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The Influence of Padeye Placement on Ship Block Lifting

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ABSTRACTS

Nowadays, steel ship construction in Indonesia is dominated by the hull block construction method. This method can reduce man-hours as the ship is manufactured by a division of the hull into several sections/blocks; here, it can be worked in parallel. Once work is finished on these blocks and then proceeding to the main hull for assembling, the lifting operation is performed on the blocks during this erecting process. Lifting of ship blocks must be planned safely to avoid damage. One of the items that must be considered is the position of the padeye. The placement or installation of the padeye in the block during the lifting operation plays a vital role in the deformation and working stress of the block structure. Consequences if this is not observed, which van cause misalignment in the welding join path on ship bloks due to excessive plastic deformation and stress. Therefore, this study aims to simulate the placement of a padeye that results in minimum deformation and structural stress. The method used in this research is the stiffness method applied in computer programs. In this studied, it had been recorded that the structure on the ship blok is deformed and stressed at each padeye position. Based on the simulation from 23 positions of the padeye, the optimal position of the pad eye is at position 10 in simulation 2 with deformation of x, y, and z coordinates which are 7 mm, 2 mm, and 7 mm, respectively. Generrally, In this case shown the deck girder and longitudinal beam structure is dominantly subjected to high deformation and stress in several position.

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INTRODUCTION

Shifting the shipbuilding method from the conventional one into the product work breakdown structure (PWBS) method has been a trend in Indonesian shipyards. The PWBS method can reduce man-hours in the shipbuilding process by applying the Hull block construction method (HBCM) technique. The concept of HBCM is the Division of the ship's hull and superstructure into several blocks with parallel work. Thus, the man-hours during ship construction can be reduced. The aim of this method is to improve collaboration among all departments in the shipyard, and as a consequence, it increases the productivity of the shipyard [1].

However, in this method, a shipyard has to provide lifting facilities with various sizes of Safe Working Load (SWL) to undertake the lifting operation of heavy panels and blocks during the assembly process. An important factor that should be taken into account when the lifting operation is the position of the padeye. The incorrect location of the padeye on the ship block will cause deformation when the ship block is lifted by the crane [2]. Lifting the ship block is a sensitive process as the lifting beam must be installed in the correct position and orientation [3]. Furthermore, in the joining process, the erection and turnover operation of a block can cause interference between the block and the wire ropes on the

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cranes [4]. Another thing that must be considered in this case is overload and interference between the ship block and the ropes, resulting in major damage [5].

Figure 1. Padeye in Ship Block.

In addition, it should be noticed that working stress on the block can exceed the allowable stress of the material. Padeye is a hook between the block and the sling crane, as seen in **Figure 1**. The other variables that should be considered in the lifting operation are plate size of padeye, ideal sling angle, and sling diameter.

Previous studies have been performed to locate the optimal position of the pedeye. For example, the optimal pedeye position from lifting the bottom portside block in the inner bottom, which is in line with the side girder position using FEM [6]. The other study, the padeye arrangement using the genetic algorithm method to obtain a safe position has been carried out by Ming le Seung et. Al [7], which in the study showed the distribution of deformation and stress in thin plate blocks after turnover and lifting. The analysis of the structural strength in the lifting of the offshore platform experiences a high-stress ratio on the beam components that require an increase in thickness [8]. Seung et al., 2021. has investigated the effect of lifting and turning a block of ships on structural stress using 2D flexible multibody dynamics [2]. Furthermore, Rizal et al., 2014 conducted a study on lifting operation and padeye design on the deck jacket wellhead tripod platform using a floating crane barge [9]. Meanwhile, a study on padeye design was conducted by Ardianto et al., 2017 by comparing the effects of symmetrical and asymmetrical padeye shapes [10]. Based on previous studies, the lifting operation in shipbuilding should be studied further, particularly in a heavy ship block

In the present study, a ship block will be modeled in the computer program and then perform a simulation of padeye placement. This study aims to estimate the deformation of block structure and then compare it with the allowable deformation recommended by IACS guidelines for shipbuilding and repair assessments No. 47. In addition, flexural and shear stress in the block will be investigated in this study and compared with allowable stress according to the classification rules

METHODS

Ship's Data

As a case study, a tugboat will be investigated in the present study. The ship is a towing tug-built block method with a transverse framing system. The ship is being in PT. XYZ, where the hull and superstructure are divided into several parts of the block, as seen in **Figure 2**. The main dimensions of this ship are as follows:

Ship Type	: Harbour Tug
LOA	: 29.00 meter
B	: 9.60 meter
H	: 4.38 meter
T	: 3.50 meter

The material used on this ship is mild steel with grade A by BKI with material properties as follows:

Modulus Young (E)	: 210000 N/mm^2
Poison Ratio (√)	: 0,3
Yield stress (Se)	: 235 N/mm^2
Tensile stress (Su)	: 400 – 520 N/mm^2
Shear Modulus	: 80 kN/mm^2

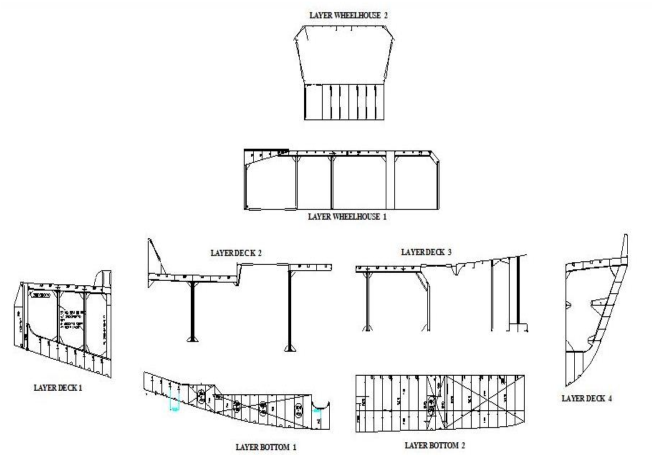


Figure 2. Blok Arrangement.

Based on **Figure 2**, the block of layer deck 2 is one of the largest blocks on the ship. This block is without a longitudinal bulkhead on the centerline. Besides, there is an opening in the middle that can reduce its strength. For this reason, this block will be examined as it is assumed that prone to deformation, particularly on the deck when the block is being lifted. The Block location is on frames 12 to 31 with the following dimensions.

Length (L)	: 9.5 meter
Width (W)	: 9.6 meter
Height (H)	: 3.6 meter

Ship Structure Modelling

In this study, the modeling of frame structure will be carried out on computer software. The following is the first step in structural modeling

1. Determination of global and local axis of the element.
2. Determination of join coordinates as element boundaries.
3. Determination of the elements in the coordinate structure.

The structural model is a frame model. The plates attached to the frame are used as a load on the nearest joint. In addition, it should be considered the role of the plate on the structural strength or the so-called effective plate. This effective plate is attached to the frame according to the location of the plate in real conditions. Assuming that the acting load distribution is supported on the ship plate, the location of the moment that is equal to zero will be determined. The distance between the moment points equal to zero will be compared with the non-supported distance in the frame. Finally, the cross-sectional length of the effective plate will be identified using the effective area graph at the maximum bending moment, as shown in **Figure 3** [11].

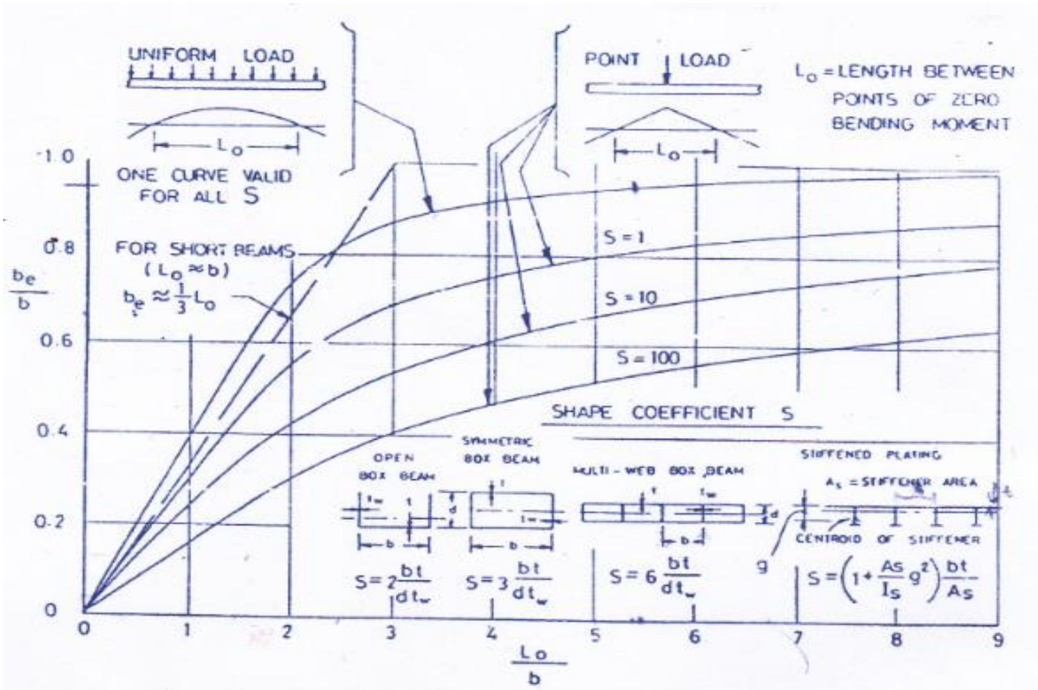


Figure 3. Graph of Plate Effective Area of Maximum Flexural Moment.

For the load used in the calculation of the effective plate area, the weather deck load and sideload formulas are applied according to BKI:

Load on ship's side [12] :

$$Ps = 10 \cdot (T - Z) + P_o \cdot C_F \cdot \left(1 + \frac{Z}{T}\right) \quad (1)$$

Load on ship's weather deck [12] :

$$P_D = P_0 \frac{20 \cdot T}{(10 + Z - T)\,H} C_D \quad (2)$$

For loading on the model, the weight of the block itself is used with a total weight of 26.46 tons. After input from the ship construction drawings is finished, the results of the structural modelling can be seen in **Figure 4.**

Volume 2 Rules BKI 2021 is used for the allowable stress of the structure. The allowable shear stress is obtained by the following equation:

$$\tau = \frac{80}{k} \quad (3)$$

For the allowable bending stress:

$$\sigma = \frac{120}{k} \quad (4)$$

Where: k is the material factor

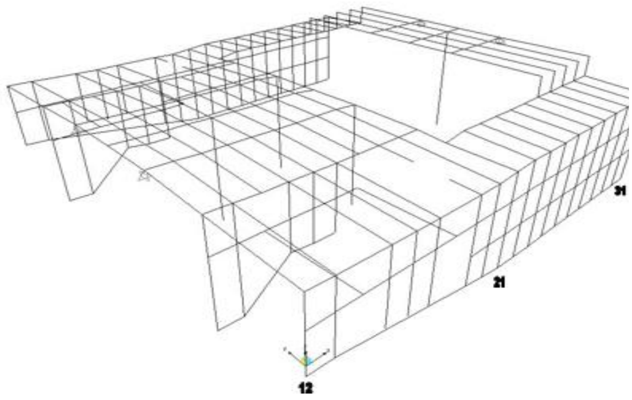


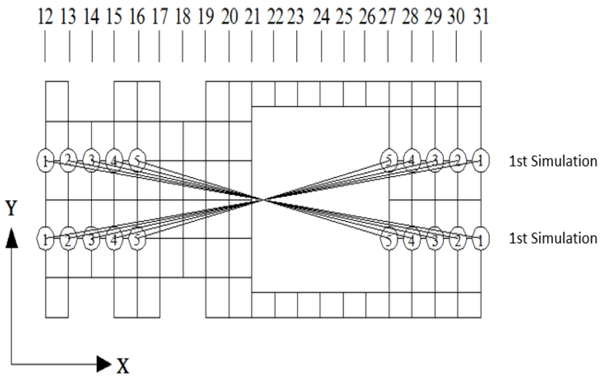
Figure 4. Frame Structure on Ship Block.

Boundary Condition

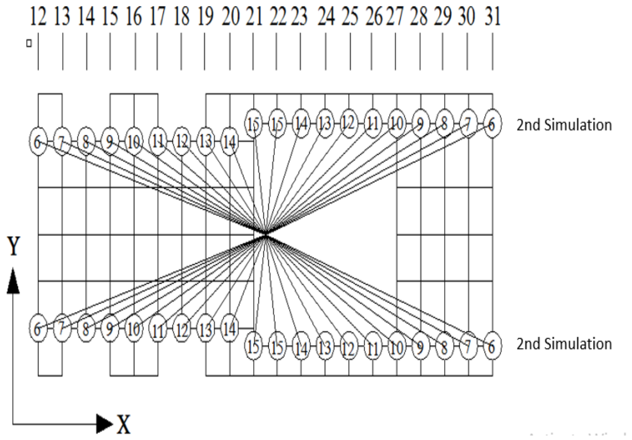
The padeye is placed at the joint between the longitudinal girder deck and the transverse deck as well as on the side of the main deck in the lifting operation of the layer, where each position is placed four-piece padeyes. In the structure model of the layer, the padeye is defined as fixed support. There are 23 lifting lug positions on the lifting operation in the main deck with labels 1 to 23.

Terms for numbering labels on the padeye position:

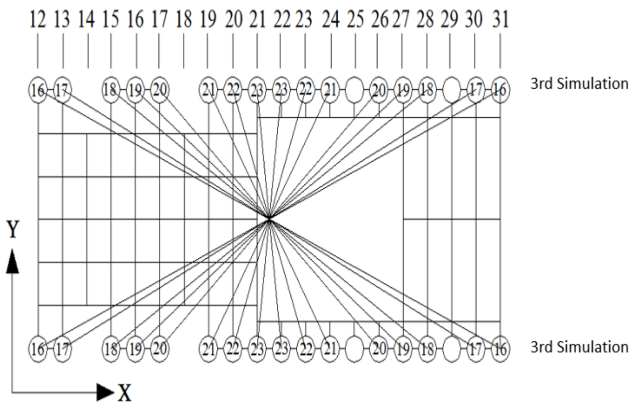
1. The labeling of the smallest number begins on deck girder 1, which is the nearest girder to the center deck girder at the starboard and portside. Then from the deck girder 2 to the outer part of the block, as shown in **Figure 5.**
2. On one deck girder, the label with the smallest number is placed at the joint between the girder deck and the outermost transverse deck.
3. For all positions, it will be divided into three simulations. In the first simulation, the padeye is placed on the joint between the deck girder and the transverse deck beam. For the second, it is placed on the joint between the deck girder and the transverse deck beam. Lastly, it is placed on the joint between the frame and the transverse deck beam.



(a)



(b)



(c)

Figure 5. Placement Simulation Padeye on the Blocks; (a) Simulation 1, (b) Simulation 2, (c) Simulation 3.

Stiffness Method

The stiffness method is a method of structural analysis in which displacement at district points is taken as the unknown quantity to be specified in the formulation process of the analysis [13]. This method is often called the displacement method, using a matrix in the structural analysis [14]. It was established in the 1800s. But this method has been rapidly developed and gained popularity in recent years in conjunction with the advancement of automatic computation that could simplify its mathematical operations [14].

In this method, the relationship between force and deflection will be determined and expressed as follows [13] :

$$\{P\} = [K] \cdot \{\delta\} \tag{5}$$

Where {P} and {δ} force and displacement vectors respectively at nodal coordinates of the beam element and [K] stiffness matrix of the element.

This method is also called the displacement method, as the analysis begins with deflection. Thus, the working sequences are as follows [13] :

1. Compatibility: Identifying the relationship between deformation and deflection or specifying deformation occurring in the elements at discrete points due to the deflection is being exposed to these structure points.
2. The equation of the relation between stress and strain ; identifying the internal forces as a result of deformation in these structural elements after got the load.
3. Equilibrium; is the last step that defines the relationship between external forces of the discrete point and the forces or determines the proper external forces at the end of the element equilibrated by the forces in the discrete points element.

RESULTS AND DISCUSSION

Table 1. Maximum Deformation on Simulation 1.

Position Code	Deformation (mm)		
	X	Y	Z
1	62	40	52
2	30	28	32
3	19	17	22
4	22	12	16
5	34	5	21

For the 2nd Simulation, the padeye is on deck girder 2, which is 3400 mm from the center girder. The position of the padeye is varied up to 10 positions which are coded numbers 6 to 15. It is placed at the joint The structural strength analysis of the ship block is performed by taking into account deformation, bending, and shear stress. Based on the simulation results of the padeye placement using SAP software. The results of the strength analysis of the ship structure are discussed as follows :

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Deformation

In simulation 1, the pedeye will be placed symmetrically at the joint between the deck girder I and the transverse deck beam labeled 1 to 5 a (**Figure 5**). Based on simulation position 1, the maximum deformation for each position is obtained, see **Table 1.**

between the transverse deck beam and deck girder 2, which has varying distances due to the asymmetrical position of the deck girder. Based on the variety of the positions, the maximum deformation is obtained, as shown in **Table 2.**

Table 2. Maximum Deformation on Simulation 2.

Position Codes	Deformation (mm)		
	X	Y	Z
6	19	7	28
7	14	8	20
8	11	8	15
9	8	3	10
10	7	2	7
11	9	4	9
12	15	7	17
13	21	10	28
14	31	13	41
15	59	14	90

Table 3. Maximum Deformation on Simulation 3.

Position Codes	Deformation (mm)		
	X	Y	Z
16	2	8	11
17	2	7	9
18	4	7	8
19	4	7	8
20	4	7	9
21	5	7	11
22	5	7	12
23	6	7	15

In the 3rd Simulation, the pad eye is at the joint between the deck beam and the frame, which is 4.6 meters from the center girder; it is placed symmetrically and starts number 16 to 23, as seen in Figure 5. The obtained maximum deformation can be seen in **Table 3**

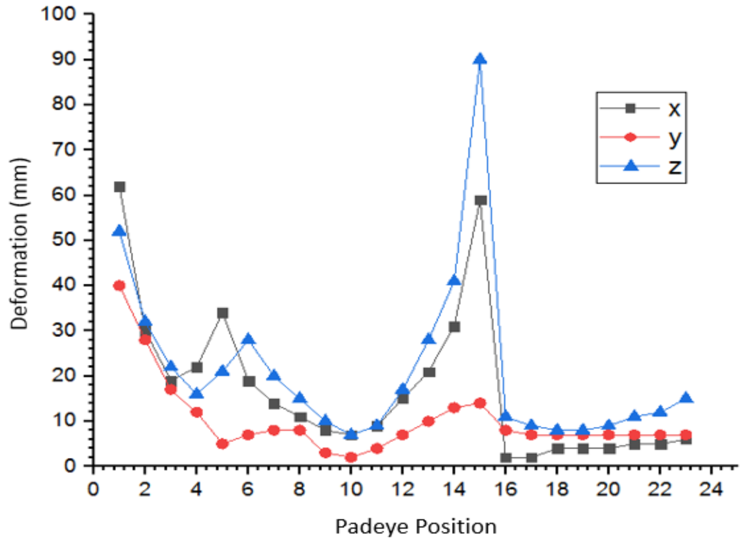

Figure 6. Distribution of Structure Deformation at Each Padeye Position.

From **Tables 1, 2,** and **3**, the maximum deformation is obtained at position 1 for x and y directions with values of 62 and 40 mm, respectively. And at position 15 with a value of 90 mm for z-direction. In contrast, the minimum deformation is at positions 16 and 17 for x and 10 for y and z, with values 2, 2, and 7 mm, respectively. The distribution of structural deformation in all simulations can be seen in **Figure 6**. From the curve, it can be seen that the deformation for the three directions shows an up-down trend. In general, the deformation values differ among all positions. To identify whether the deformation is elastic or plastic, this can be associated with the obtained stress value in the analysis of shear and bending stress at each pad eye position in the following section.

If compared with the IACS rules, several deformation values exceed the IACS No. 47 Standard for Shipbuilding and Repair Quality [15], as shown in **Table 4.**

Table 4. Permissible Deformation Standard.

No	Item	Deformation (mm)	
		Standard	Limit
1	Shell plate -Parraller part (side & bottom shell)	4	8
	Shell plate - Fore & aft part	5	8
2	Tank Top Plate	4	8
3	Strenght deck- parralel part	4	8
	Strength deck – Fore & aft part	6	9
	Strength – covered part	7	9

3.2 Stress

For strength analysis, it refers to the bending and shear stress obtained in all simulations. The stress is examined solely in the construction element, excluding the pedeye. The obtained strength values are as follows:

Shear Stress

The shear stress obtained at each padeye position can be seen in **Table 5**. Based on the table, it is found that the minimum shear stress is in simulation 3 at position 16 with 23.98 N / mm2. While the maximum value in simulation 2 at position 15 with 124.15 N / mm2. Overall, The shear stress for all positions in the pedeye is satisfied with the BKI standards as follows in **Table 5**, excluding position 15 in simulation 2. The tendency of shear stress for almost all positions that satisfy the standards is influenced by the moment of inertia and dimensions of the structure, which are sufficient to withstand the shear forces due to the lifting operation. The shear stress of structural elements can be seen in **Figure 7**.

Bending Stress

For the bending stress values, it can be seen in **Table 6.** Based on the Table, the maximum bending stress is in simulation 1 and at position 1 with 672.86 N / mm2. Meanwhile, the minimum value is in simulation 2 and at position 10 with 106.70 N / mm2. The tendency of bending stress is not satisfied with the BKI standards as follows **Table 6** is caused by the moment due to the gravitational force resulting from the lifting operation. The distribution of the bending stress can be seen in **Figure 7.**

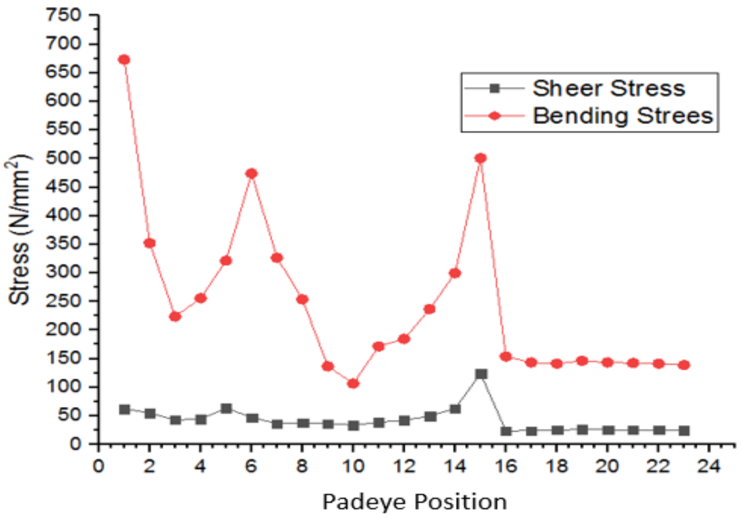

Figure 7. Stress Distribution at Placement Simulation of Padeye.

From the curve in **Figure 7**, it can be seen that the bending stress is bigger than the shear stress when the lifting operation. From a total of 23 positions. the most suitable is position 10, with minimum bending stress compared to others. As for the shear stress, it tends to be similar for all except for position 15. Thus, position 10 is recommended for placing the pad eye for lifting operatio

Table 5. Shear Stress on Each Pedeye Position.

Padeye Position	Shear Stress (N/mm2)		Condition	Element
	BKI Standard	Working		
1	80.00	62.57	Satisfied	Longitudinal deck beam 1
2	80.00	55.44	Satisfied	Hacthway Cover 30
3	80.00	43.36	Satisfied	Longitudinal deck beam 2
4	80.00	44.57	Satisfied	Longitudinal deck beam 1
5	80.00	64.00	Satisfied	Haatcway Cover 27
6	80.00	47.59	Satisfied	Centre Long. deck beam
7	80.00	36.61	Satisfied	Girder &trans. Deck beam 30
8	80.00	38.52	Satisfied	Centre Long. deck beam
9	80.00	36.63	Satisfied	Longitudinal deck beam 2
10	80.00	34.07	Satisfied	Girder &trans. Deck beam 27
11	80.00	39.02	Satisfied	Longitudinal deck beam 2
12	80.00	42.71	Satisfied	Longitudinal deck beam 2
13	80.00	50.10	Satisfied	Centre Long. deck beam
14	80.00	62.95	Satisfied	Centre Long. deck beam
15	80.00	124.15	Not satisfied	Girder &trans. Deck beam 21
16	80.00	23.98	Satisfied	Girder &trans. Deck beam 16
17	80.00	24.45	Satisfied	Girder &trans. Deck beam 16
18	80.00	25.48	Satisfied	Girder &trans. Deck beam 16
19	80.00	26.43	Satisfied	Girder &trans. Deck beam 16
20	80.00	25.91	Satisfied	Girder &trans. Deck beam 16
21	80.00	25.73	Satisfied	Girder &trans. Deck beam 16
22	80.00	25.52	Satisfied	Girder &trans. Deck beam 16
23	80.00	25.20	Satisfied	Girder &trans. Deck beam 16

Table 6. Bending Stress at each Pedeye Position.

Padeye Position	Bending Stress (N/mm^2)		Condition	Element
	Standard	Working		
1	120.00	672.86	Not satisfied	Haatcway Cover 31
2	120.00	352.21	Not satisfied	Transverse deck beam 13
3	120.00	223.77	Not satisfied	Girder beam 14
4	120.00	255.99	Not satisfied	Haatcway Cover 28
5	120.00	321.77	Not satisfied	Haatcway Cover 27
6	120.00	474.16	Not satisfied	Transverse deck beam 12
7	120.00	326.77	Not satisfied	Transverse deck beam 13
8	120.00	253.91	Not satisfied	Transverse deck beam 12
9	120.00	136.87	Not satisfied	Transverse deck beam 12
10	120.00	106.70	Satisfied	Girder &trans. Deck beam 27
11	120.00	171.67	Not satisfied	Longitudinal deck beam 2
12	120.00	184.80	Not satisfied	Longitudinal deck beam 2
13	120.00	236.86	Not satisfied	Centre Long. deck beam
14	120.00	299.66	Not satisfied	Girder &trans. Deck beam 21
15	120.00	500.97	Not satisfied	Girder &trans. Deck beam 21
16	120.00	153.80	Not satisfied	Transverse deck beam 12
17	120.00	143.61	Not satisfied	Transverse deck beam 12
18	120.00	141.39	Not satisfied	Girder &trans. Deck beam 16
19	120.00	146.50	Not satisfied	Girder &trans. Deck beam 16
20	120.00	143.69	Not satisfied	Girder &trans. Deck beam 16
21	120.00	142.58	Not satisfied	Girder &trans. Deck beam 16
22	120.00	141.31	Not satisfied	Girder &trans. Deck beam 16
23	120.00	139.03	Not satisfied	Girder &trans. Deck beam 16

CONCLUSION

The simulation of padeye placement in the lifting operation of the ship block has been carried out with the stiffness method. From the simulation, it is obtained a number of results consisting of the deformation in 3 translation directions, shear, and bending stress of the ship block. Of the 23 simulated positions, position 10 is the favorable position, as it has the minimum deformation in the three translation directions and the smallest bending stress. While the shear stress tends to be similar in all positions of the padeye placement.

Based on the simulation results, it is proved that deformation tends to be higher if the not supported longitudinal distance (padeye distance) is greater. The bending stress is formed by the developed moment due to the large moment arm against the block construction weight. Thus, the ideal position is in the space of not supported distance, has a short moment arm, and uniform weight distribution across all the pedeyes.

Further study on padeye arrangement in the lifting operation of ship block will be performed using the finite element method (FEM) and examining translational and rotational deformation and the structural strength of the ship block construction.

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