TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 19
Number 2
June 2025

DOI: 10.12716/1001.19.02.23

Impact Study of Shipyard Limitations to Designed Floating Dock Construction

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ABSTRACT: The development of modern marine technology requires flexibility in design and high-quality craftsmanship. To some extent, this necessitates considering the various limitations imposed by shipbuilding enterprises. These limitations influence ships' and marine equipment's construction, characteristics, and operational behavior. The article analyzes the impact of production constraints on a steel floating dock's design and strength characteristics. The strength properties of the facility, determining its suitability for use, have been analyzed using the MARS 2000 software. Two structural models of a floating dock have been developed—one with imposed width constraints and the other without constraints, with the same lifting capacity. It turns out that in the structure with constraints, the strength characteristics are close to those determined by the regulations. This provides grounds to claim that the geometric constraints of small and medium sized enterprises(SME)s do not always negatively impact the structural qualities of floating objects.

1 INTRODUCTION

The design of ships and marine facilities is a complex iterative process involving numerous trade-off decisions. It is directly related to meeting client requirements and the specified input data.

Commercial shipbuilding has shifted far to the East, to countries like China, Korea, Japan, and others in recent years. In Europe, only the construction of specialized ships and marine structures has remained. This necessitates a reorientation of the market niche for European shipbuilding enterprises, primarily small and medium-sized ones, which are the backbone of the European economy.

European shipbuilding enterprises construct passenger ships, dredging fleet vessels, auxiliary port fleet vessels, floating docks, and more. Some European countries rank among the leaders in the statistics for building floating docks.

Small and medium-sized shipbuilding enterprises often face limitations. These limitations can be divided into two main groups: production-related and geometric. These two groups of limitations affect the characteristics and qualities of the designed and constructed ships and marine equipment. For this reason, a study was conducted on their impact on a floating dock's operational and strength qualities during the conceptual design stage.

Floating docks are subjected to various loads caused by the environment and their operation. These loads include hydrostatic, hydrodynamic, contact, and mooring loads, with six degrees of freedom [7]. During the simulation, the loads from mooring and docking were taken into account. No significant changes in the dock's structure were observed as a result of the loads.

A finite element model can adequately assess the strength of ships and marine structures. Such an assessment has been carried out in [3], where the longitudinal and transverse strength of a floating dock has been evaluated. Using a dock model in the finite element environment, the current stresses have been assessed and compared with those specified by the rules of classification societies.

Floating docks are used not only for ship repair activities but also in other branches of industry. An analysis of a floating dock in the form of a platform is presented in [4]. During the design, modeling, and analysis, two groups of constraints were considered, which can be divided into linear and nonlinear categories. The linear constraints are related to the geometry of the dock, while the nonlinear ones are associated with its operation. Taking these constraints into account, two geometries of the floating dock have been developed.

Over time, the structure of floating docks loses some of its operational capacity. This is caused by the effects of corrosion. The behavior of a dock, considering the effects of corrosion and modeling with six degrees of freedom, is analyzed in [5]. It has been found that after damage caused by corrosion—holes in the ballast tanks of the dock—the inclination angles increase, which can lead to a serious accident or environmental disaster.

Modular floating docks find application in the shipbuilding and ship repair industry. The connection between individual modules is articulated. The calculation of the load and strength analysis of this type of floating structure was performed in [6]. The analysis was carried out using the SESAME program. The evaluation of the properties was conducted through the modeling of a three-dimensional wave flow. In the initial design, the stress values in the areas of the connections were high, but after reinforcing the structure, they decreased to permissible limits.

The structural strength of a floating dock during ship docking was evaluated using the finite element method in [8]. The evaluation employed the so-called "load per linear meter" method. Constraints were imposed on the main dimensions of the dock, stemming from the specifics of its operation. The developed procedure and model can be successfully used to assess proper ballasting to reduce stresses in the hull structure. The simplicity of the method makes it easily adaptable to similar structures with different main dimensions.

The conversion of a dock from a single-pontoon to a multi-pontoon structure without significant modification to its design is presented and analyzed in [9]. Once again, the authors have used the finite element method to assess the stress state. It was determined that after the conversion, the stresses are lower than the allowable limits, which provides grounds to claim that the structure operates on the safe side. An economic analysis of the activity has also been conducted.

One possible and quick way to construct a floating dock is by converting a ship that has been decommissioned for various reasons. Such is the case presented in [2], where an offshore barge is converted into a floating dock. An assessment of the global and local strength was conducted under two scenarios using a 3D finite element model. The dock is constrained in terms of width and length. During the analysis, stress concentrations were identified in the area of the main deck around the ballast tanks, but these were eliminated after structural improvements.

A large part of the research related to marine engineering, and more specifically to floating docks, is based on strength assessment using the finite element method. It would be beneficial for the evaluation to also take into account the constraints from a manufacturing perspective and to assess their impact on the characteristics of the marine structure's design.

2 MODEL DEVELOPMENT

The development of a model for assessing the impact of production constraints on the designed marine structures was carried out using the specialized software MARS 2000. The article examines and studies the influence of the constraints of a small and medium-sized shipbuilding enterprise on the characteristics of the floating structure design.

The imposed constraints are geometric and directly related to marine structures' design and operation. The assessment applied a width limitation of 16.0 meters to the floating structure. For comparison and evaluation, a similar model without constraints was used while maintaining the same load capacity. The main dimensions of both models are shown in tabl.1 and tabl.2

Table 1. Floating dock main dimension with restriction

L,m	80.00
B,m	16.00
D,m	10.20
t,m	7.20
LC,t	2000
Disolacement, t	8974.08
Double bottom height, m	2.20
Side tank depth, m	2.20

Table 2. Floating dock main dimension without restriction

L,m	60.00
B,m	20.00
D,m	10.20
t,m	7.20
LC,t	2000
Displacement, t	8413.2
Double bottom height, m	2.20
Side tank depth, m	2.20

The floating dock analyzed in the study is entirely made of steel. It is designed for docking ships and marine structures with a launching weight of up to 2000 tons. The design of the structure follows the rules for floating docks set by the classification society Bureau Veritas. The material used for construction is ST 235, a standard shipbuilding steel. The ordinary frame spacing is 600 mm, while the web frame spacing is 1800 mm for both cases. The shear forces and bending moments acting on the dock during operation have been determined according to the classification society's rules. The corrosion allowance for determining the type of profiles and their geometry has been established according to the procedure set in the rules and is in the range of 1.5-2.0 mm.

The section modulus of the bottom and deck shall not be less than that calculated by the following formulas:[1]:

for bottom

$$Z_{ab} = \frac{Iy}{N}, m^3 \tag{1}$$

for deck

$$Z_{ad} = \frac{Iy}{V_D}, m^3 \tag{2}$$

where:
Iy - moment of inertia of the hull transverse section about its horizontal neutral axis, m^4;
N is Z co-ordinate, in m, of the centre of gravity of the hull transverse section, m
Z is Z coordinate, in m, of the calculation point of a structural element., m;
V_D- vertical distance, in m; in general:

$$V_D = Z_D - N \tag{3}$$

Z_D is a Z co-ordinate, in m, of strength deck with respect to the reference co-ordinate system, m

Figures 1 and 2 show the models of the dock's midship sections. They show that the structure has a double bottom and double sides, with a height of 2200 mm and a width of 2200 mm.

A longitudinal framing system has been used, incorporating bulb profiles. In both constructions, HP 160x8 profiles have been utilized for the framing in the double bottom structure, the side construction, and the deck. In the double bottom, a watertight stringer is located at a distance of 25% of the dock's width for both models. On the sides, two non-watertight platforms are positioned at 25% of the side's depth.

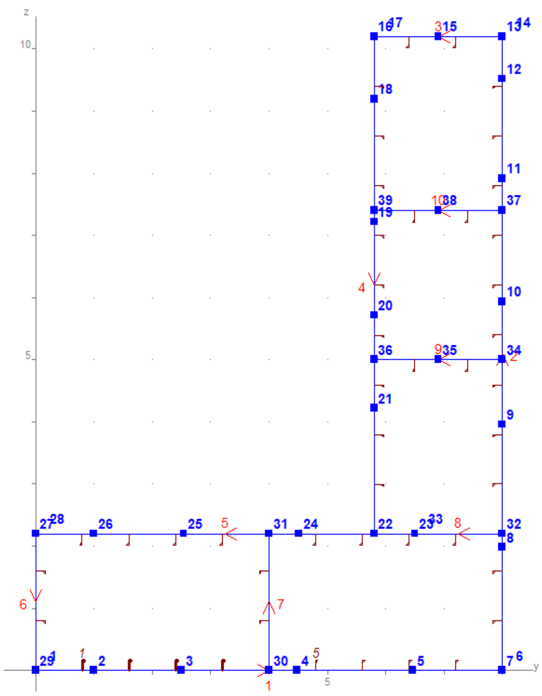

Figure 1. Midsection of the floating dock with restricted breadth, L= 80.00m, B=16.00m

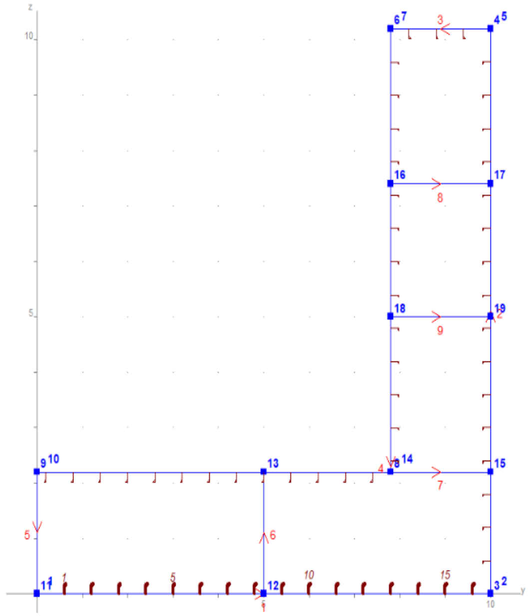

Figure 2. Midsection of the floating dock without restrictions, L=60.00m, B=20.00m

The designed structure is loaded with the weights acting upon it. In this case, these are the weight of the cargo, which represents the dock's lifting capacity, and the pressure from the water in the ballast tanks. This is achieved by dividing the structure into its constituent ballast tanks and compartments.

3 CONSTRUCTION ANALYZE

The impact of geometric and manufacturing constraints on the structure of the floating dock has been evaluated in several aspects, which are part of the classification societies' requirements for the strength of ships and marine structures. The first aspect evaluates bending moments concerning the bottom and the deck, the second evaluates normal stresses, and the third assesses global strength.

The evaluation of the actual section modulus is presented in fig.3 and fig.4.

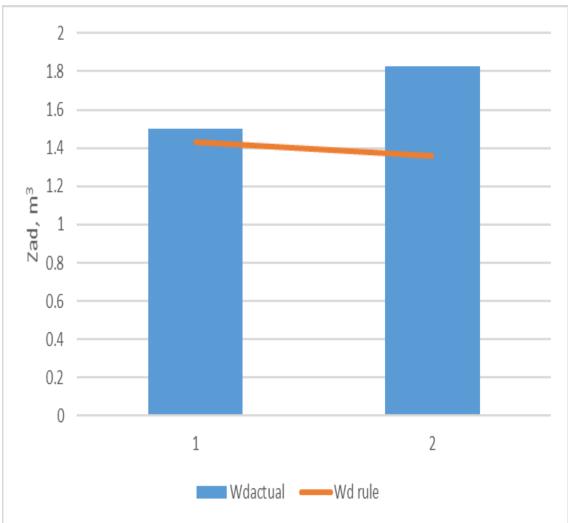

Figure 3. Section modulus at deck

From the graph presented in Fig. 3, it can be observed that the current section modulus has higher values than those determined by the minimum requirements of classification society rules (orange line). The values of the current and minimum section modulus have been determined using the specialized software MARS 2000, in which the rules of the classification society are implemented. With the dock structure designed under the imposed constraint (1), the value of the bending moment relative to the bottom is close to the minimum value. In contrast, in the case without the constraint, the current value is relatively higher than the minimum. This indicates that the dock designed with the constraint will have a comparatively lower launching weight.

A similar situation is observed with the bending moments relative to the bottom, as shown in the figure. In both cases, the values are significantly higher than those determined by the rules of the classification society. The minimum values are represented by the orange line, the dock with constraints is marked as 1, and the other as 2. Although the bending moment values significantly exceed the minimums, modifying the structure would compromise local strength.

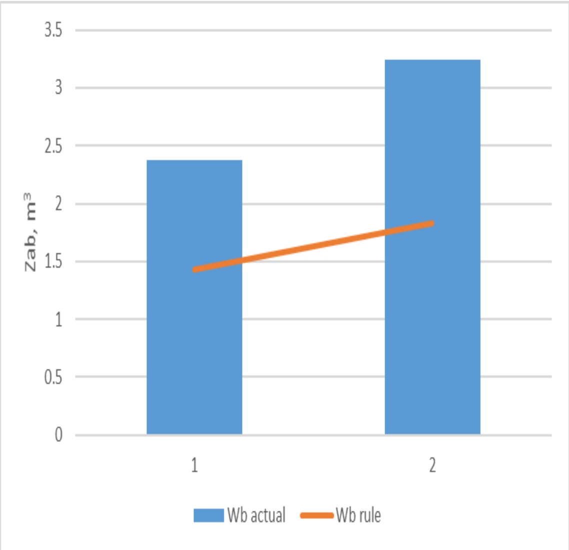

Figure 4. Section modulus at bottom

The normal stresses in the structure arise from applied bending moments. Their distribution depends on the position of the neutral line within the structure. Figure 5 and 6 show the distribution of normal stresses in the structures of both models under identical loading conditions.

The hull girder normal stresses at any point of the net hull girder transverse section, calculated with the following condition [BV]:

$$\sigma_1 \leq \sigma_{1AB} \tag{4}$$

where:

σ_{1AB} - allowable hull girder normal stress, N/mm²

$$\sigma_{1AB} = \frac{190}{k} \quad \text{for steel hull;}$$

K - material factor, for shipbuilding steel ST 235, k=1;

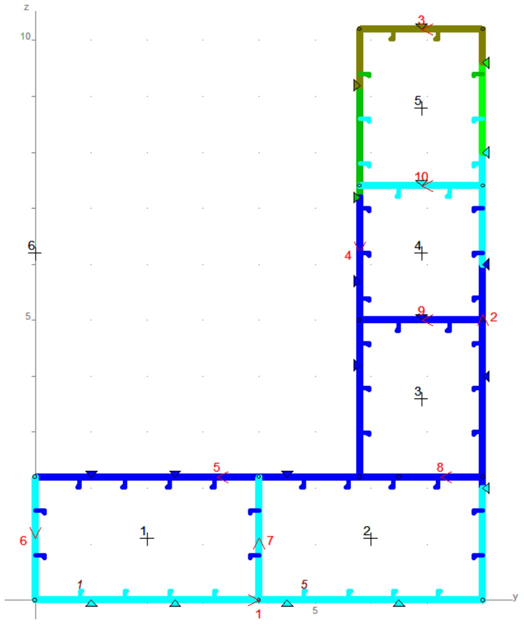

Figure 5. Normal stress distribution with restricted breath

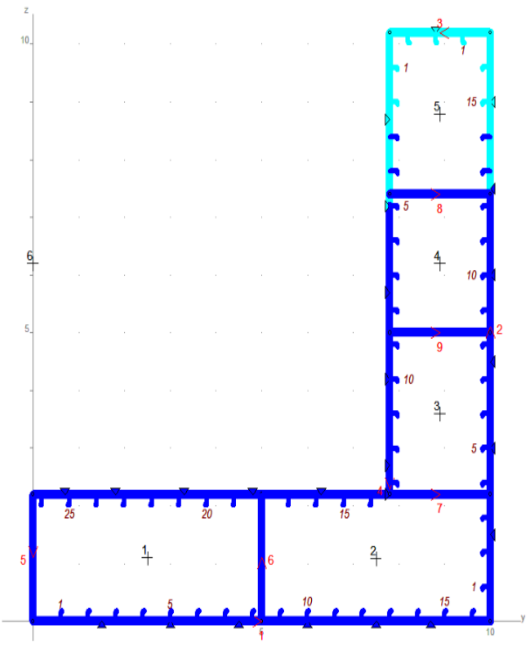

Figure 6. Normal stress distribution without restricted breath

The values of the normal stresses in both cases are below the allowable limits for the structure. For the constrained structure, the normal stresses have a value of σ_{1r}=166,77 N/mm², while for the unconstrained structure, they have a value of σ_1=115,17 N/mm². The obtained values, compared to the allowable ones, are lower. For the constrained structure, the values are close to the allowable limit, around 90%.

Figures 7 and 8 present the overall strength results. The stress distribution in the structure with the constraint appears more vulnerable, i.e., the values are closer to the nominal ones.

In the dock structure with imposed constraints, the loads from overall strength are carried by all structural elements. The elements farthest from the neutral axis are particularly loaded, fig.7.

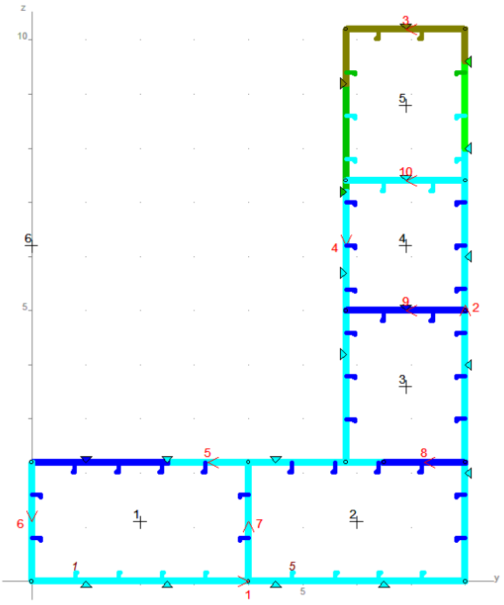

Figure 7. Hull global strength with restricted breath

The overall strength is different in the structure without imposed constraints. In this case, the areas around the bottom and part of the double hull are not intensively loaded. Loading is observed only in the area of the last plate from the double bottom to the double hull, but it is not significant.

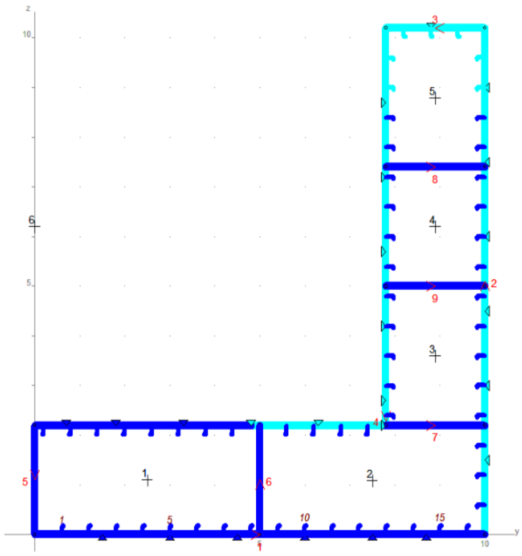

Figure 8. Hull global strength without restriction

The approximate mass of the steel structure of the dock, considering the constraints, is around 563.0 tons, and without the constraints, it is around 484.0 tons. The manufacturing cost of the steel structure is approximately 366155.4$ for the constrained version and 314293.59$ for the unconstrained version.

4 CONCLUSIONS

The article examines and analyzes the impact of the limitations of small and medium-sized shipbuilding enterprises on the floating dock design. The influence of the limited width of the building and launching facility on the behavior of the floating dock structure is analyzed in the article.

Two variants of the floating dock structure have been developed: with and without width limitations. Using a model in the MARS 2000 program environment, an assessment of the strength was carried out with and without the imposed limitations.

The strength assessment was conducted in three aspects: evaluation of the section modulus to the bottom and the deck, distribution of normal stresses from bending moments in calm water and waves, and overall strength.

The obtained values of the section moduli to the bottom and the deck are higher than those determined according to the rules of the classification society. For the structure with limited width, it is observed that the section modulus value for the deck is close to the allowable limit.

The normal stress values in both cases are within the allowable limits for the structure. For the constrained structure, the normal stresses are σ_{1r} = 166.77 N/mm^2, while for the unconstrained structure, they are σ_1 = 115.17 N/mm^2. The obtained values of the normal stresses for the constrained structure are close to the allowable limits but do not exceed them.

In the dock structure with imposed constraints, the overall strength loads are distributed across all structural elements, with the elements furthest from the neutral axis experiencing the greatest load. In contrast, the overall strength behavior differs in the structure without constraints. In this case, the regions near the bottom and part of the double hull are not heavily loaded. The loading is primarily concentrated in the area of the last plate connecting the double bottom to the double hull, but it remains minimal.

The designed structure of the floating dock, considering production constraints, does not exhibit inferior qualities compared to the one without constraints. In the structure with limited width, relatively lower values of the section moduls are observed, which indicates the efficient use of material rather than the excessive reserve.

ACKNOWLEDGMENT

The article was developed under the National Program "Young Scientists and Postdoctoral Researchers - 2" at the Technical University of Varna, within the Postdoctoral Researchers section.

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