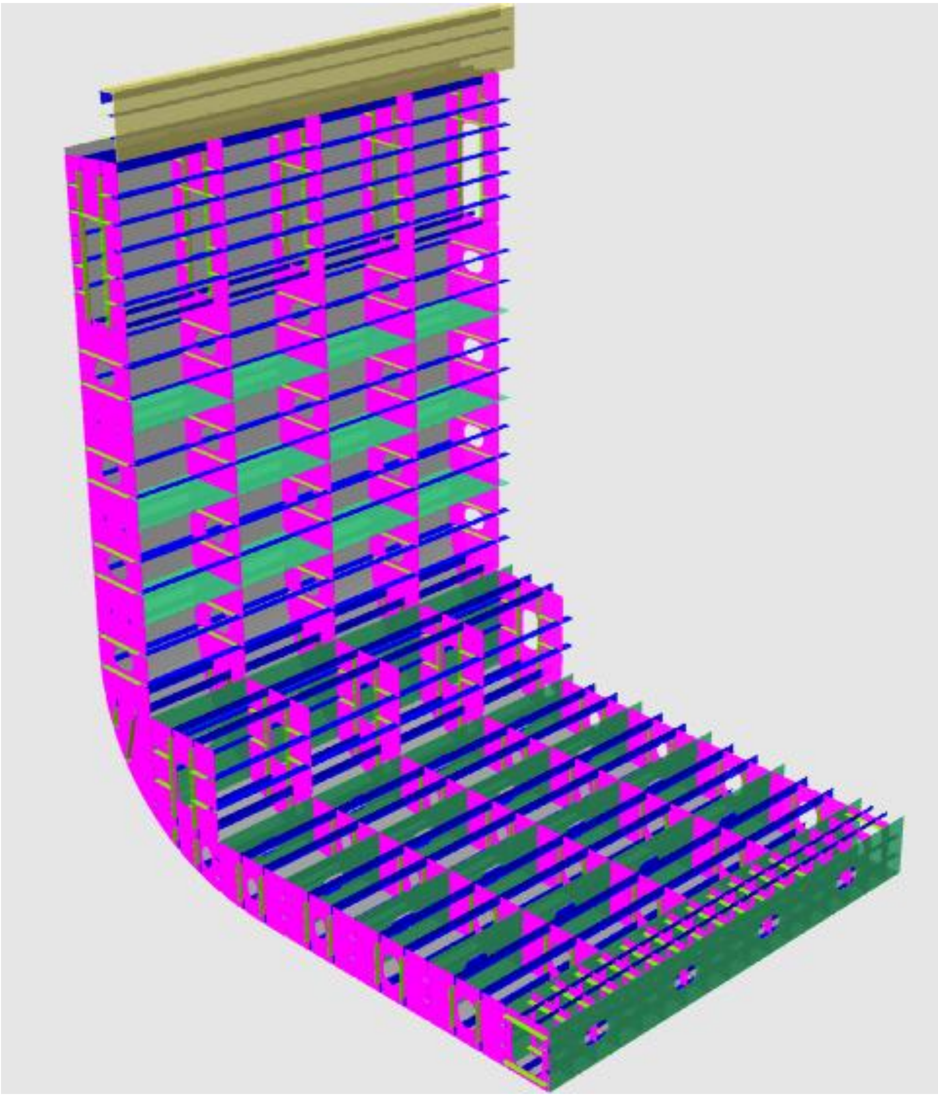
Combination of vertical bending moment, torsional moment and horizontal bending moment.



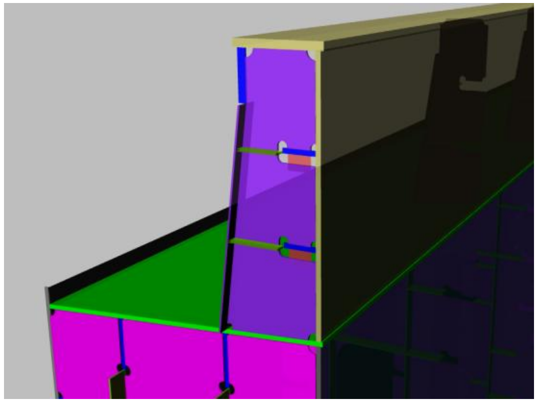
max. v.Mises= 246.6 N/mm^2 at Y= 14094 mm, Z= 15095 mm

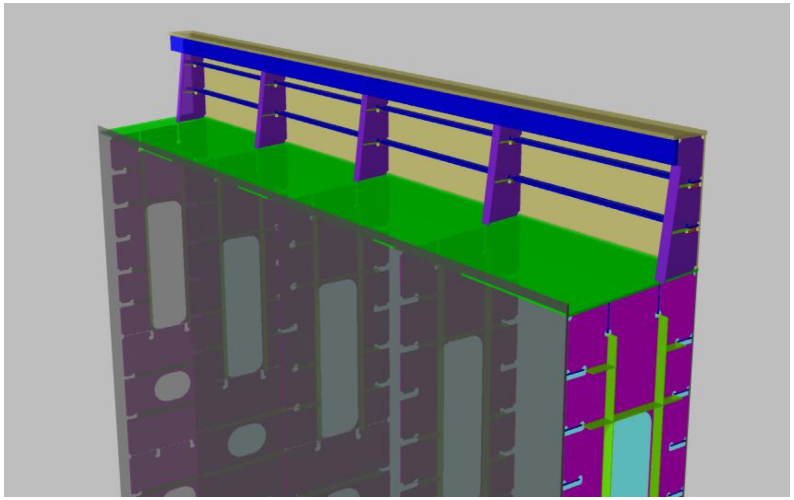
In the longitudinal direction, the model extend from frame 130 to frame 146

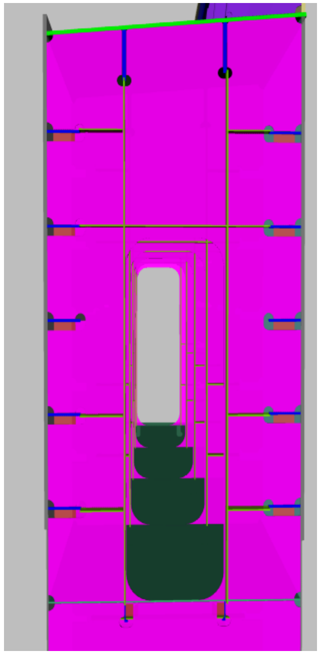


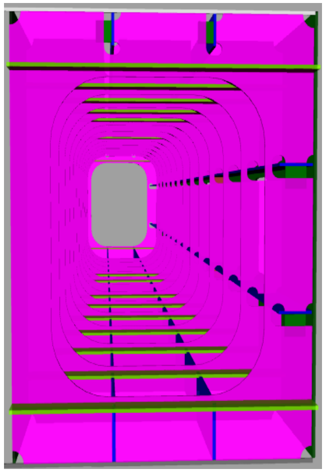


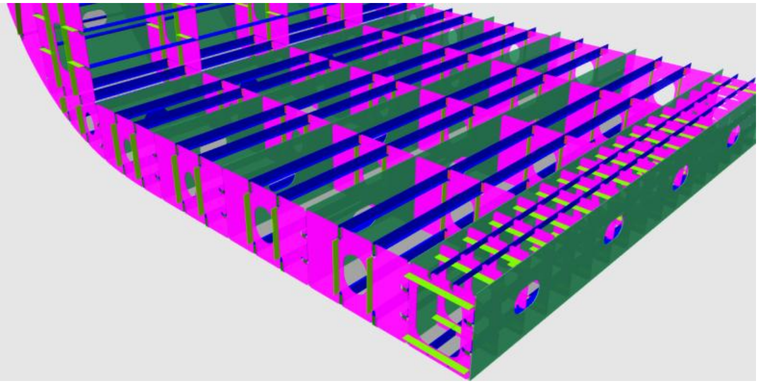
5. Three-D Visualisation of a Part of the Hull Structure Using Tribon Software

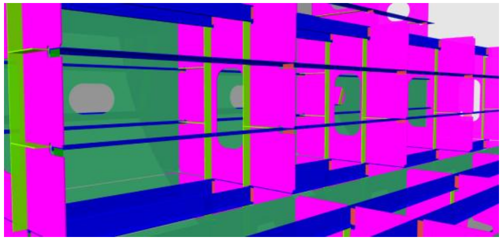


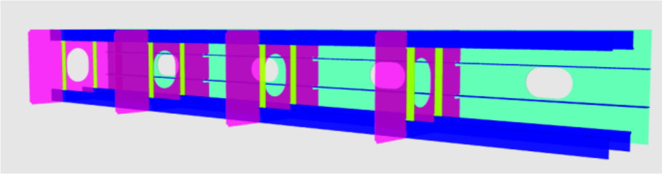




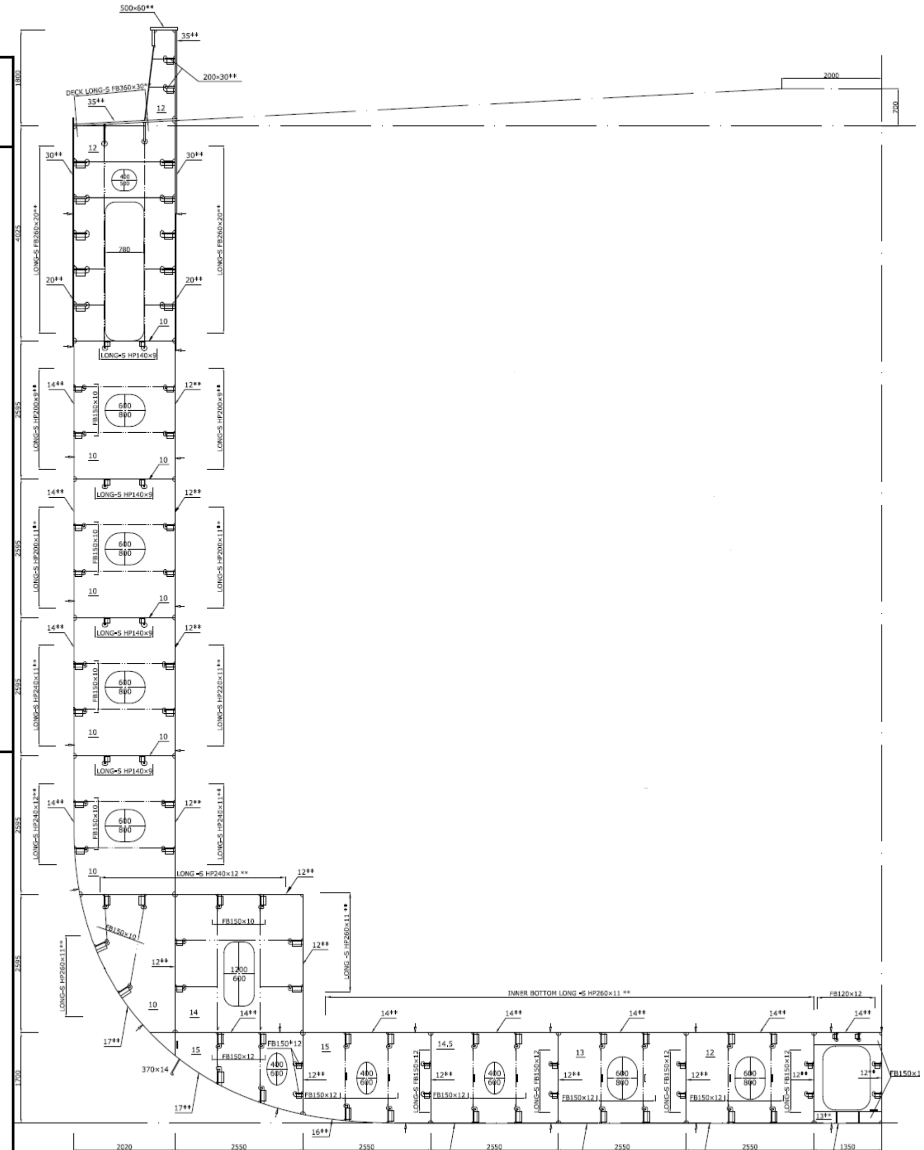








Steel	R_{eH}, N/mm²	Structural members
AH	355	Shell plating; longitudinal girders and the first stringer in the double side structure; Lower vertical framework of the transverse bulkheads; Longitudinal hatch coamings including their longitudinal stiffeners; Longitudinal stiffeners in the plates of shell.
A	235	Transverse members; plates forming transverse bulkheads; Longitudinal stringers in the double shell structure; Longitudinal stiffeners.



7. Conclusions

The scantling of the structural members is carried out using two approaches provided by Poseidon software:

- pre-sized structure according to construction rules;
- pre-sized structure based on direct calculation using FEM.

Looking at the results of the first approach, an initial scantling which fulfils the requirement of the GL rules with the minimum thickness is obtained in an iterative process.

The results of the finite element analysis provides a good insight about deflection, normal stress, shear stress and von Mises stress in the structural members which allows selecting the critical structural regions, such as the middle part of the top coaming and some parts of the floors.

These structural regions were strengthened by increasing their thicknesses.

7. Conclusions

The result from the checking of the bulking strength in the plates of the outer bottom indicates that the minimum thickness under the specified conditions should not be less than 15.4 mm. Hence the thickness 16 mm as well as stiffeners HP 280×11 is sufficient against buckling.

Thank you for your attention