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Analysis of Effect of Pillars Position on Longitudinal Strength in Perintis Ship Structure Type 1200 GT

H. Yudo, H.Z. Abdillah & A.F. Zakki
Diponegoro University, Semarang, Jawa, Indonesia

ABSTRACT: Perintis ships are sea transportation highly relied upon by the people in remote, frontier, underdeveloped, and border islands, considering the absence of other types of vehicle operating in the area. Perintis Ships can carry up to 500 people and connect islands categorized as 3TP with larger ports. This ship will be analyzed in longitudinal strength with variations in pillar positions. The analysis results will be compared, and whether the research results allowed the BKI regulatory standards. The maximum stress value produced by the variation without pillars is 21.76 N/m2 in calm water conditions, 41.19 MPa in sagging conditions, and 10.67 MPa in hogging conditions. The variation of the pillars on the side is 21.95 MPa in calm water, 41.54 MPa in sagging conditions, and 10.76 MPa in hogging Conditions. The variation of the pillar in the middle obtained maximum stress 21.96 MPa in calm water conditions, 41.55 MPa in sagging conditions, and 10.77 MPa in hogging conditions. Of all the variations, it has met the criteria of the BKI regulations, where the allowable stress is not to exceed 140.14 MPa. From the analysis that has been done, it can be concluded that the position of the pillar laying does not significantly affect the longitudinal strength of the ship.

1 INTRODUCTION

Indonesia is a commodity for sea transportation where the economic sector through loading and unloading is done chiefly at sea because it is more efficient and cheaper as well as transportation from one island to another island, therefore the government has launched a program that can provide overall welfare to its people through shipbuilding programs. Perintis in several shipyards as a supporter of sea transportation commodities in Indonesia.

Perintis ships are one of the sea transportations that are highly relied upon by people living on remote islands and borders because there are no other types of transportation operating in these areas. Without a Perintis ship, the economic veins in the region will be disrupted, where this ship can carry passengers up to 500 people and can accommodate cargo for the needs of remote communities, and also functions as a liaison for islands that have category 3TP with larger ports [1].

The ship used in this study is a Perintis ship with a type of 1200 GT, which uses a transverse construction system because the ship's structure does not have an elongated bulkhead, which is construction braces are installed using steel pipe pillars.

To regulate all forms of activities in the Indonesian sea transportation sector, regulations are issued directly by BKI (Ship Classification Bureau), where BKI is a state-owned business in charge of issuing rules and regulations in the sea sector in Indonesia, including shipping, offshore buildings, and others related to the Indonesian sea sector to ensure the safety of Indonesian-flagged vessels and offshore structures located both domestically and internationally [2].

So in this research, the calculation of the structure construction on the Perintis ship 1200 GT was carried out according to the rules and regulations that have been regulated by the Indonesian Classification Bureau (BKI) in Volume II Rules for Hull 2018, which determines the ship's maximum stress and allowable stress when the water conditions are calm, sagging, and hogging.

In previous studies, many analyses were carried out, including variations in the structure of ship construction, such as the results of stress from changes in ship length, variations in longitudinal construction systems, and transverse and mixed construction. therefore is also research on changes in the distance of the tusks on the ship to the results of the maximum stress received by the ship. Has met the Allowable stress from the Indonesian Classification Bureau in Volume II Rules for Hull 2018 [3].

In this study, an analysis was made of the variation of the influence of the position of the pillar or reinforcement on the ship's hull to the maximum stress that occurs when the calm water, sagging, and hogging occurs on the 1200 GT Perintis ship.

The purpose of doing this research from the explanation above is as follows:

1. To determine the pillars' effect on the stresses in the structure of the 1200 GT Perintis ship.
2. Knowing the efficient laying of pillars on the structure of the 1200 GT Perintis ship.
3. Get the maximum response value on the stress of hogging, sagging, and calm water from the three variations of the ship structure.

2 METHOD

2.1 *Object of Research*

The object of this research is the 1200 GT Perintis ship which has the following main sizes:

Tabel 1. Main Dimension of Ship

	Data
Material	Steel
Loa	62.8 m
Lpp	57.36 m
Breadth	12.0 m
Height	2.7 m
Main Deck Height	4.0 m
Coefficient Block	0.663
Speed	12 knots
Engine power	2 x 1000 HP
Frame distance	0.6 m

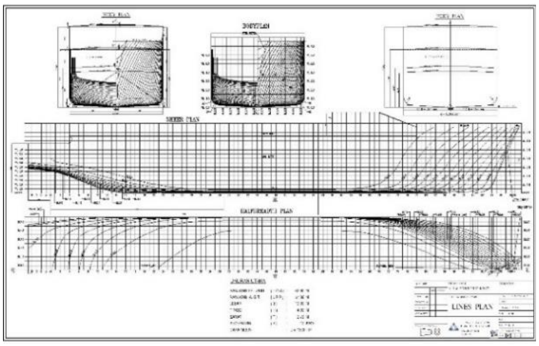

Figure 1. Lines plan

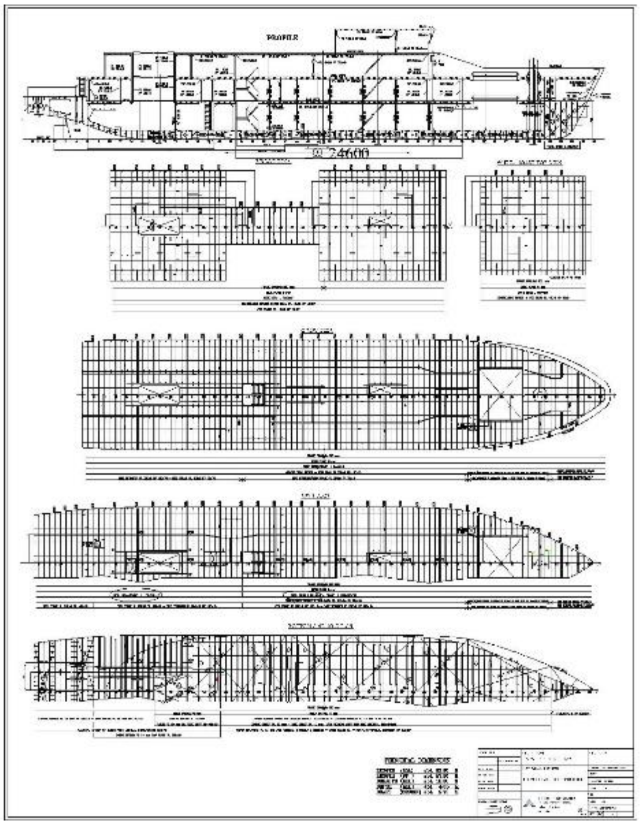

Figure 2. Profile Construction

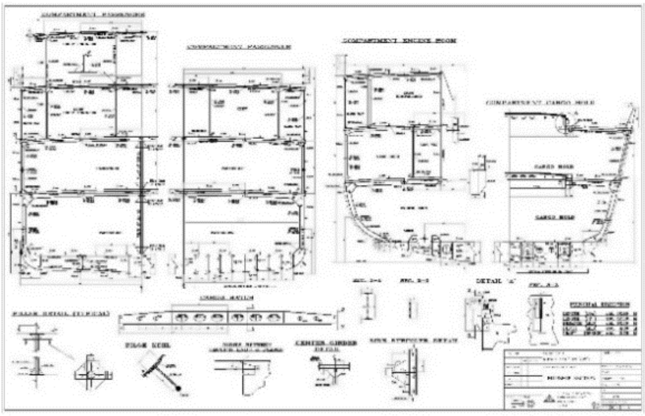

Figure 3. Midship Section

2.2 *Research Variable*

In this study, the author will make variations of the pillar position with a size of Ø4 inches above the main deck and Ø5 inches above the double bottom in

Perintis ship construction. The variations in the position of the pillars analyzed are:

1. Ship construction without pillars
2. Pillar construction in the middle/above the center girder
3. Pillar construction on the side/above the side girder and analysis of the maximum stress at the time of the ship's condition.
4. Calm water
5. Sagging
6. Hogging

This research has a limitation: the structure of the ship's construction has not been changed, such as the dimension of the profile and the plate, only the laying of the pillars.

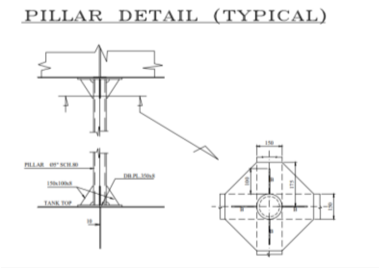

Figure 4. Details of the pillar structure

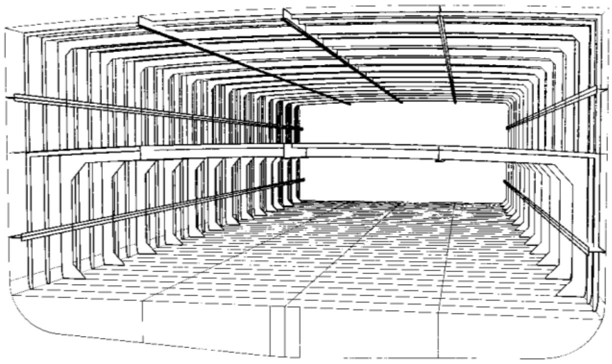

Figure 5. Variations without pillars

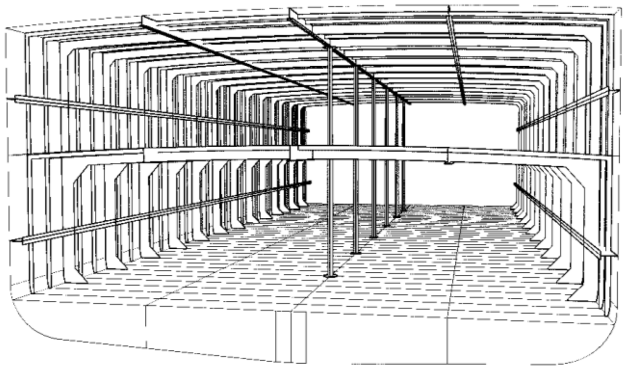

Figure 6. Variations of the pillar in the middle

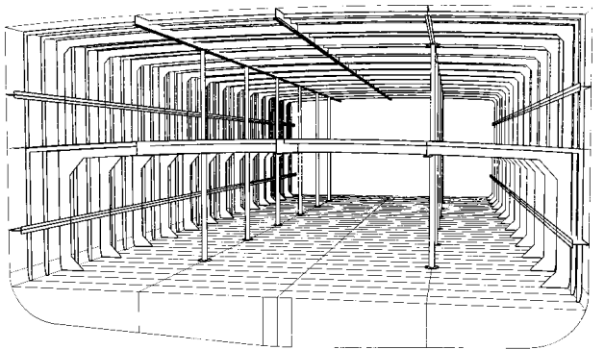

Figure 7. Variations of the pillar on the side

2.3 *Determination of Ship Profile Dimension*

The size of the profile used in the construction of the 1200 GT Perintis ship is available in the data provided by the ship's consultant, such as the profile construction, shell expansion, and midship section, which will be used as a reference in this study.

2.4 *Ship Load Distribution*

In calculating the shear force and bending moment of the ship, which is to first determine the distribution of gravity along with the ship by distributing this weight, this is part of the load that will cause bending moment, which is the result of the sum of the weight distribution of the empty ship (LWT) with the weight of the cargo, supplies, crew, passengers, fuel, lubricants, fresh water, and others (DWT) which is the total weight when the ship is sailing [4].

After that, determine the buoyancy of the ship. This buoyant force is a reaction from the mass of water against the ship, which is referred to as a displacement, where the displacement is equal to the total mass of the ship, as well as the resultant upward pressure must be on a vertical line with the resultant gravity, where the displacement of the ship can be obtained, from the integration of the longitudinal direction of the water mass along with the ship underwater [5].

2.5 *Sagging And Hogging Waves*

Sagging is a condition where the ship's load is centered on the center of the ship so that it will cause the pressure in the middle of the ship to be greater, which as a result of the shape of the ship will curve downwards while sagging can also occur because of the two crests of the waves, namely at the front and the back of the ship so that will cause the upward force on the ship at the tip to be greater in value, while at the center of the ship will experience a greater downward compressive force [6].

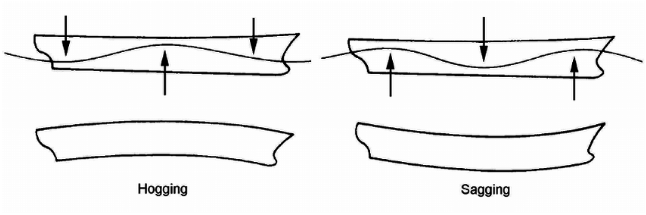

Figure 8. Sagging and Hogging

Hogging is a condition in which the ship's cargo is centered on the front and back of the ship, causing greater pressure at the end of the ship as a result, the shape of the ship will curve upwards, large in the middle of the ship, while at the end of the ship will experience a greater downward pressure [7].

2.6 *Finite Element Method*

The finite element method is a numerical method that is suitable to be applied to calculate internal forces in various cases in the engineering field. The analysis process is based on the stiffness method presented in a matrix formulation. The advantage of the finite element method is its ability to create models from various geometric shapes of irregular structures and aspects of nonlinearity in geometry and materials [8].

The finite element method has also become a commonly used method in engineering where this method is an analytical method for predicting the response of a structural system by dividing a continuous form into several parts with a finite number, these parts are called elements. Where each element is connected to a node, then from the mathematical equation, each element will be a representation of the results of the model structure [9].

These elements can also be called finite elements and are linked at several vertices.

2.7 *Maximum Stress and Allowable Stress*

After the ship's construction structure has been designed, the structure's response is analyzed with static loading using the finite element method when the vessel is fully loaded in calm water conditions, sagging and hogging. For the height of the waves at the time of sagging and hogging formula

$$Hw = \frac{Lpp}{20}\ [m] \quad (1)$$

where :
H_w Wave Height
L_{pp} Ship Length from AP to FP

Based on the ship structure strength book [10], where if calculated by Lpp along 57.36 m, then the height of the sagging and hogging waves is 2.868 m.

The formula for Calculation of Allowed Stress for ships with a length of fewer than 90 meters according to BKI regulations is [11]

$$\sigma p = cs \cdot \sigma p_0 \left[\mathrm{N}/mm^2 \right] \quad (2)$$

where:
σp Ship Allowable Stress
σp_0 $18{,}5\sqrt{L}/k$ for ships < 90 meters
c 1.0 for area $0{,}30 \leqslant x/L \leqslant 0{,}70$

from the calculation formula above, the allowable stress according to BKI regulations on the 1200 GT Perintis ship is 140.14 MPa.

2.8 *Material Definition*

The material used in this research is steel with the following specifications:

- Modulus of Elasticity: 210000 MPa
- Poisson Ratio: 0.3
- Density: 7850 kg/m^3
- Yield: 235 MPa
- Ultimate Stress: 400 Mpa

2.9 *Cross-Sectional Modulus and Moment of Inertia*

The modulus calculation is by the BKI Voll II Rules for Hull 2018 regulation with the formula.

$$W_{\min} = k \cdot c_0 \cdot L^2 \cdot B \cdot (Cb + 0{,}7) \cdot 10^{-6} \quad [m3] \quad (3)$$

where :
W_{min} = Minimum Modulus
c_0 =10.75-((300-L)/100)1.5
L = Ship Length
K = 1
B = ship width
Cb= coefficient block

The calculation of the moment of inertia is by the BKI Voll II Rules for Hull 2018 regulation with the formula.

$$I = 3 \cdot 10^{-2} \cdot W \cdot L/k \quad \left[m^4 \right] \quad (4)$$

where :
I = minimal moment of inertia
L = Ship Length
k = 1
W = Ship's Modulus

3 RESULTS AND DISCUSSION

3.1 *Calculation of Ship Load Distribution*

The load distribution on the ship is the load from the mass distribution of the construction and the full load of the ship, which is distributed at a predetermined division of each station which will produce bending moments as a result of the response to the addition of the mass distribution of the empty ship with the cargo mass (DWT + LWT) [12].

This calculation begins with finding the total mass of LWT and DWT on the ship first, where the ship's length will be divided into 40 stations first. After that, the value of the mass distribution at each station can be seen from these results.

After obtaining the total mass on the empty ship of 834.11 tons, the total mass of the DWT of 452.52 tons, and the mass displacement of the ship is 1286,632 tons.

The ship’s loading can be seen in the graphic chart figure as follows.

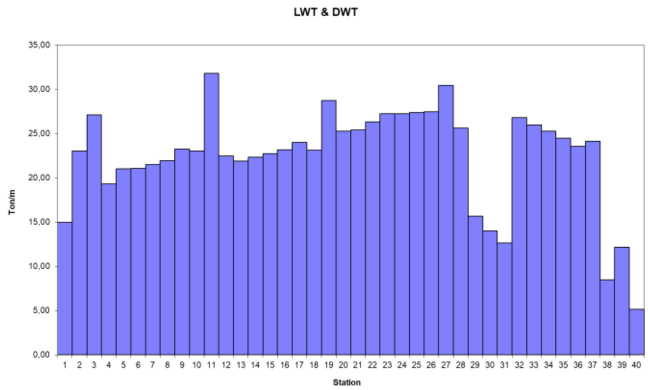

Figure 9. Ship Load Distribution Chart

3.2 *Calculation of Shear Force and Bending Moment*

At this stage, the 3D model of the existing ship is divided into 40 stations. This serves to distribute the load of the current ship as a whole.

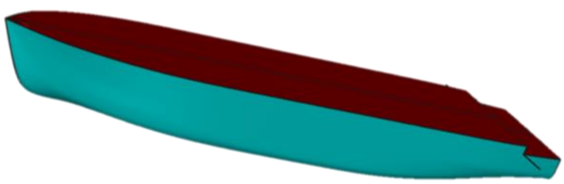

Figure 10. Hull in 3D model

Furthermore, the results calculating the load distribution that have been obtained are entered into loadcase via software Maxsurf Stability and then input menu loadcase [13]. Then the moment analysis is carried out by entering the value of the existing sagging and hogging wave heights that have been calculated in formula no 1, which is 2.868 m in each condition of the ship.

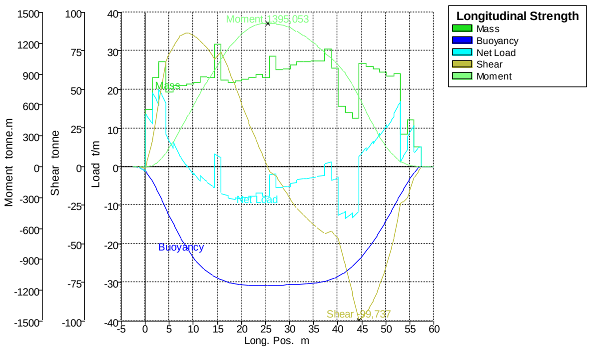

Figure 11. Graphs of Calm Water Conditions

From the graph above, the maximum moment that occurs in calm water conditions is 1394.55 ton.m and converted into Nm units, namely 13,675,849.81 Nm.

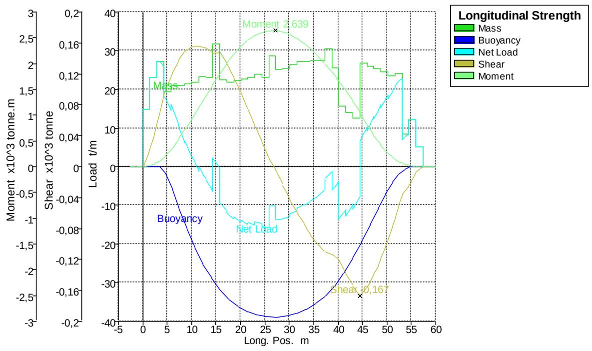

Figure 12. Graphs of Sagging Conditions

From the graph above, the maximum moment that occurs in sagging conditions is 2,639 ton.m and converted into Nm units, namely 25,879,722.96 Nm.

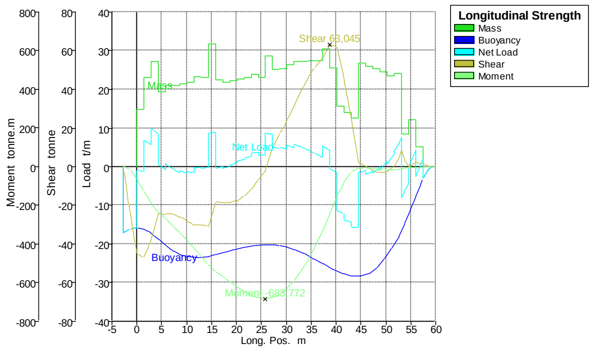

Figure 13. Graph of Hogging Conditions

From the graph above, the maximum moment that occurs in hogging conditions is -683.77 ton.m and converted into Nm units, namely 6,705,486.233 Nm.

3.3 *Structure Modeling and Meshing*

Modeling in the finite element method begins with creating a 3D initial geometric model. Then the model is divided into small elements through a meshing process [14]. The division of elements is carried out according to the laying of the profile to be made, so that it must be in accordance with the distance of the ship's tusks, after meshing the model is given properties on the thickness of the plate, and the type of material that has been determined.

Below is a Figure of the ship structure model when it has meshed.

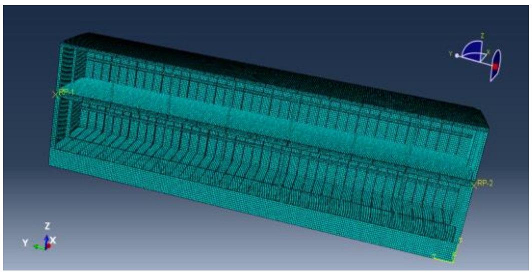

Figure 14. Meshing Process on Ship Model

3.4 *Boundary Condition and Load Input On Ship Structure*

Before doing the analysis, determine the boundary conditions on each model of the construction system. The boundary conditions determine the object's shape being analyzed [15].

Table 2. Boundary Condition [16]

Location	δx	δy	δz	θx	θy	θz
	Maximum Stress Analysis					
After endpoint	Fix	-	Fix	-	Fix	-
Front endpoint	Fix	-	Fix	-	-	-

The load used is the maximum moment calculated previously for each water condition. Load Inputs are placed at the center of gravity on the front and back ends of the 3d model.

3.5 *Stress Calculation*

After determining the boundary conditions and load on the model, an analysis can be carried out to obtain the maximum stress in each construction system using FEM-based software.

The results of the maximum stress analysis are in the form of maximum stress values and also contours or color changes in the parts of the model according to the stresses that occur.

Samples of the contours and bending that occur can be seen in the figure below.

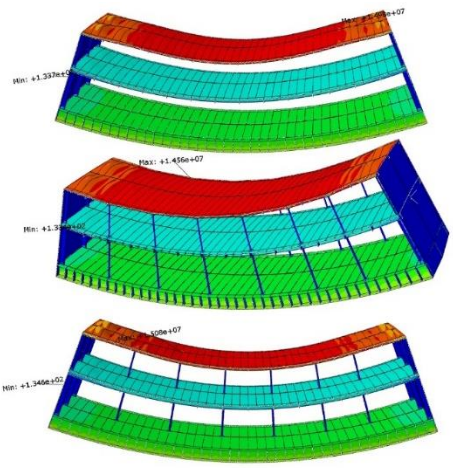

Figure 15. Stress around the pillars in calm water conditions

In the post-processing figure using von Mises, it is explained that the stress that occurs in the construction of the ship (a) without pillars is 14.98 MPa, (b) pillar on the side is 14.56 MPa, and (c) pillar in the middle is 15.08 MPa in calm water conditions.

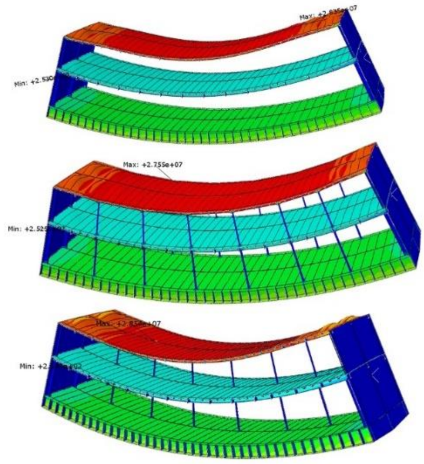

Figure 16. Stress around the pillars in sagging conditions

In the post-processing figure using von Mises, it is explained that the stress that occurs in the construction of the ship (a) without pillars is 28.35 MPa, (b) pillar on the side is 27.55 MPa, and (c) pillar in the middle is 28.54 MPa in sagging conditions.

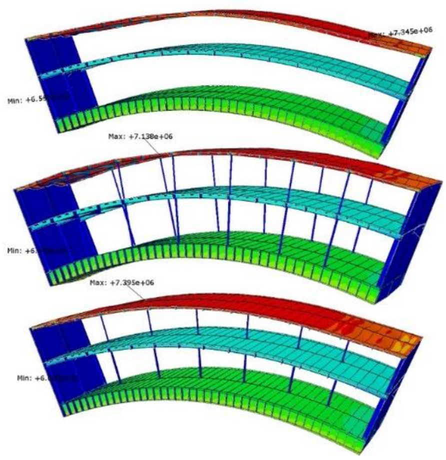

Figure 17. Stress around the pillars in hogging conditions

In the post-processing figure using von Mises, it is explained that the stress that occurs in the construction of the ship (a) without pillars is 7.345 MPa, (b) pillar on the side is 7.138 MPa, and (c) pillar in the middle is 7.395 MPa in hogging conditions.

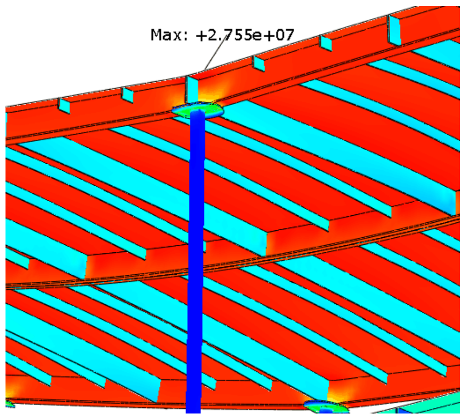

Figure 18. Details of the stress around the pillar on the side of the sagging condition

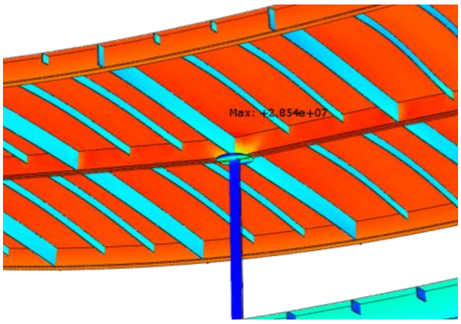

Figure 19. Details of the stress around the pillar in the middle of sagging condition

From figure 18 and figure 19, it can be seen from the stress contours that occur at the connection of the pillar with the center deck girder where the connection part has a high enough stress.

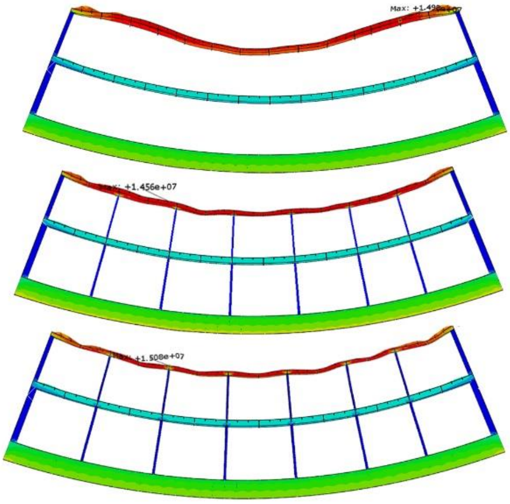

Figure 20. Comparison of the deflection and stress that occurs in calm water conditions (a) without pillar (b) side pillar (c) middle pillar

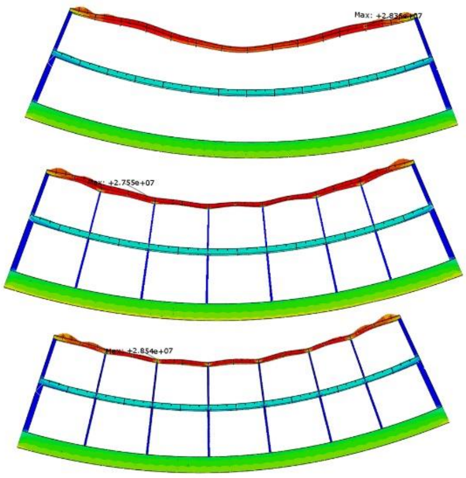

Figure 21. Comparison of the deflection and stress that occurs in sagging conditions (a) without pillar (b) side pillar (c) middle pillar

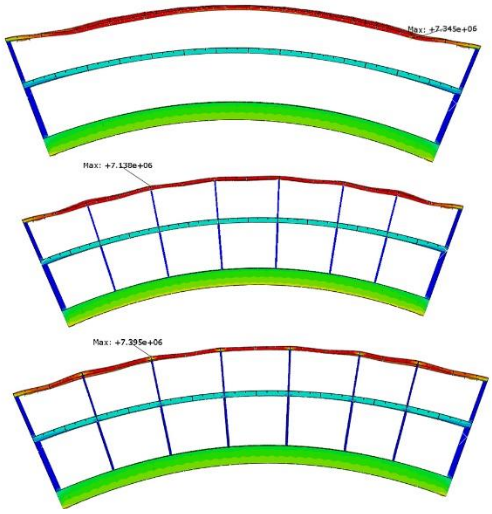

Figure 22. Comparison of the deflection and stress that occurs in hogging conditions (a) without pillar (b) side pillar (c) middle pillar

From figure 20, figure 21, and figure 22 show that the comparison at the centerline intersection in each construction illustrates the deflection and stress that occurs where the comparison is not too significant.

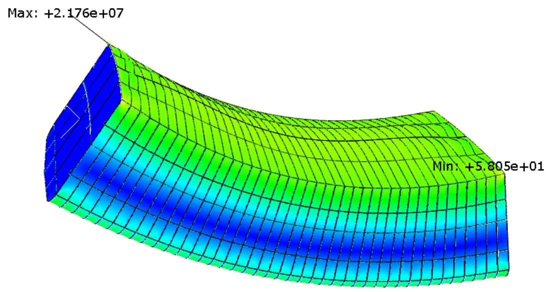

Figure 23. Maximum stress without pillars in calm water condition

In the post-processing image using von Mises, the maximum stress when the ship is in a calm water condition is 21.76 MPa.

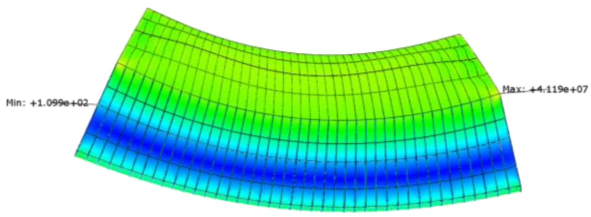

Figure 24. Maximum stress without pillars in sagging condition

In the post-processing image using von Mises, the maximum stress when the ship is in a sagging condition is 41.19 MPa.

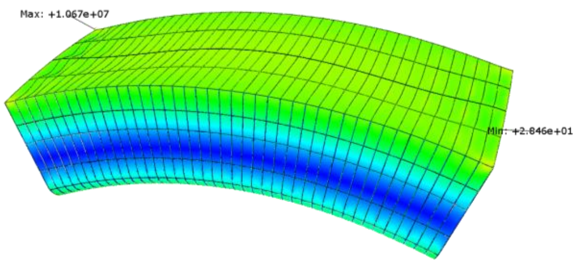

Figure 25. Maximum stress without pillars in hogging condition

In the post-processing image using von Mises, the maximum stress when the ship is in a hogging condition is 10.67 MPa.

Table 3. Results of Stress Analysis in the pillar area in MPa

Variation/Condition	No Pillar	Middle Pillar	Side Pillar
Calm water	14.98	15.08	14.56
Sagging	28.35	28.54	27.55
Hogging	7.345	7.395	7.138

Table 4. Maximum Stress Analysis Results in MPa

Variation/Condition	No Pillar	Middle Pillar	Side Pillar
Calm water	21.76	21.96	21.95
Sagging	41.19	41.55	41.54
Hogging	10.67	10.77	10.76

Based on the analysis that has been done, it can be seen that without pillar has smaller maximum stress in all wave conditions. At the same time, the pillar in the middle has the greatest maximum stress in all wave conditions.

3.6 *Calculation of Allowable Stress*

Calculations are carried out to determine whether the maximum stress of each planned variation system has met the regulation's criteria that is the reference for this research, namely in formula no 2 BKI Volume II of 2018 Rules for Hull.

Table 5. Results of checking the Allowable stress

Condition	Stress (MPa)	Allowable stress (MPa)	Information
Without Pillar			
Calm water	21.76	140.14	Allowed
Sagging	41.19	140.14	Allowed
Hogging	10.67	140.14	Allowed
Pillar in the Middle			
Calm water	21.96	140.14	Allowed
Sagging	41.55	140.14	Allowed
Hogging	10.77	140.14	Allowed
Pillar on the Side			
Calm water	21.95	140.14	Allowed
Sagging	41.54	140.14	Allowed
Hogging	10.76	140.14	Allowed

3.7 *Calculation of the cross-sectional modulus and moment of inertia*

By using the calculation in formula number 3, the minimum modulus of the ship is obtained, which is 0.375 m3. The analysis of the ship's modulus is 4.75 m3, on the ship's deck and 2.44 on the double bottom of the ship, where according to regulations from BKI, the modulus on the deck and double bottom of the ship must be more than Wmin.

In the calculations that have been carried out, the modulus of the construction is allowed from the minimal modulus (Wmin).

Table 6. Results of checking the modulus

Location	Modulus (m^3)	Minimum modulus (m^3)	Information
Deck	4.75	0.375	Allowed
Double Bottom	2.44	0.375	Allowed

By using the calculation in formula number 4, the minimum moment of inertia is obtained. It is obtained by 0.645 m^4, and calculating the moment of inertia on the ship is 6.459 m^4.

Table 7. Results of checking the moment of inertia

Moment of inertia (m^4)	Minimum Moment of Inertia (m^4)	Information
6.65	0.645	Allowed

4 CONCLUSION

Based on the analysis of the longitudinal strength calculation on the 1200 GT Perintis ship with variations in pillar positions that have been carried, the maximum stress results have met the allowable stress criteria of the BKI regulation.

In the detailed drawing of the stress contours that occur in variations that have pillars, there is large stress that appears at the connection of the pillar to the ship's deck girder. It can be concluded that the position of the pillar slightly affects the local stresses that occur in the ship structure, although it is not very significant.

Comparison of the maximum stress obtained in the three variations where the stresses that occur in ship construction without pillars are smaller than in ship construction with pillars in the middle with a difference of 0.20 MPa in calm water, 0.36 MPa in sagging conditions, and 0,10 MPa at hogging condition.

For the calculation of the ship's cross-sectional modulus, which is 4.75 m^3 on the deck and 2.44 m^3 on the double bottom, the two cross-sectional modulus have met the criteria of the BKI regulation, which is more than 0.375 m^3.

For the calculation of the moment of inertia of the ship, which is 6.65 m^4, where the moment of inertia has met the criteria of the BKI regulation, which is more than 0.645 m^4.

From the results of this analysis, it can be concluded that the position of the pillar laying does not significantly affect the longitudinal strength of the ship.

The longitudinal strength of the ship is more significant by changes in longitudinal construction variations, changes in transverse construction variations have no significant effect on longitudinal strength.

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