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Design Study of Additional Construction of Dock Fenders (Case: Politani Pangkep Education Dock)

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ABSTRACT

Dock fenders play a crucial role in protecting both the dock structure and vessels from damage due to impact during mooring operations. With increasing ship traffic and vessel sizes, upgrading the existing fender system is necessary. This study aims to design additional fender structures based on energy absorption requirements, ship specifications, and existing structural characteristics. The research methodology includes site surveys, impact energy calculations, selection of appropriate fender types, and structural integration analysis using simulation software. The results indicate that the ship impact energy is 0.015 ton-meter, with the fender absorbing 50% of that energy, or 0.008 tons. Each fender point is equipped with two tires, resulting in a reaction force (RF) of 0.02 tons, which exceeds the required absorption value (0.008 tons), indicating a safe condition. Based on the analysis, the use of "Gajah Tunggal" GT Super 88 N tire fenders is effective in absorbing the impact from the training vessel of the Pangkajene and Islands State Agricultural Polytechnic, due to its high elasticity

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INTRODUCTION

As a vital part of port infrastructure, docks must be capable of safely and efficiently accommodating various types of vessels. One of the key components that ensures safety during mooring is the dock fender, which functions as an energy-absorbing buffer between the vessel and the port structure, thus preventing structural damage or hull deformation (PIANC, 2002). At older docks, the existing fender systems are often no longer adequate due to increased vessel capacity. Therefore, a design study for additional fenders that considers both technical needs and current conditions is necessary.

The Pangkajene and Islands State Agricultural Polytechnic (Politani Pangkep) owns three training vessels, which currently berth at Awerange Port in Barru Regency, located approximately 17 km from the campus. This situation poses challenges in terms of vessel security and incurs additional costs for night guards while the vessels are docked. Furthermore, an on-campus educational dock is essential for student practicals in port and marine engineering, and it can be developed alongside other surrounding infrastructure such as fish ponds, mangrove parks, and more, for mutual support.

The educational dock site faces the Makassar Strait and lacks natural wave protection, resulting in high waves carrying significant energy toward the shoreline. This presents a technical challenge in ensuring the safety of moored vessels. The currently installed fenders are deemed insufficient in absorbing vessel impacts, hence additional fender construction is required to ensure safer berthing.

Construction of the educational dock at Politani began in 2019 and was completed in 2020. Given its location in open waters directly facing the Makassar Strait, without natural wave breakers, the site experiences strong waves with high energy. As a result, the dock's positioning must be carefully planned to mitigate these effects.

The shoreline at the construction site is gently sloped, necessitating a long trestle structure, which significantly increases construction costs. Additionally, the sloped beach causes wave energy to intensify as waves reach breaking conditions near the shore. Given these realities, it is crucial that the dock is equipped with effective fenders capable of absorbing ship impact energy, as the existing ones have proven inadequate.

This study aims to design additional fender constructions that reduce vessel movement during mooring at Politani's educational dock. The research focuses on planning the design of additional fenders for the existing dock, in response to the growing frequency of medium-sized vessel mooring. The objective is to determine the appropriate type and capacity of fender and to design a structurally integrated and safe installation system.

LITERATURE REVIEW

Force Equation on the fender

When the ship is about to dock, the ship will hit the pier. Collisions also occur while the ship is docked at the pier to carry out loading and unloading activities. The force caused by the collision between the ship and the dock is known as the Berthing Force. The effective kinetic energy at berthing is calculated using the equation (Japanese Port and Harbour Association (JPHA, 1989)).

$$E = \frac{W.V^2}{2.g}.Cm.Ce.Cs.Cc$$

Where:

E = kinetic energy that occurs
Cm = hydrodynamic mass coefficient
W = virtual weight of the ship (tonnes)
V = ship docking speed (m/sec)
Ce = eccentricity coefficient
Cs = softness coefficient
CC = mooring configuration coefficient

The parameter coefficients for kinetic energy calculation are:

CC = mooring configuration coefficient

The magnitude of the parameter coefficient for the calculation of kinetic energy is:

a. Virtual Weight

The virtual weight of the ship (W) is calculated using the following equation:

$$W = W_a + W_d$$

Where :

Wa = added weight =
Wd = displacement tonnage (tonnes).

b. Hydrodynamic Mass (Cm)

Is a coefficient that affects the movement of water around the ship calculated using the following equation:

$$Cm = 1 + \frac{2d}{B}$$

Where:

d = ship draft (m)
B = ship width (m)

c. Eccentricity (Ce)

The coefficient of reduction of energy transferred to the fender when the point of impact of the ship is not parallel to the centre of mass of the ship and is calculated using the following equation:

$$Ce = \frac{K^2 + R^2 \cos^2 \gamma}{K^2 + R^2}$$

Where:

K = radius ration of the ship (m)

K = (0.19Cb + 0.11)Loa)

R = Distance between the centre of mass and the ship's impact point, calculated geometrically using Figure 3.12 (m)

β = Angle formed between the ship's point of impact with the velocity vector and the ship using Figure 1. (degrees)

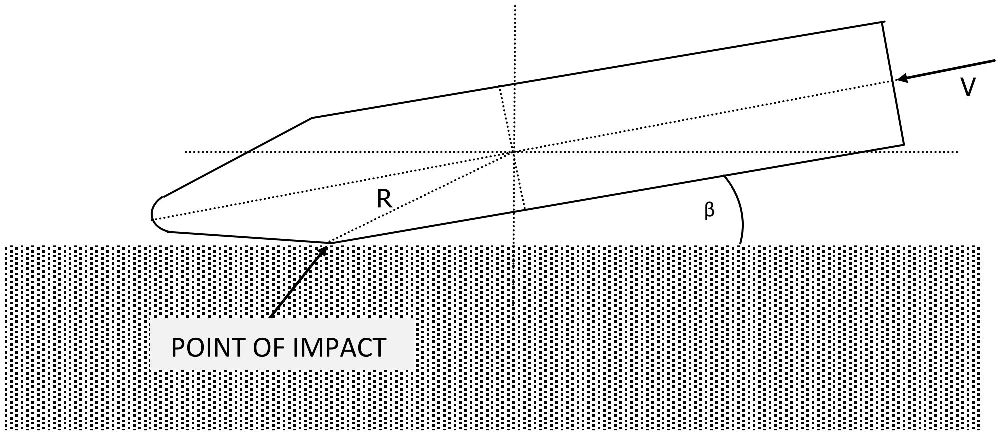

Figure 1. Ship Berthing Conditions.

d. Coefficient of Block (Cb)

Calculated with the equation:

$$Cb = \frac{W}{Loa.B.d.\gamma_{airlaut}}$$

with : $\rho_{seawater}$ = density of seawater (kg/m^3)

e. Softness Coefficient (Cs)

Is a coefficient due to the effect of impact energy absorbed by the hull.

f. Berthing Coefficient (Cc)

A coefficient that shows the effect of the mass of water trapped between the hull and the quayside. The value of Cc depends on the type of dock construction (Figure 2) which is as follows:

Cc = 1.0 for pier structure types with pile foundations

0.8 < Cc < 1.0 for type of pier structure with retaining wall

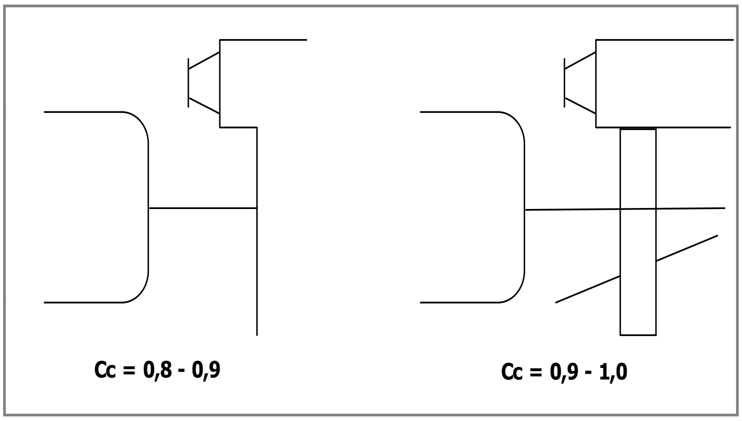

Figure 2. Berthing Coefficient (Cc) According to Pier Type

Fender Position

From the calculation of berthing energy above, the type and size of fender required can be determined. The fender placement is determined from the dimensions of the smallest ship that will moor at low tide (Figure 3). An example of installation can be seen in the following figure.

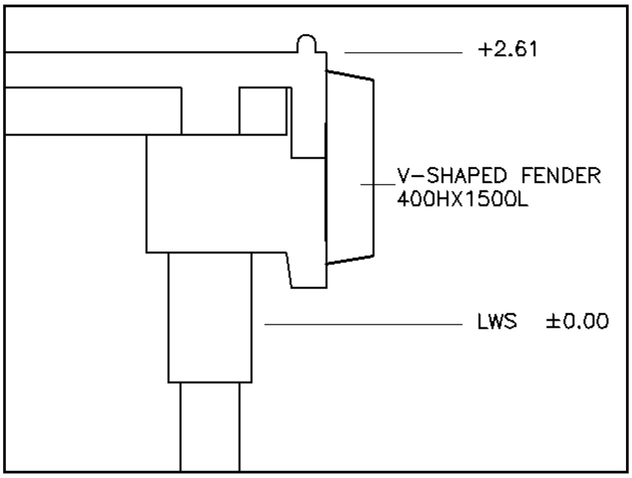

Figure 3. Example of Fender Position on a Pier

Distance Between Fenders

In the horizontal direction, the distance between the fenders must be determined in such a way as to avoid direct contact between the ship and the pier wall. The fender spacing in the horizontal direction can be seen in the figure below.

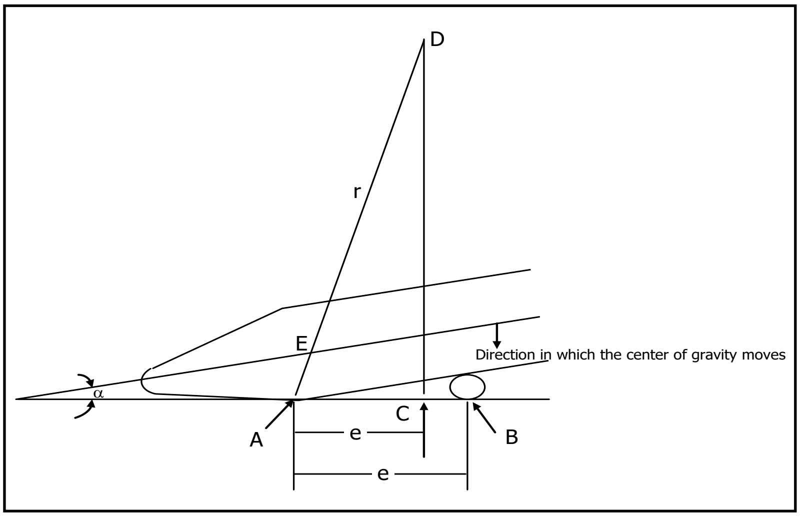

Figure 4. Distance Between Fenders

The maximum distance between fenders can be calculated with the following equation:

$$21 \leq 2\sqrt{r^2 - (r-h)^2}$$

with :
21 = distance between fenders (m)
r = bending radius of the bow (m)
h = height of the fender when the kinetic energy of the ship is absorbed (m).

The curved radius of the bow of the ship is calculated using the following formula:

$$\alpha_b = 10° : \log(r_{bow}) = -0{,}113 + 0{,}44\log(W_d)$$

Fender Loading Condition

Analysis of the reaction force of the fender is carried out on 2 berthing conditions as follows:

1. Berthing Angle 10^0

In this condition, the reaction force of the fender is analysed due to the berthing of the ship at maximum speed with a berthing angle (βb) = 10^0.

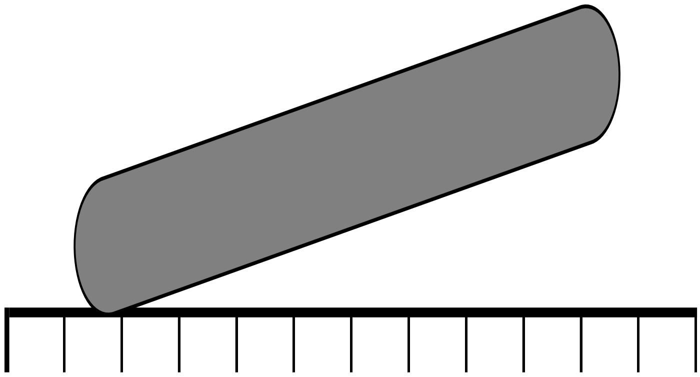

Figure 5. Berthing Condition βb = 100

2. Berthing Angle 0^0

In this condition, the reaction force of each fender is analysed when the ship is berthing with the maximum speed at the berthing angle (βb) = 0^0.

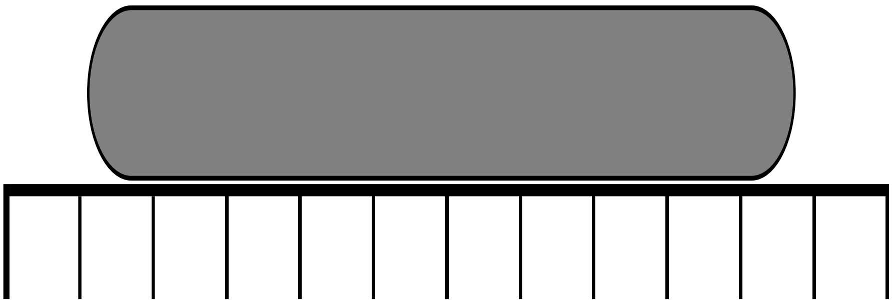

Figure 6. Berthing Condition βb = 0^0

METHODOLOGY

Basic Assumptions

The formulation of equations that relate measurable quantities with wave energy is based on the fundamental assumption that wave propagation on the sea surface occurs due to driving energy, which includes both kinetic and potential energy (Rahayu, 2000; Sorensen, 2006). Kinetic energy (Ek) refers to the circular motion of water molecules, while potential energy (Ep) results from the movement of waves above the sea surface. Potential energy is not concentrated at a single point, but rather distributed throughout all parts of the wave. The basic concept is that a fender absorbs the impact energy between the vessel and the dock and transfers it to the dock structure. The force is transmitted to the dock while the fender undergoes deflection ranging from 20% to 45%. According to Suyono and Hardi (2017), minor collisions between ships or between a ship and the dock wall are common, even when vessels are moored and have dropped anchor.

Some of the basic assumptions used by Rahayu (2000) are as follows:

1. The fluid or wave particles are homogeneous and incompressible, so mass density is considered constant.
2. Surface tension is neglected.
3. The Coriolis force, which arises due to Earth's rotation, is neglected.
4. The motion of water particles is assumed to be irrotational.
5. The seabed is assumed to be flat, fixed, and impermeable, so the vertical velocity at the bottom is zero.
6. The surface pressure is assumed to be uniform and constant.
7. The velocity of water particles is relatively smaller than the wave propagation speed.
8. The wave motion is cylindrical and perpendicular to the direction of wave propagation, making the wave two-dimensional.

Wave Height (H) Calculation

Wave formation in deep sea conditions is analyzed using empirical formulas derived from parametric models based on the JONSWAP (Joint North Sea Wave Project) wave spectrum (CERC, 1984). This forecasting method applies to both fetch-limited and duration-limited conditions. In fetch-limited conditions, the wind blows consistently over a sufficient distance for the wave height at the end of the fetch to reach equilibrium. In contrast, duration-limited conditions are when wave height is limited by the duration of wind activity. The significant wave height spectrum (H_0) and the spectral peak period (Tp) are considered.

Current measurements were carried out directly in the waters of Mandalle. Observations were conducted at two locations using a current meter or floater during both spring tide (highest tide) and neap tide (lowest tide) within the same month. If possible, current data are visualized through a current simulation application using computer software.

One method of wave forecasting involves processing wind data. Wave predictions based on historical meteorological conditions are known as hindcasting. The waves being forecasted are deep-sea waves generated by wind, which then propagate toward the coast and break as the water becomes shallower near the shore. The wave forecast results include significant wave height and period for each wind data point. The required data for wave prediction includes:

1. Wind data converted into wind stress factor (UA).
2. Effective fetch length.

To obtain the design wave characteristics, wave forecasting is conducted using long-term wind data. The applied method follows the procedures outlined in the Shore Protection Manual by the U.S. Army Corps of Engineers, 1984 edition.

Fender Impact Energy Calculation

When a ship approaches the dock, it makes contact with the dock structure. Collisions also occur while the ship is moored and engaged in loading and unloading operations. The force generated from the impact between the ship and the dock is referred to as the berthing force. The effective kinetic energy during berthing is calculated using the following formula:

This research was conducted in Pangkep Regency, South Sulawesi, with a focus on the coastal sub-districts that serve as key blue swimming crab centers: Ma'rang, Mandalle, Segeri, and Labakkang. A descriptive approach was used, and sampling was conducted through a non-probability technique (purposive sampling). Six fisher households engaged in crab-related activities were selected based on specific criteria.

Data collection methods included:

1. Direct observation of the activities and challenges faced by blue swimming crab fisher families.
2. Structured interviews using questionnaires to gather detailed information.
3. Literature review to examine relevant previous research findings.

The collected data were then selected and analyzed using the SWOT (Strengths, Weaknesses, Opportunities, Threats) method to develop appropriate business strategies. The analysis included identifying SWOT variables, formulating strategic alternatives, and selecting the most suitable strategies.

RESULTS AND DISCUSSION

A fender is a structure located along the edge of a dock or port designed to protect vessels from collisions or friction with the dock. The additional fender design for the educational dock at Politani aims to enhance protection and improve fender performance in accommodating larger vessels or addressing specific operational challenges.

The additional fender design must be based on an analysis of the specific needs of the particular port or dock, including the types of vessels typically moored, vessel dimensions, water conditions, as well as the available budget and resources. An appropriate design will help improve safety, reduce damage to both vessels and dock structures, and enhance operational efficiency at the port or dock. The following outlines the design process for the additional fender system.

Calculating Ship Impact Energy.

The ship used as a design ship is the KM 10 Politani Training Ship with the following image data:

Figure 7. Politani Training Ship

Politani Training Ship data is as follows:

Maximum ship length (LoA)	= 25 m
Ship width (B)	= 5.25 m
Draft full load (d)	= 1.5 m
Docking speed (V)	= 0.15 m / sec
Specific gravity of seawater (y)	= 1.024 t/m^3
Gross tonnage (GT)	= 60 tonnes
Length of waterline (lpp)	= 22.506 m

The data from this ship is then processed first before determining the fender to be used. The amount of ship impact energy against the dock fender is a parameter that needs to be taken into account. The stages of calculating the amount of ship impact energy are as follows:

1. Ship weight (W)

$$W = Cb \times Lpp \times B \times d \times y$$

$$= 0{,}634 \times 22{,}506 \times 5{,}25 \times 1{,}5 \times 1{,}024$$

$$= 115 \text{ tonnes}$$

A 60 GT vessel docked to the quay at an angle of 15° to the front of the quay, as shown in the figure below.

2. Ship Block Coefficient

Ship block coefficient (Cb)

$$Cb = \frac{Wa}{Lpp.\ B.\ d.\ \gamma}$$

$$= \frac{115}{22{,}506 \times 5{,}25 \times 1{,}5 \times 1{,}024}$$

$$= 0{,}634 \text{ m}$$

A fully loaded vessel docks at the quay at an angle of 15° to the front of the quay, as shown in the figure below:

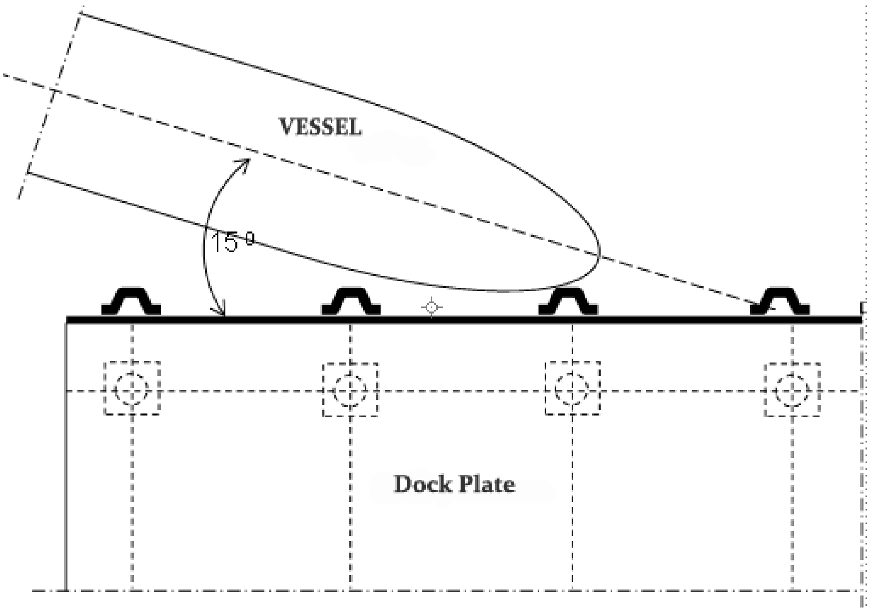

Figure 8. Vessel Position

3. The impact energy of the ship is determined based on the following equation:

$$E = \frac{wv^2}{2g}\ Ce\ Cm\ Cs\ Cc$$

Where:
Cm = mass mooring coefficient
Cm = taken 1.707 (processing can be seen in the appendix)
Cs = hardness coefficient, taken = 1.0
Cc = coefficient of the shape of the mooring. The movement of the ship docked to the dock, the water between the ship and the dock facilities creates a cushioning effect which results in the energy absorbed by the fender being reduced so that the impact factor of the berth (Cc) is smaller than one. However, for safety, a value of Cc = 1.0 is taken.
Ce = Eccentricity Coefficient
Ce = 0.459 but for safety factor taken = 1.0
From all these data, the impact energy is obtained as follows:

$$E = \frac{wv^2}{2g}\ Ce\ Cm\ Cs\ Cc$$

$$E = \frac{115{,}1\ x\ (0{,}15\ Sin\ 15)^2}{2\ x\ 9{,}81}\ 1{,}0\ x\ 1{,}701\ x\ 1{,}0\ x\ 1{,}0$$

E = 0,0151 tm
Energy absorption fender = 50% E = 0.008 tonnes

According to Hardi and Suyono (2017), the impact energy received by the fender from the impact of the ship is absorbed in the form of potential energy characterised by elastic deformation of the material. This elastic deformation is reversible or will return to its original position when the acting force is removed. When the force stops, the rubber will release energy back to the ship. If the impact is small enough, for example due to waves around the harbour or small ocean currents, this will not be a problem. The rebound energy received by the ship is quite small and has no harmful effect on the ship. However, under special conditions, such as human error leading to a collision between the ship and the dock, the energy absorbed by the fender is quite large. This energy will be returned to the ship, causing the ship to lose stability. The part of the ship that hits will suffer serious damage. The use of additional materials in the fender design that have both elastic and plastic deformation properties is expected to improve this condition.

4. From the impact energy, the Gajah Tunggal GT Super 88 N tyre fender was determined with the following data:

Elephant Single GT Super 88 N tyre
Capacity R = 1.4 tonnes
Energy E = 2.8 tonnes m
Contact Area = 0.15 m^2

Magnitude of force against impact

$$RF\ (Reactioan\ Force) = \frac{E}{Efender} x\ Capacity$$

$$RF\ (Reactioan\ Force) = \frac{0{,}015}{2{,}8} x\ 1{,}4 = 0{,}008$$

In each fender 2 tyres are installed as additional absorption so RF = 2 x 0.008 = 0.02 tonnes, then RF > Absorption Fender = 0.02 > 0.008 tonnes so it is declared Safe.

Based on data analysis, the use of Gajah Tunggal GT Super 88 N tyre fenders is able to reduce the impact of the Politani training ship and is quite safe to use because of its high elasticity.

Additional Fender Design Picture

In this fender design, the tyre fender will overlay the previous fender with a total of 2 fenders in each V fender. On each tyre will be planted with 4 pieces of stainless steel embedded in the dock cast. Here are the design drawings.

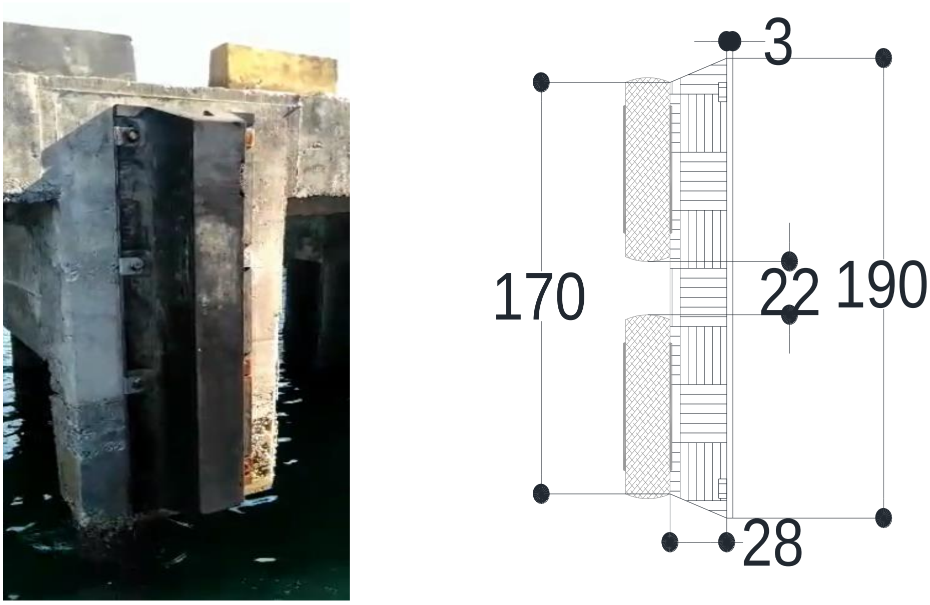

Figure 9. Additional Fender Design

CONCLUSION

Based on the results of the study, the following conclusions were drawn:

1. Ship impact energy E = 0.0151 tm, Energy absorption fender = 50% E = 0.008 tonnes. In each fender point installed 2 tyres, as an additional absorption force then RF (Reaction Force) = 2 x 0.008 = 0.02 tonnes, so RF > Absorption Fender = 0.02 > 0.008 tonnes, then declared Safe.
2. Based on data analysis, the use of Gajah Tunggal Tyre GT Super 88 N fenders is able to reduce the impact of the Politani training ship and is quite safe to use because the elasticity is quite high.

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