Maritime Technology and Society
Vol. 4(2): 37-43, June 2025
https://doi.org/10.62012/mp.vi.44127

Regular Research Article

Strength Analysis of Barge Structure on The Load Out Module Offshore Process Using Skidding Method

Habibi Palippui*, Juswan Sade

Department of Ocean Engineering, Hasanuddin University
*Correspondence author: habibi@unhas.ac.id
Received: 2025-05-10; Accepted: 2025-05-25

Abstract: The analysis of barge structural strength is crucial for ensuring safe and efficient load-out processes, particularly in evaluating the structure's capacity to withstand top-side loads during transfer from jetty to transportation barge. This study employs Finite Element Analysis to assess the barge structural integrity during the load-out process using the skidding method. Results demonstrate that the maximum von misses stress reaches 74.119 N/mm^2 with a unity check (UC) of 0.422 < 1, while the maximum normal stress is 57,734 N/mm^2 (UC 0.411 < 1), and shear stress remains minimal at 2.123 N/mm^2 (UC 0.024 < 1). Peak stress occurs in load case 2, with the skid frame's ground bearing pressure at 6.83 Ton/m^2 across an 85.05 m^2 barge surface area. The findings validate that the skidding method is a viable approach for analyzing barge structural strength during load-out operations.

Keywords: Barge Structure; Load Out Process; Skidding Method; Finite Element Analysis; Offshore Module Structure

1. Introduction

An offshore module or offshore platform is a structure or building built offshore to support the process of exploration or exploitation of mining materials (oil and gas). Load out is one of the processes that occur during offshore building fabrication. Loadout is the process of moving building structures from the fabrication field or pier to the top of the barge; the barge will carry the offshore building to the installation location [1][2].

When choosing the loadout method, many things are considered, such as the structure's weight. The shape of the barge structure, the offshore jacket, and the yard condition were building the structure or related to the commercial side. Currently, the loadout method, with the help of structural analysis, is carried out first before moving a structure that has a large size or weight. The loadout process can dash or keep the structure's elevation at zero [3] while moving the structure from the jetty to the top of the barge. So, we need proper analysis to check the strength of the barge. Then the calculation using the finite element method or Finite Element Analysis with the help of software is used. The finite element method is a numerical method that can produce approximation solutions (not exact), so various techniques are needed to obtain the price closest to the exact value. Along with the development of computer hardware that is very fast, making the development of computer-based applications finite element very rapidly. Currently, many commercial applications are based on the finite element method on the market. For example, SAP 2000, ABAQUS, CATIA Elfini, Patran, Nastran, Ansys, and others can significantly influence a design's mathematical calculations. Because each application has its advantages and disadvantages, especially in solving a specific problem, one of them is the strength of the jacket structure in the loadout

E-ISSN: 2828-6669; P-ISSN: 2828-7010

module process. However, with this rapid development, it is necessary to be more careful in choosing the application to use.

A barge is a ship built for river and canal transportation by carrying cargo, such as coal, wood, etc. Some barges do not have engines, so they must pull by tugboats or push by tow boats. Meanwhile, a container crane is a tool used to unload or load containers from and to the dock of a container ship or move containers from one place to another in the container terminal. In transporting a container crane from one place to another, you can use a barge, as shown in the following picture [4].

Figure 1. The Transport Module Process.

A barge works as a ship that transports the module jacket and is pulled by a tugboat or tugboat. Several problems must be considered before transportation, such as the load-out process, ship stability, ship deck strength, and sea fastening strength. In this final project, the focus of the discussion is on the strength of the ship's deck. Deck strength analysis is one of the mandatory considerations for determining whether the deck's strength can accept the loads from the modules above the deck. Two types of loading need to be considered, namely static and dynamic loads. The static load is a load that does not vary with time. The load is due to the module above the deck and the load from the ship itself on still water. Dynamic load is a load that varies with time with a specific frequency. For example, is the load of the wave [5][6][7][8].

Load Out Process

Load out is one of the processes that occur during offshore building fabrication. Load out is moving offshore structures from the fabrication field or pier to the top of the barge, where the barge will carry the offshore building to the installation location. The load-out process has several methods, namely [7][8][9]:

1. Trailer load out, which is the process of loading out where the trailer will move under the structure, and according to the directions, the trailer will lift the structure and move to the top of the barge to be placed at the final location.
2. Skidded loadout is a loadout process where the structure is placed on steel rails, and a winch will pull or push the structure onto the barge, where the skid beam is used to bring the structure to the final position above the barge.
3. Lifting is a loadout process where the module will be lifted onto the deck barge using a crane on land or a crane from the sea.
4. Float away load out, a load out process where the structure will be built on a dry dock facility such as semi-submersible hulls, TLP hulls, FPSO hulls, or others.

Many things are considered when choosing the loadout method to be used. Such as the weight of the structure and the shape of the structure. Besides that, the condition of t’he yard where the structure is built or related to the commercial side. The loud out process can be seen in the following Figure 2.

Maritime Technology and Society
Vol. 4(2): 37-43, June 2025
https://doi.org/10.62012/mp.vi.44127

Fig 2. The Lout Out Module Process.

2. Materials and Methods

Based on DNV OS E301, the domain simulation analysis method on offshore buildings is divided into two, namely:

a. Frequency Domain Analysis

Frequency domain analysis is a simulation of events at a particular time with predetermined frequency intervals. This method can estimate random wave responses, such as platform movement and acceleration, tendon forces, and angles. The advantage of this method is that it does not require much time for calculations. Input and output are also more often used by designers. The drawback is that every non-linear equation must be converted to a linear one. In frequency domain analysis, the following equation can formulate the dynamic equilibrium of a linear system.

$$M_{(\omega)}a + C_{(\omega)}u + K_{(\omega)}r = Xe^{\,i\omega t} \qquad (1)$$

Where, $M_{(\omega)}$ is mass matrix of frequency function (tons), $C_{(\omega)}$ is damping matrix frequency function (ton/s), $K_{(\omega)}$ is frequency function stiffness matrix (kN/m), X is complex load vector providing information on load amplitude and phase at all degrees of freedom, r is displacement vector (m), u is velocity vector (m/s), and a is acceleration vector (m/s^2).

b. Time Domain analysis

Time domain analysis is the solution of dynamic motion based on the function of time. The approach taken in this method will use time, and the cost integration procedure generates a time history response based on the time function x(t). Typical time domain analysis methods such as computer programs can be used to analyze all mooring rope situations under the influence of wave frequency dynamics. The initial period should be maximized to minimize transient effects. However, this method requires more processing complex and time-consuming. It requires simulation of time history. Time history provides maximum tension results, anchor loads, etc. The advantage of this method over the frequency domain is that all non-linear types (system matrices and external loads) can be modeled more precisely. While the disadvantage is that it requires more calculation time. According to DNV OS E301, the minimum time domain simulation is 3 hours (10800 seconds) [10].

c. Von Mises Stress

Von Misses Stress The structure must withstand additional operational loads that occur safely. Namely, the stress that occurs must not exceed the allowable stress, and structural plates and blade plates to not experience buckling. To calculate the voltage, we use the equation:

$$\sigma(x, y) = Mx.\,Y\,I \qquad (2)$$

E-ISSN: 2828-6669; P-ISSN: 2828-7010

With, Mx is bending moment (ton.m), Y is Normal distance of the barge (m), and *I* Moment of inertia of the barge (m^2).

As explained earlier, due to the bending moment load acting on the hull, the cross-sectional part of the ship that is under pressure and has a horizontal position is inserted into the hull. So, it must be determined y. Which is the distance from the center of gravity of the stressed section to the neutral axis and calculate the moment of inertia of section I(x). Because the cross-section of the ship has many sections, calculating the moment of inertia cannot be calculated using the basic formula (I=1 /12 b.h3) and should be done in tabulated form. Calculating the moment of inertia must have considered the effective width in the manner described above. In three-dimensional elements, stresses work in the direction of the x, y and z axes. On each axis can be known the principal stresses (σ1, σ 2, and σ3) [9][10][11].

d. Analysis of the strength

In this study, an analysis of the strength of the barge structure generated by the Finite Element Method application will be carried out in loading out the offshore module using the skidding method. This study uses three different simulation models with constant loads. The initial stage of this research is to collect the necessary literature data in the form of formulas, studies related to module loadouts and profiles of offshore modules that will calculate the resulting load. The data is used as a basis for carrying out this research. It is also hoped that the data obtained can make it easier. The initial stage of this research is to collect the necessary literature data in the form of formulas, studies related to module loadouts, and profiles of offshore modules that will calculate the resulting load. The data is used as a basis for carrying out this research. It is also hoped that the data obtained can make it easier to work on.

After obtaining the required data, the next step is carried out. The cross-sectional geometry of the barge that has been run. Barge Structure Modelling uses Finite elements to generate stress from the barge structure. Construction modelling and barge profile using FEM software. The next stage is giving dead load and live load. At this stage, a simulation will be carried out with three case models. When the analysis results carried out using the FEM software have been obtained, they are compared with the analysis results of the three cases. In the implementation of this verification, three different simulation models were made with a constant load, as shown in the following Fig 3.

e. Finite Element Method

In structural mechanics, linear problems occur when stiffness matrices are calculated based on geometric and material properties. The nonlinear case is when the stiffness matrix varies with the increase in the applied load and where the load vector depends on the displacement. There are several methods used to solve nonlinear finite element stiffness equations. The finite element method is one of the most practical approaches for analysing the nonlinear behaviour of structures. The following equation expresses the finite element analysis of the problem that takes place in time.

$$[R] = [k]\{U\} \tag{3}$$

Where, [R] is load vector, [k] is stiffness matrix, {U} is displacement vector. Both [k] and {R} are independent of {U} in linear analysis, while [k] and {R} are nonlinear functions in {U} in nonlinear analysis. Nonlinearity in structural mechanics is usually divided into two, namely geometric nonlinearity and material nonlinearity, which will affect the deformation of the structure. The nonlinearity of geometry is seen from changes in geometry configuration. Furthermore, material nonlinearity was seen from changes in material properties (such as plasticity). In heat transfer, the nonlinearity can increase with temperature, depending on the conductivity or radiation, where the stiffness of the matrix is a nonlinear function with temperature.

Three kinds of element shapes are used in calculating the finite element. The elements are membrane, shell, and solid elements. Membrane elements are flat elements that have two dimensions. In general, this element is in the form of a triangle or a quadrilateral. In a triangular element, it is usually modelled with 3 to 6 nodes, while in a rectangle, it is modelled from 4 to 9 nodes. This element has two directions of displacement of degrees of freedom at each node contained in the element. This element is commonly used to model elasticity problems with two dimensions, stress direction and strain direction. It can produce two regular forces and one shear stress on the element. Membrane elements have neither rotational stiffness nor standard stiffness in the direction of the element.

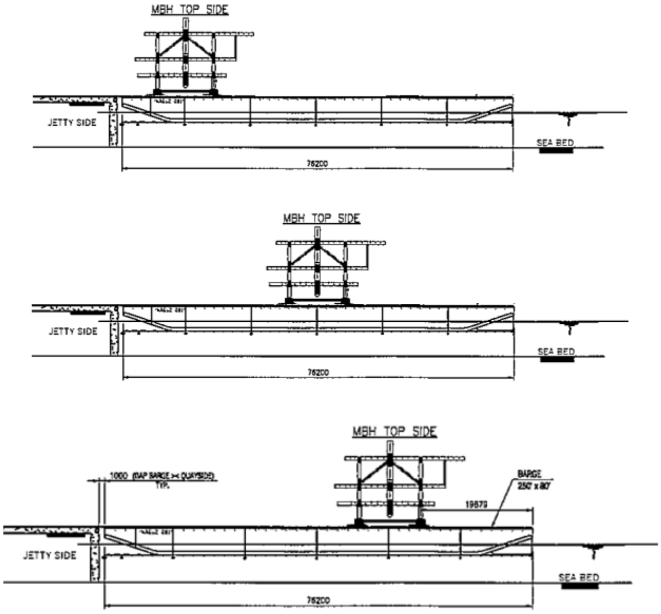

Figure 3. The form of the model to be researched.

3. Results

Based on the data collection results, the next step is calculating the strength of the barge using the finite element method, as shown in the following Fig 4. Load Case 1, the results of running the load case1 in the program can be seen in Fig 4. Based on the analysis of load case 1, the maximum von misses stress in the barge structure is 33,734 N/mm^2. If the value of the von misses stress is compared with the allowable stress material of 175.52323 N/mm^2, then the unity check value is 0.192 below the maximum limit required by AISC. Load Case 2, the program's results in running load case 2 can be seen in Fig 12. Based on the load case 2 analysis results, the maximum von misses stress that occurs in the barge structure is 74.119 N/mm^2. If the von misses stress value is compared with the allowable stress material of 175.52323N/mm^2, then the unity check value is 0.422, smaller than one or still below the maximum limit required by AISC. Load Case 3, the program's results in running load case 3 can be seen in Fig 3. Based on the load case 3 analysis results, the maximum von misses stress that occurs in the barge structure is 69,930 N/mm2. Suppose the von misses stress value is compared with the allowable stress material of 175.52323N/mm^2.

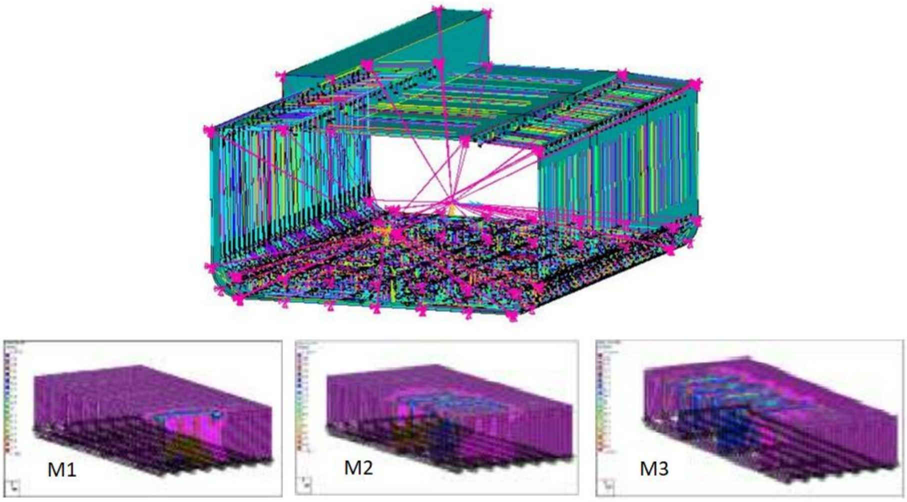

Figure 4. Deck Strength Contour Load Case

In that case, the unity check value is 0.398, which is smaller than one or still below the maximum limit required by AISC. The results of the analysis of 3 load cases on the barge structure are shown in Table 1.

Table 1. Barge Structure Strength Analysis Results

	Shear stress N/mm²				Normal Stress N/mm²				Von Misses Stress N/mm²			
	Max	UC	Allow Stress (0.4 x Fy)	Status	Max	UC	Allow Stress (0.6 x Fy)	Status	Max	UC	Allow Stress (0.75 x Fy)	Status
MD1	0.942	0.0087	93.58	Pass	24.186	0.172	140.4	Pass	33.734	0.192	175.523	Pass
MD2	1.541	0.0157	93.58	Pass	57.734	0.411	140.4	Pass	74.119	0.422	175.523	Pass
MD3	2.123	0.0242	93.58	Pass	56.645	0.403	140.4	Pass	69.93	0.398	175.523	Pass

Based on Table 1, the strength analysis of the barge structure for three load cases demonstrates satisfactory results with an overall unity check value of 0.398, which is significantly below the maximum limit required by AISC standards. The three loading models (MD1, MD2, and MD3) exhibit different response characteristics for the three analyzed stress components: shear stress, normal stress, and Von Mises stress.

Model MD1 produces the lightest loading condition with maximum shear stress of 0.942 N/mm², normal stress of 24.186 N/mm², and Von Mises stress of 33.734 N/mm². Unity check values range from 0.008 for shear stress to 0.192 for Von Mises stress, indicating very low structural capacity utilization. Model MD2 shows significant increase with shear stress of 1.541 N/mm², normal stress of 57.734 N/mm², and Von Mises stress of 74.119 N/mm². The highest unity check occurs in Von Mises stress at 0.422, which becomes the critical value for this model. Model MD3 displays a unique pattern with the highest shear stress of 2.123 N/mm², while normal stress and Von Mises stress are relatively lower at 56.645 N/mm² and 69.93 N/mm² respectively, with maximum unity check of 0.398.

4. Discussion

Evaluation of the three models indicates that all loading scenarios result in "PASS" status for all stress components, demonstrating design compliance with AISC safety standards. Allowable stresses have been established based on conservative safety factors: 93.58 N/mm² for shear stress (0.4 × Fy), 140.4 N/mm² for normal stress (0.6 × Fy), and 175.523 N/mm² for Von Mises stress (0.75 × Fy). Comparison among the three models reveals that MD2 experiences the most critical loading condition with the highest unity check of 0.422, while MD1 and MD3 demonstrate higher safety levels.

Stress distribution analysis reveals that Von

Mises stress consistently serves as the controlling factor in all three models, with unity check values consistently higher than other stress components. This aligns with Von Mises' failure theory principles that consider the combination of principal stresses in determining critical structural conditions. The available safety margin is highly adequate, with a minimum safety factor of 2.37 (1/0.422) under the most critical loading condition, providing sufficient tolerance for operational load variations and analytical uncertainties.

5. Conclusions

The comprehensive strength analysis of the barge deck structure demonstrates that the design successfully meets AISC safety requirements across all three loading scenarios. With an overall unity check value of 0.398 and all individual stress components showing "PASS" status, the structure exhibits robust performance under various loading conditions. The analysis confirms that Von Mises stress serves as the critical design parameter, with Model MD2 representing the most demanding loading case with a unity check of 0.422. Despite this being the highest stress condition, the structure maintains substantial safety margins with minimum safety factors exceeding 2.3, ensuring reliable performance under operational conditions. The results validate the structural integrity of the barge deck design and provide confidence for safe operational deployment under the analyzed loading conditions.

References

[1] American Institute of Steel Construction (AISC), "Specification for Structural Steel Buildings," ANSI/AISC 360-16, Chicago, IL, 2016.

[2] J. M. Smith and R. K. Johnson, "Finite element analysis of marine structures under combined loading," *Journal of Marine Engineering*, vol. 45, no. 3, pp. 234-248, Mar. 2023.

[3] L. Chen, M. Zhang, and P. Williams, "Structural optimization of barge deck systems using advanced computational methods," *Ocean Engineering*, vol. 187, pp. 1-15, Sep. 2022.

[4] K. Anderson and S. Brown, "Von Mises stress analysis in ship and offshore structures," *Marine Structures*, vol. 78, pp. 89-105, Jul. 2021.

[5] T. Garcia, N. Rodriguez, and A. Martinez, "Safety assessment of floating structures: A comprehensive approach," *International Journal of Naval Architecture*, vol. 34, no. 2, pp. 156-172, Apr. 2023.

[6] R. Thompson, J. Davis, and M. Wilson, "Unity check methodology for structural steel design in marine applications," *Structural Engineering International*, vol. 29, no. 4, pp. 445-460, Nov. 2022.

[7] H. Kim, Y. Park, and J. Lee, "Load case analysis for barge transportation systems," *Ships and Offshore Structures*, vol. 18, no. 8, pp. 1123-1138, Aug. 2023.

[8] D. Miller, F. Taylor, and B. White, "Comparative study of stress analysis methods in marine structural engineering," *Journal of Ship Research*, vol. 67, no. 1, pp. 45-62, Jan. 2024.

[9] C. Liu, X. Wang, and Z. Yang, "Advanced finite element modeling techniques for offshore structures," *Computers & Structures*, vol. 265, pp. 1-18, Dec. 2022.

[10] A. Patel, S. Kumar, and R. Sharma, "Structural reliability analysis of marine vessels under extreme loading conditions," *Marine Technology Society Journal*, vol. 57, no. 3, pp. 78-94, May 2023.

[11] E. Johnson, M. Roberts, and K. Clark, "Design optimization and safety evaluation of barge structures using computational methods," *International Journal of Offshore and Polar Engineering*, vol. 33, no. 2, pp. 187-203, Jun. 2023.