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STRESS AND DEFORMATION ANALYSIS OF A MODULAR FLOATING DOCK WITH A 5000-TON LIFTING CAPACITY

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ABSTRACT

This study investigates the global structural behaviour of a modular floating dock with a 5000-ton lifting capacity. Using the finite element method (FEM), the research assesses stress and deformation responses under different operational conditions, namely lightship, ballasted, and full-load, both in calm water and under wave loads. Identifying the vessel's critical stress concentration zones, the study effectively evaluates these areas, providing targeted recommendations to optimize the vessel's structure and improve its operational reliability.

Keywords: floating dock, finite element analysis, scantling, global analysis

1. INTRODUCTION

This paper focuses on the global structural behaviour of a floating dock with a 5000-ton lifting capacity under realistic operational conditions. The dock is subjected to loads corresponding to real operating conditions: the lightship condition, the ballasted (immersion) condition, and the full-load condition, both in calm water and under equivalent design wave loads. The study follows these steps:

1. Determination of main dimensions and lifting capacity.
2. Structural scantling based on Bureau Veritas classification rules (NR217 [3] and NR612 [4]).
3. Development of structural and tank arrangement plans.
4. 3D CAD and FE model using Simcenter Femap [2].
5. Load application and evaluation of stresses and deformations.

2. GENERAL DESCRIPTION OF THE 5000-TON LIFTING CAPACITY MODULAR DOCK

A global structural analysis is conducted for a 5000-ton lifting capacity modular dock, with the main dimensions listed in Table 1.

Table 1. Main characteristics

L_{OA} [m]	99.98
L_{WL} [m]	99.98
B [m]	32.00
B_V [m]	26.00
D [m]	12.25
T_F [m]	2.40
T_B [m]	10.25
T_V [m]	8.25
C [t]	5000

The dock is classed under Bureau Veritas notation:

I✠HULL 5 FLOATING DOCK/LIFTING CAPACITY (5000 tons)/MODULAR/ HS ≤ 1.2.

3. DETERMINATION OF MAIN DIMENSIONS AND LIFTING CAPACITY

3.1 Lifting capacity

To calculate the lifting capacity and the freeboard, the dock was modeled as ten idealized modules. The volumes of the tanks within each module were computed according to the dimensions shown in Figure 1, followed by the calculation of parameter *J* to ensure the minimum freeboard in accordance with the requirements of Bureau Veritas classification society.

For the immersion case, the minimum freeboard required by the regulations is one meter. After the calculations, assuming a maximum dock height of 11.25 meters, the total displacement of the dock at maximum immersion is 13541.25 tons. Considering the estimated structural mass of the dock at 2,300 tons, the required ballast for this condition is 11241 tons. Figure 2 illustrates the variation of displacement as a function of draft.

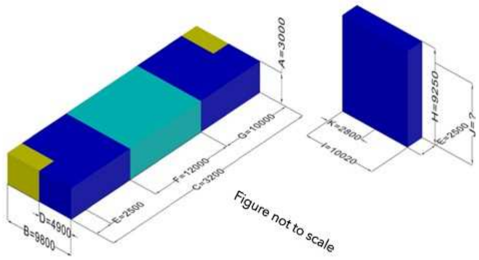

Figure 1. Module dimensions

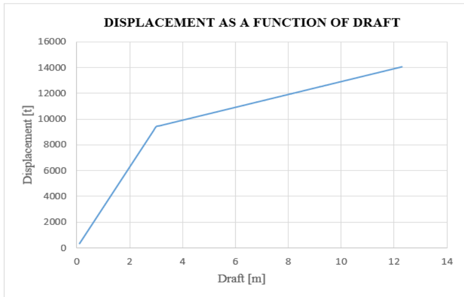

Figure 2. Displacement as a function of draft

3.2 Structure scantling

For the scantling process, the Bureau Veritas classification society's software, *MARS Inland* [5], was used. Based on this program, the minimum dimensions of the structural elements (S235 steel) were determined, deck plating: 15 mm with HP280x11 stiffeners, bottom plating: 13mm with HP180x8 stiffeners, side plating: 10-13 mm with HP160x8-220x10 stiffeners, module connections: 25mm plates with HP220x10 stiffeners, as illustrated in Figures 3-5, ensuring compliance with the minimum strength criteria specified in the classification society's regulations, as presented in Figure 6.

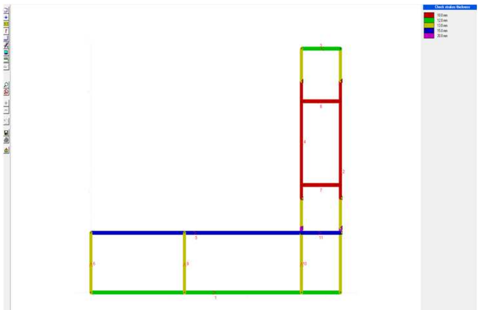

Figure 3. Strakes thickness

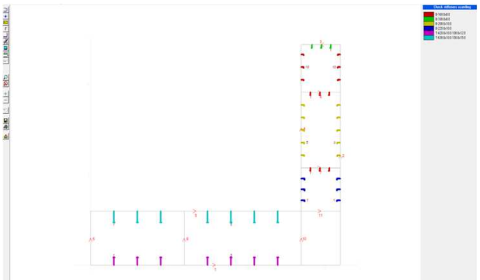

Figure 4. Longitudinal stiffeners scantling

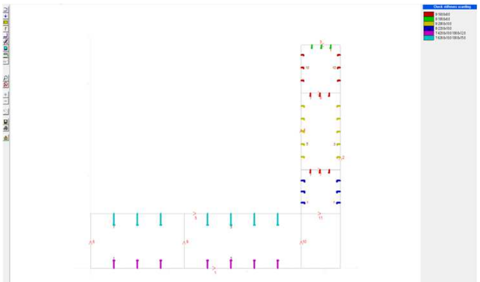

Figure 5. Transverse stiffeners scantling

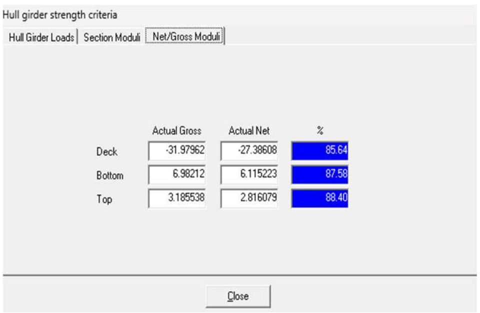

Figure 6. Hull girder strength criteria

3.3 Structural, tank, and keel blocks arrangement plans

Based on the scantling results and the module geometry, the structural (Figure 7-12), tank (Figure 13-15), and keel blocks arrangement (Figure 16) plans [1] were developed.

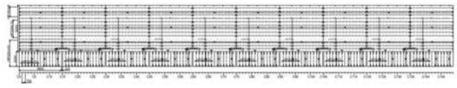

Figure 7. Longitudinal section at shell level

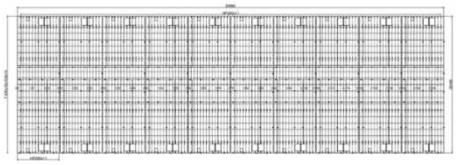

Figure 8. Main deck

Figure 9. Bottom

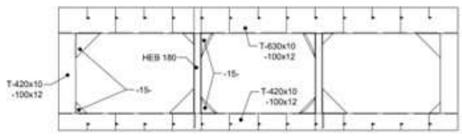

Figure 10. Typical longitudinal section

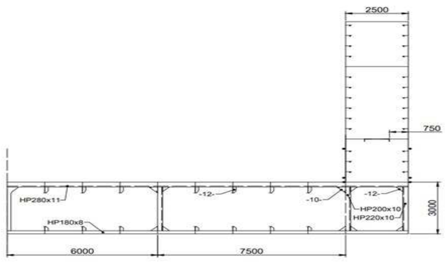

Figure 11. Typical frame

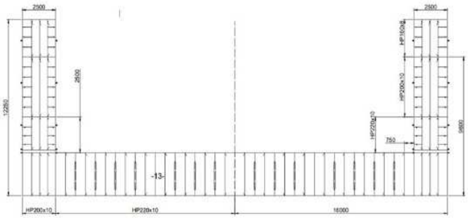

Figure 12. Web frame

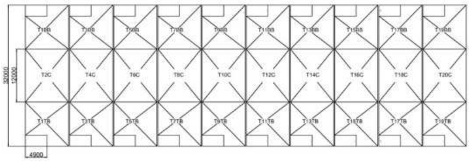

Figure 13. Tank top

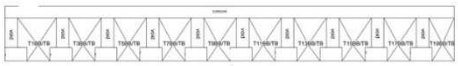

Figure 14. Longitudinal section at shell level

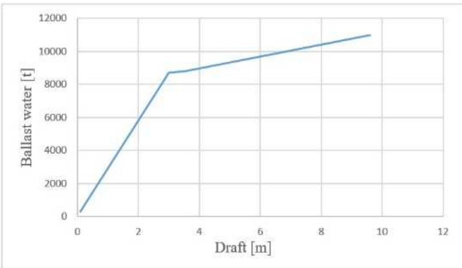

Figure 15. Water ballast tank capacity as function of draft

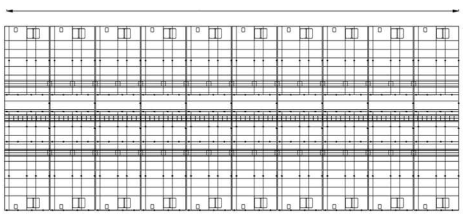

Figure 16. Keel block arrangement

3.4 Geometric modelling and mesh generation

The dock structure was idealized, and the CAD (Figure 17, 18) and FE (Figure 19-21) were modeled in Simcenter Femap [2] software. The structure consists of 10 modular units. The double bottom is transversely stiffened, while the double sides are longitudinal stiffened to provide bending and torsional resistance.

The FE model includes approximately **1.78 million elements** and **1.72 million nodes** (2D QUAD (PLATE)) elements [6].

Boundary conditions follow IACS [7] recommendations, constraining translations along specific nodes in the bow and stern, to prevent rigid body motion as listed in Figure 22.

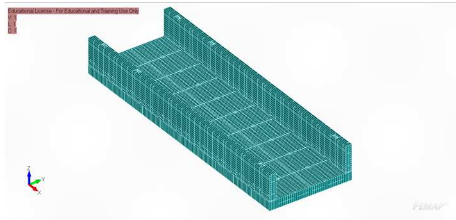

Figure 17

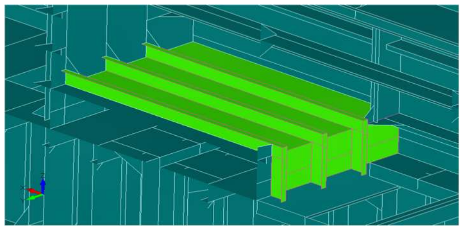

Figure 18

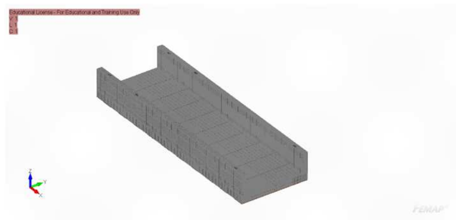

Figure 19

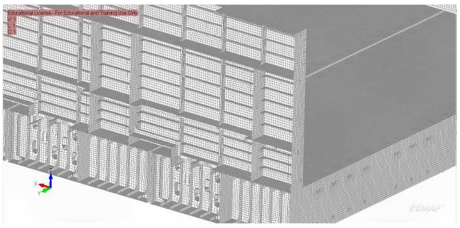

Figure 20

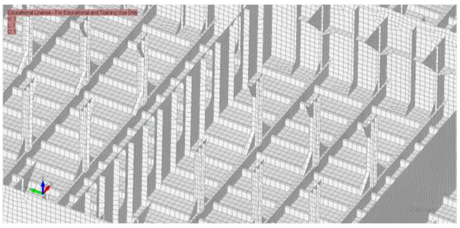

Figure 21

Location		Direction	Type
Aft	Center line	T_x, T_y, T_z	Translation
Fore	Portside	T_z	Translation
	Center line	T_y	Translation
	Starboard	T_z	Translation

Figure 22. Constraints

4 Analysis

The dock was analyzed under three operational states:

1. Lightship condition (Figure 25) – minimal draft (0.745 m), calm water, and design wave loads.

2. Ballasted condition (Figure 26) – complete immersion (10.25 m draft), accounting for hydrostatic pressure/design wave loads and ballast water weight (Figure 23).

3. Full-load condition (Figure 27) – lifting a 5000-ton vessel (2.4 m draft, Figure 24), hydrostatic pressure/design wave loads.

Wave loads correspond to an equivalent design wave of 1.2 m significant height.

The steel used in the analysis has a yield strength of 235 MPa, with an allowable limit (safety factor 0.75) of 176 MPa.

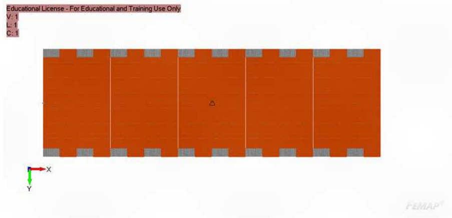

Figure 23. Ballast water mass distribution on bottom plating

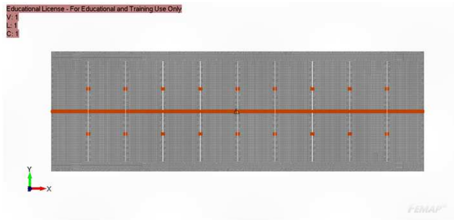

Figure 24. Lifted vessel mass distribution on keel blocks

Lightship

Case	Plate Top VonMises Stress [MPa]	Deformation [mm]	Safety limit [MPa]
Calm water	125.81	10.333	176
Hogging	235	66.509	176
Sagging	235	45.989	176

Figure 25

Ballast

Case	Plate Top VonMises Stress [MPa]	Deformation [mm]	Safety limit [MPa]
Calm water	235	41.524	176
Hogging	235	38.844	176
Sagging	235	44.788	176

Figure 26

Full-load

Case	Plate Top VonMises Stress [MPa]	Deformation [mm]	Safety limit [MPa]
Calm water	235	34.743	176
Hogging	235	84.801	176
Sagging	235	33.474	176

Figure 27

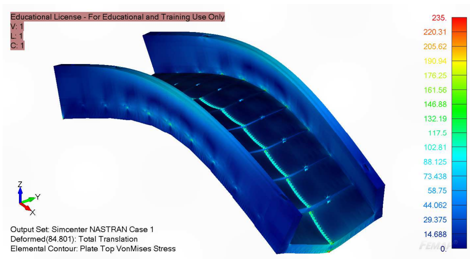

Figure 28

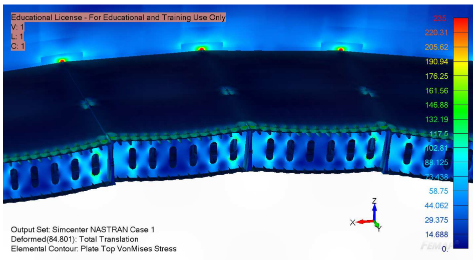

Figure 29

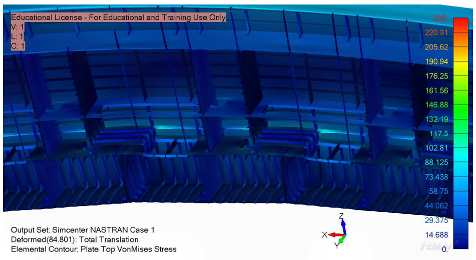

Figure 30

Maximum stresses occur near module coupling joints and longitudinal center supports as shown in Figures 25-30. Stress levels exceeding the allowable limit suggest local reinforcement is required/upgrading the steel grade to S355.

5 Concluding remarks

This study confirms that the modular floating dock meets the Bureau Veritas standards for inland and harbor use. The dock maintains structural integrity under normal operating loads, with critical stress concentrations exceeding 235MPa localized at the module connections. Reinforcing these areas, increasing plate thickness or employing higher-grade steel significantly enhance safety and durability.

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[2] Siemens, *Simcenter Femap Student Edition*.
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[4] Bureau Veritas, *Rules for Classification of Harbour Equipment (NR612)*.
[5] Bureau Veritas, *Mars Inland*
[6] Domnisoru, L. *Finite Element Method in Naval Construction – Lecture Notes*.
[7] IACS (International Association of Classification Societies).

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