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Strength Analysis of High Density Polyethylene Floating Jetty Deck with Finite Element Method

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Abstract—**Floating Jetty or commonly called a floating dock, is one of the facilities in the harbour for loading and unloading passengers from ships to land or vice versa. HDPE (High-density polyethene) is a type of plastic that is more resistant to chemical solutions or contaminants and can be recycled. HDPE (High Density Polyethylene) material can be used for marine building construction. At the design stage, there is a stage to determine the strength of marine building construction to avoid failure in its operation. One of the methods used to analyse structural strength is the finite element method. In this study, the strength of floating dock decks made from HDPE is analysed using the finite element method. The results of modelling using finite elements show that the construction of floating dock decks made from HDPE has a von mises stress of 3.05 Mpa and a deformation of 0.0035 mm which is still below the allowable stress and deformation values determined by the classification society.**

Keywords— floating jetty, hdpe, high density polyethylene, finite element method.

I. INTRODUCTION

Floating jetty or floating dock is one of the facilities in the port in the form of a floating dock that can operate up and down according to the water level. Floating docks have shapes and dimensions according to the ship that will dock and are used for loading and unloading passengers, also for tourism [1]. The advantages include an easy construction-production process, its operation does not depend on water conditions, and this type of pier is easy to move [2].

In the design and construction process of a floating or marine building structure, one step must be taken to ensure that the construction has good structural strength and does not experience structural failure [3]. The usual step to determine the strength of the structure is the structural strength analysis process carried out to prevent structural failure [4].

The finite element method is one of the numerical methods that is often used for the structural strength analysis process. The process of structural strength analysis with the finite element method is:

1. Preprocessing is the modelling stage and the selection of element types and meshing.
2. Solution is the stage for applying loads, boundary conditions, and completion.
3. Postprocessing is the stage of reading the results, such as stress, displacement, etc. [5].

HDPE (High-density polyethene) is a type of plastic that is more resistant to chemical solutions and contaminants and is recyclable. HDPE material that has been recycled, can be used as a material for boat construction [6] [7]. It is widely used for construction and buildings and is also used for ship construction, where it is recyclable, durable, and easy to maintain [8]. HDPE material can be used as ship's construction material [9]. Marine small craft building HDPE is widely used as the main construction material [10]. In addition, the joint of HDPE material with hot gas and extruder methods has good strength, so the construction of ships with HDPE material can be used [11]. In the strength aspect, HDPE can be used as a primary material for shipbuilding based on flexural strength [12] and based on the tensile strength [13]. The dynamic analysis results show that the HDPE pontoon-type harbour provides better impact resistance capacity in the structural members [14]. FEM can be widely used for HDPE material analysis, and it is possible to obtain fast and accurate results for stress and strain analysis [15][16].

This research will discuss the construction of floating docks made from HDPE and structural strength analysis using the finite element method.

II. METHOD

A. Model

In this study, the main sizes of the floating dock are:

Length (L) : 10 m
Width (B) : 2,5 m
Height (H) : 1,5 m

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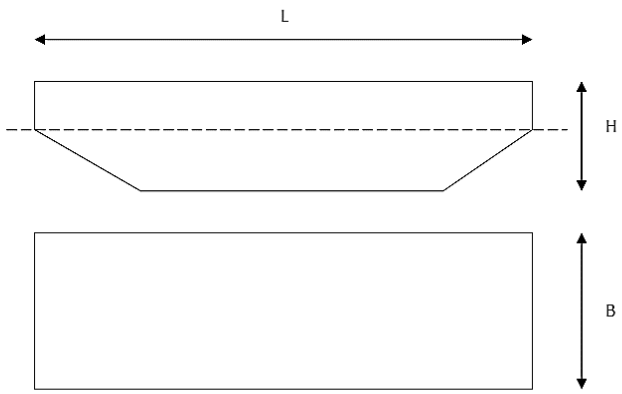

Figure 1. The shape of the floating jetty

The shape of the floating jetty can be seen in Figure 1. Swim-End Pontoons, a pontoon or barge-shaped dock model that is widely chosen because it is safer and more stable, this dock model is usually larger than the typical pontoon dock and more durable.

B. Constructions

In this study, to determine the size of construction using regulations from the Rules for Classification of Floating Docks in 2009 [17].

Plates

The thickness of the plates on the deck shall not be less than,

t =10 x S mm

where :

S is the distance between stiffeners (m)

The distance between stiffeners in this model is 0.5 metres, so:

t = 10 x 0.5

t = 5 mm

the minimum thickness of the plate is 7.5 mm

In accordance with the minimum requirements, the plate thickness of 8.0 mm is taken.

Stiffeners

The size of the stiffener construction uses the following equation

W = C x s x l^2 cm^3

C = 14,5

s = distance between stiffeners (m)

l = longitudinal span or beam (m)

so that:

W = 14.5 x 0.5 x 2.5^2

W = 45.3125 cm^3

Selection of a rectangular bar profile, 12 mm thick, and 160 mm high, with a section modulus of 51.2 cm^3. The midship section of the planned floating dock construction is shown in Figure 2.

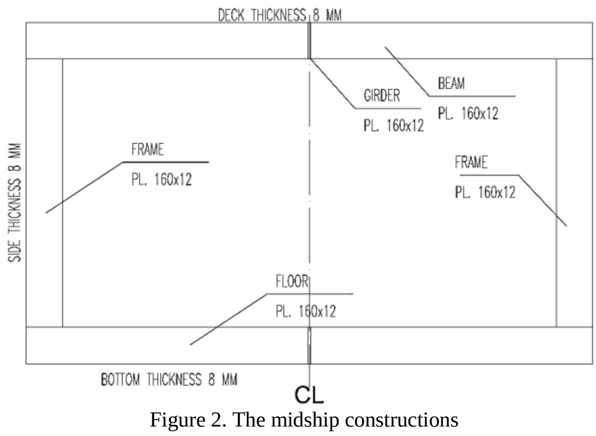

Figure 2. The midship constructions

C. Finite element methods

Calculation with the finite element method is assisted by software for the calculation process. The steps taken are:

1. Element Determination

The elements used in this study use the SHELL181 and BEAM189 element types. The SHELL181 element has 4 nodes with three degrees of translation-rotation at each node and linear interpolation is used in the element [18]. Composite plates using SHELL181 are very compatible with analytical solutions for plates in a structure [19]. BEAM189 is a suitable element type for analysing slender and thick beam structures [20].

2. Material Characteristics

HDPE material is an isotropic material for both compression moulded and injection moulded HDPE [21]. Where in general, the characteristics of HDPE material are as follows:

Tensile stress at yield 25 MPa

Elongation at yield 9%

Specific density 95 g/cm^3

Modulus of elasticity in tension 1000 MPa

Poisson's ratio 0.40 - 0.45

3. Load

In the design of the floating dock, it is planned to be used for human crossing facilities, with a total of 20 people at the time of crossing simultaneously, with the weight of each person of 75 kg. Seen in Figure 3, the simulated floating dock is used to pass passengers.

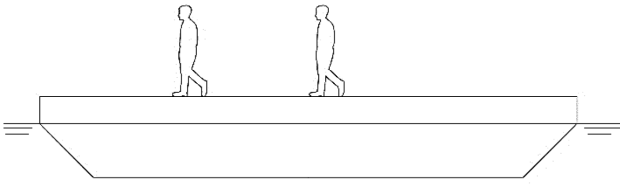

Figure 3. The load of floating jetty

4. Boundary Conditions

The boundary conditions in modelling using the finite element method are to determine which parts will be assumed to be fixed, where in HDPE ship construction can use fixed boundary conditions (fixed support) [22].

The boundary conditions on the model are simulated fixed (fixed support) at the ends of the model. In general, the use of boundary conditions in ship construction with a fairly complex construction, the use of simply support or fixed support boundary conditions is not recommended, but in extreme conditions the use of these boundary conditions can be used [23]. For floating dock, the hinge boundary could be used as a boundary condition [24]. The model in this study focuses on the construction of floating dock decks, as shown in Figure 4.

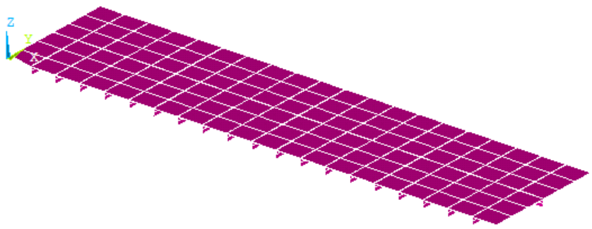

Figure 4. The deck model of floating jetty

III. Results and Discussion

In analysing the strength of structures using the finite element method with the assistance of software, the most important final step is convergence. Convergence has an important role in the accuracy of the solution obtained from the use of the finite element method, so it needs to be analysed comprehensively in each problem. The convergence curve in finite element analysis is the relationship between grid interval and analysis accuracy, where the curve formed depends on the selection of elements, boundary conditions and the re-meshing process [25]. The convergence process includes reducing the element size and analysing it against the accuracy of the results, in general the smaller the mesh size or the greater the number of elements, the more accurate the results.

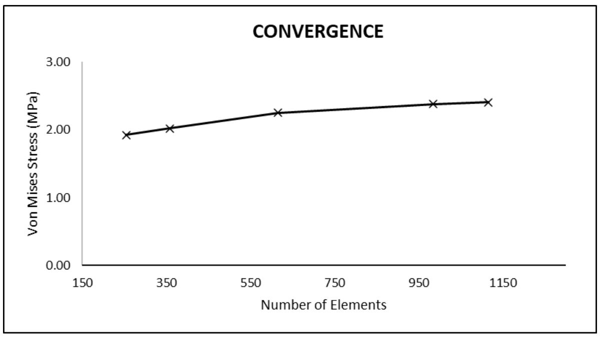

Figure 5. Convergence curve

The maximum von mises stress (Von Mises Stress) in the deck construction is 3.05 MPa, occurring at node 886. Where the location of the highest stress is located at the longitudinal deck, as shown in Figure 6, where it can be seen that the location of the highest stress is at the longitudinal deck.

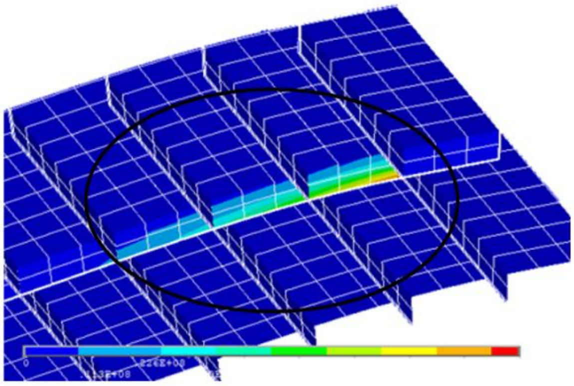

Figure 6. The highest stress of deck strucuture

The results of the analysis with the help of Finite Element Analysis Software resulted in a maximum stress of 3.05 MPa, the maximum stress results are still below the provisions required by Türk Loydu, where according to the Türk Loydu rules in 2014, High Density Polyethylene (HDPE) material has a Tensile Yield Stress value of 17 MPa [26]. In Figure 7, the von mises stress results are shown, where deflection occurs in the deck structure. As previous research conducted by Cho, in 2012 which states for ships made from HDPE, where the hull with HDPE construction has a high density value, where this material is a very ductile material, so that at the design stage the determination of the strength value of the material must be set to 90% of the yield stress [27]. The stress results that occur are still below 90% of the fatigue stress value of HDPE material.

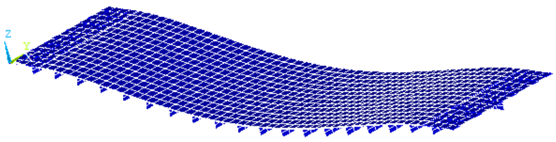

Figure 7. The deck deflection (autocalculate graph)

The deformation that occurs is 0.0035 mm, where the deformation that occurs is still below the rules set by the classification body. The permissible deformation or deflection is 0.4% l, where l is the unsupported span [28]. In the research, the span of the unsupported beam is 1250 mm, so the permissible deformation is 5 mm.

IV. Conclusion

In this study, a floating dock made of High Density Polyethylene (HDPE) has been carried out a strength analysis process using the finite element method. The construction of the floating dock deck with a plate thickness of 8 mm, as well as the size of the rectangular bar construction with a thickness of 12 mm and a height of 160 mm, produces a von mises stress of 3.05 MPa which is still below the yield value of the material required by the classification. And the deformation value of 0.0035 mm that occurs is still below the deformation value allowed by the classification.

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