Analysis of Pier Type Requirements and Ship Mooring Facilities at Rowosari River Pier

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Rowosari Pier is located in Rowosari Subdistrict, Kendal Regency, Central Java Province. To present day, Rowosari Pier remains active as a river pier for community crossing activities around Rowosari Subdistrict to Batang Regency to fulfill their needs. However, the loading and unloading of passengers and vehicles to and from the ship does not take safety aspects into consideration, such as the lack of a bridge connecting the pier and the ship, which has the potential to cause accidents, and the type of pier that does not take into account the tidal conditions of the pier. Therefore, further analysis is needed to determine the type of pier and mooring facilities that are suitable for the conditions and can support safety aspects. The objectives of this study are: (1) to determine the required pier type; and (2) to determine the mooring facilities that support ship mooring activities at Rowosari Pier. The method of analyzing pier types and mooring facilities is based on tidal data and the LOA of ships operating at present day Rowosari Pier.

Based on the analysis results, the type of pier that is suitable for tidal conditions is a pontoon type with dimensions of 17.4 meters in length and 7.25 meters in width. The mooring facilities required are 15 FR2 cylinder-type fenders with a distance of 1.17 meters between fenders and 7 bolder units with a distance of 2.6 meters between bolder for ship mooring safety. Planning mooring facilities that are suitable for water conditions can support passenger safety when boarding and disembarking ships. In addition, the use of corrosion-resistant materials and familiarization with passenger and vehicle transportation procedures on ships can improve effective, efficient, and safe voyages.

Keywords: Pier, Pontoon, Fender, Bolder, Ferry transportation

1 Introduction

1.1 Background

The Rowosari River in Rowosari Subdistrict, Kendal Regency, Central Java Province plays an important role in the natural hydrological system that supports agricultural, fishery, and water transportation activities for the communities around the Rowosari River.
The existence of connecting bridges between villages in the Rowosari subdistrict, which are considered quite far apart, has led the community to choose river transportation as an effective and efficient means of mobility for fulfilling their daily

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needs, such as trade, social activities, education, and other activities, because it can cut travel time by 10 to 20 minutes compared to using land transportation.

A semi-permanent pier along the Rowosari River, known as the boat bridge, serves as a mooring facility for wooden boats that transport people, goods, and two-wheeled vehicles from the subdistrict center to villages in the Rowosari subdistrict.

Currently, the structure of the pier on the Rowosari River still uses bamboo as a facility for tying ship ropes and wooden structures as the pier floor, as shown at figure 1.1 below.

Figure 1.1 condition of the Rowosari-Yosorejo pier

The provision of effective, efficient, and safe transportation to support community mobility and regional development is one of the objectives and targets of the national transportation system, so the government needs to provide dock and ship berthing facilities that take into account safety and security factors.

Based on this, it is necessary to further analyze the need for dock types and ship berthing facilities at the Rowosari river dock.

1.2 Issue Problems

Based on the above background, the following problems can be formulated:

1. What type of pier is suitable for the current conditions of the Rowosari River?
2. What facilities are needed to support docking activities at the Rowosari River pier?

2 Literature Review and Theoretical Bases

Studies on the analysis of mooring facility requirements in the form of docks, fenders, and bolders in river transportation have been conducted by several researchers in the past. Therefore, the results of previous relevant studies can be used as a reference in the analysis in this study.

Nugraha.AR, et al (2013) conducted a study to determine the elevation and length of pier 136 at the mouth of the Mahakam River, Sanga-Sanga, East Kalimantan, using bathymetric mapping and tidal analysis. The analysis method used was quantitative statistics with modeling. The results of the analysis showed that the water depth at the mouth of the Mahakam River was between -1.3 and -8.6 meters with a mixed tidal type (prominent double type), tidal interval data of MSL 82 cm to 260 cm, MLWL (-28.60 cm), LLWL (-90 cm), and HHWL (+167 cm). Based on the tidal analysis, the pier floor height is designed to be +2.76 m with a Zo value of ± 0.00 m and +2.04 with MSL as the ± 0.00 m point, while the recommended pier length to serve one ship with an LOA of 95.70 m is 114.84 m. The maximum draft of the largest vessel that can safely berth at this design is 5 meters.

Sulistiyono.N, et al (2023) conducted a study on the evaluation of ship berthing facilities at the anchor crossing port in Situbondo Regency, East Java Province. Quantitative statistical analysis and observation methods were used to evaluate the existing berthing facilities. Based on the length of the pier, the magnitude of ship impact energy, and ship characteristics, eight KCEF 1000H fenders are required, with a distance of 12.8 meters between each fender. In addition, the distance between the bolders needs to be rearranged in accordance with the present day number of breathing dolphins.

2.1 Floting Peir

The jetty system is also known as a floating dock, which is generally used as a mooring facility for passenger ships at river or lake docks that do not require strong construction to withstand transport loads.

However, there are several requirements that must be considered when selecting a floating dock type. The requirements for fulfilling the function of a pontoon dock are as follows:

a. Have sufficient water depth to maneuver ships, which is a minimum of 1.20–1.30 times the maximum draft of a particular ship or a minimum of the ship's draft plus 0.5 m.
b. Have a dock floor height that is compatible with the ship's freeboard, generally the planned dock. The dock height is taken to be 0.3 to 1.0 m above mean high water level (MHWL) at a tidal range of less than 3 m.
c. The pier shall be constructed 0.5 m to 1.5 m above the average high water level at a tidal range of more than 3 m.
d. The length of the pier shall be in accordance with the overall length of the vessel (LOA) so that the vessel can be moored at an angle of 300 to 450 parallel to the pier.
e. The current must be calm so as not to interfere with the mooring process.
f. It must be able to withstand ship collisions.
g. There must be bollards/bolder for mooring ships.

2.1.1 Pier Dimension

The length of the pier for one mooring is equal to the length of the largest ship using that pier. However, if the pier is used to moor more than one ship, then the distance between ships is 10% times the length of the largest ship moored there. Usually, ships in a port vary in size, so the ship length used to determine the length of the pier is the average length (Triatmodjo, 2009). The calculation to determine the length of the pier uses the following equation 2.2.

$$L_p = nL_{Oa} + (n+1)x10\%\ x\ L_{oa} \qquad 2.1$$

Description:

L_p : Length of pier (m)
L_{Oa} : length overall(m)
n : Number of moored ships
According to Triadmodjo B. (2010), the width of a dock can be calculated by determining the width of the largest ship planned to dock at that location. The calculation to determine the width of a dock can be done using the following equation 2.2.

$$d = n\, x\, B + (n-1)xb + 2\, x\, a \qquad (2.3)$$

d : Dock width (m)
n : Number of moored ships
B : Width of the largest ship (m)
b : Safe distance between ships of0, 3 meters
a : Safe distance from the end of the dock to the ship of 0, 5 meters
The height of the dock floor or dock elevation is obtained by adding the planned water level elevation (DWL) and the guard height (0.5 - 1.5 m).
However, it can also be calculated based on the freeboard value of ships berthed at the pier and can be calculated using equation 2.3.

$$The\ height\ of\ the\ pier\ floor = \frac{\sum \quad Freeboard}{n} \qquad (2.4)$$

With:

$$n = number\ of\ ships$$

2.1.2 Trestle

a. Slope

The maximum slope (α) of the bridge is 20° to ensure passenger safety and prevent slipping when crossing the bridge. The length of the connecting bridge is calculated using equation 2.5.

$$PMB = \frac{Tinggi\ Trestel - (freeboard\ ponton + LLWL)}{sinsin\ \alpha} \qquad (2.5)$$

b. Trestle hight

The height of the trestle is determined based on the highest tide level at the dock location (Triatmodjo, 2009). The height of the trestle can be calculated using equation 2.6.

$$Trestle\ Hight = HHWL + Tinggi\ jagaan \qquad (2.6)$$

c. Trestle width

The width of the trestle must be adjusted to the amount of traffic on the trestle, with passenger conditions during passing serving as an indicator in determining the width of the trestle as described in the table bellow:

Table 1. Motorcycle Lane Width

User	lane width (m)	
	Local	Region
Motorcycle	3,50	2,25

The width of the pedestrian gangway may refer to the design of a non-level pedestrian bridge as stipulated in SE Dirjen Bina Marga No.18/SE/Db/2023 concerning the technical planning of pedestrian facilities, namely a minimum width of 2.0 meters with a ramp slope of 18% (1:12) equipped with handrails on both sides with a minimum height of 0.8 m from the floor surface.

d. Distance between the pontoon dock and the trestle

The calculation of the distance between the pier and the trestle must take into account the moving end of the bridge, so the calculation of the distance between the pier and the trestle is given by the following equation 2.7.

$$P + r = \frac{Tinggi\ trestle - (freeboard\ ponton + llwl)}{Tan\ 20°} \qquad (2.8)$$

With:

$$P = Length\ of\ the\ movable\ bridge\ (m)$$
$$r = Distance\ between\ the\ end\ of\ the\ movable\ bridge$$
$$and\ the\ end\ of\ the\ pontoon\ (m)$$

e. Trestle slope at tide

The slope angle of the trestle used as a gangway or flexible connector on a pontoon dock is based on the highest tide level. It can be calculated using equation 2.8.

$$sin\ sin\ \alpha\ = \frac{trestle\ hidht - (freeboard\ ponton + HHWL)}{movable\ bridge\ length} \qquad (2.8)$$

2.1.3 Fender

Fenders function as shock absorbers placed in front of the dock. Fenders absorb the energy of collisions between ships and docks and transfer the force to the dock structure. The force transferred to the dock depends on the type of fender and the allowable fender deflection. Fenders are generally divided into two types based on their construction material: wood and rubber. One of the most commonly used types of rubber fenders are V-shaped and cylindrical fenders. The shock absorption capacity of V-shaped and cylindrical fenders is shown in Tables 2 and 3.

Table 2. Damping Capacity of Type V Fenders

Type	Energy (Ton-Meter)	Reaction (Ton)	Deflection (mm)
300 H	2,25	22,5	135
400 H	4	30	180
500 H	6,25	37,5	225
600 H	9	45	270
800 H	16	60	360

Type	Energy (Ton-Meter)	Reaction (Ton)	Deflection (mm)
1000 H	25	75	450
1300 H	42,25	97,5	585

Tabel 3. Cylinder Type Fender Absorption Capacity

Code	outer diameter (mm)	Force (Ton)	Energy (Ton/mm)
FR 1	150	5	0,14
FR 2	200	7	0,27
FR 3	250	8	0,42
FR 4	300	10	0,61
FR 5	400	13	1
FR 6	500	16	1,6

The ship's mooring energy can be calculated using the formula in equation 2.9.

$$E = \frac{Wv}{2g}\ x\ C_m\ x\ C_c\ x\ C_s\ x\ C_e \qquad (2.9)$$

$with$:

$$E \quad = Berthing\ ener$$
$$Wv = \ Full\ load\ vessel\ weight$$
$$C_m \ = Mass\ coefficient$$
$$C_c = Hardness\ coefficient$$
$$C_s = Shape\ coefficient\ with\ a\ fixed\ value\ of\ 1.0$$
$$C_e = Eccentricity\ coefficient$$

2.1.4 Bollard

A bolder or bollard (corner mooring post) is a mooring facility at a dock used to secure a ship's ropes during loading and unloading activities or when other circumstances require the ship to dock at the pier.

Bollards that are typically used on small docks and floating docks are single or double bitt bollards, as shown in the image below.

Source: https://www.mpmperkasa.com/2023/01/distributor-bitt-bollard-di-tanah-laut.html

Figure 2.1. Singge Bitt Bollard

The distance between bolsters is calculated based on the overall length of the ship that will berth at the pier. In general, the distance between bolsters is calculated using equation 2.10.

Distance between bolders $= \frac{1}{3} x\ LOA$ (2.10)

With LOA = Length overall (m)

while the number of Bolder is based on the dimensions of the deramaga with calculations in equation 2.11.

$Number\ of\ Bolder = \frac{pier\ legth}{Distance\ between\ bolders}$ (2.11)

3 Research Methods

3.1 Research Design

Time and Location of Research

The research was conducted over a period of four months, from April to August 2025, at the Rowosari-Yosorejo Boat Bridge Pier, Rowosai District, Kendal Regency, Central Java Province.

3.2 Data Collection Techniques

Primary data sources are obtained directly in the field through measurement surveys and observations. Primary data consists of:

1) Tidal data for 5 days;
2) Average ship length data;
3) Data on the number of vehicles and ship passengers for 30 days;
4) Ship speed data;
5) Data on the depth of the riverbed in front of the pier.

While, Secondary data is obtained by institutional methods, the data obtained include:

1) Tidal data for the Rowosari River over 30 days;
2) Annual passenger productivity data;
3) Kendal district population data;
4) And ship characteristic data.

3.3 Data Analysis Techniques

Analysis of Pier Type.

The determination of the dock type is based on the tidal range value at the Rowosari dock location, using the following equation 3.1.

TP = HHWL – LLWL (3.1)

Explanation

TP : High Water Level

HHWL : Highest water level in a year

LLWL : Lowest water level in a year

According to Kramadibrata (2002), the selection of pier type can be determined based on tidal range with the following values:

TP < 0.75 m = fixed pier type
TP > 0.75 m = non-fixed pier type

Analysis of Analysis of Berthing Facility Requirements at the Pier.
The analysis of berthing facility requirements, such as pier dimensions, number and distance between fenders, and number and distance between boulders, is calculated using the equations described in the theoretical basis above.

4 Analysis and Discussion

4.1 Data Presentation

Existing Conditions of the Pier
Rowosari River Pier is located in Sari baru Village, Rowosari District, Kendal Regency, Central Java Province, precisely at coordinates 6°54'12“ S 110°02'47” E. Based on the Kendal Regency transportation network map, this pier connects Rowosari Subdistrict in Kendal Regency with Yosorejo Subdistrict in Batang Regency and serves as an alternative river crossing in the area. Traveling by boat across this bridge cuts travel time by 15-20 minutes compared to the land route via the nearest bridge. The location of the pier is shown in Figure 4.1.

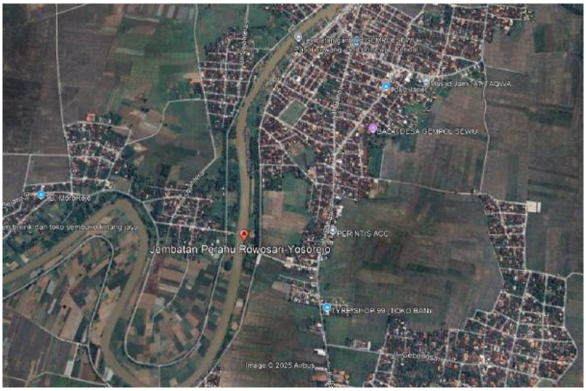

Figure 4.1 Rowosari-Yosorejo Pier Location

There are two wooden boats or ships serving the Rowosari-Yoserejo route, as shown in Figure 4.2.

Figure 4.2 Ferry transportation in Rowosari pier

Based on ship measurements and characteristic data in the ship's PAS letter, the sizes of boats operating at the dock are as shown in Table 4.1.

Table 4.1. Ferry Boats Dimension

No.	Boats's Name	Size					Bahan	Penggerak
		LOA (m)	B (m)	D (m)	d (m)	f (m)		
1	Sumber Rijki	7,80	2,96	1,00	0,25	0,75	Kayu	Galah
2	Mili Mintir	6,70	2,90	1,10	0,25	0,85	Kayu	Galah

The ferry at the Rowosari-Yososeno pier operates daily from 5:00 a.m. to 8:00 p.m. with 30 to 40 departures per day, depending on demand, and a maximum capacity of 10 two-wheeled vehicles (motorcycles).

Rowosari River Tidal Data

The tidal data for the Rowosari River over a 30-day period measured in April 2025. The constants obtained from tidal data analysis are used to determine the Mean Sea Level (MSL), Highest HighWater Level (HHWL), and Lowest Low Water Level (LLWL). In addition, the constants can also determine the form number (F) to identify the type of tides at the research location. The tidal analysis data are presented in Table 4.2 below.

Table 4.2. Tidal Analysis Data

HHWL	LLWL	MSL
1,1	0.2	0.6

Boats Berthing Speed Data

A survey of vessel velocity at berthing was conducted to determine the type of fender that is suitable for the characteristics of vessels on the Rowosari River. Speed was measured when the vessel was approximately 10 meters away from the berthing location. The measurement results are shown in Table 4.3.

Table 4.3. Ship Berthing Velocity

No	Boats's Name	Time (second)	Distances (meter)	Velocity (m/s)	Average (m/s)
1	Sumber Rejeki	24,31	10	0,41	0,41 m/s
2	Mili Mintir	24,04	10	0,42	

Pier Pool Depth Data

The depth of the pier pool was measured manually due to the limitations of the echo sounder. Measurements were taken using a weighted tape measure to determine the depth of the dock basin every 5 (five) meters from the starting point to the end, 25 meters from the dock. The data from the dock basin depth measurements are shown in Table 4.4 and visualized in Figure 4.3.

Table 4.4. Pier Pool Depth Data

No	Measurement Point	Measuring Distance	Depth
1	T1	5 meters	1,53 meters
2	T2	10 meters	1,86 meters
3	T3	15 meters	2,14 meters
4	T4	20 meters	2,72 meters
5	T5	25 meters	3,12 meters

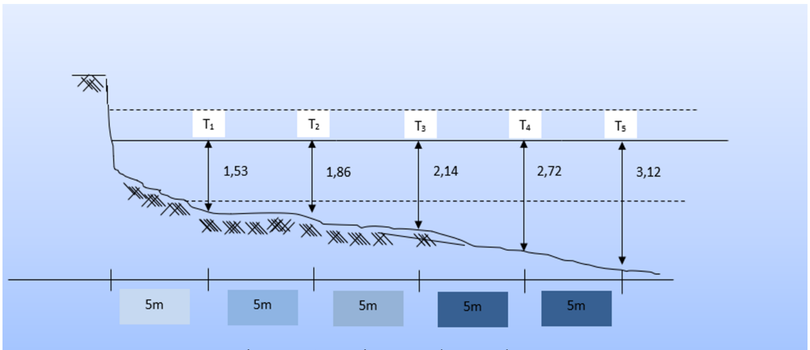

Figure 4.3 Pier Pool Depth Data

4.2 Data analysis

Pier Type Analysis

The type of pier is based on the tidal range at the pier location. Based on tidal data, the tidal range can be calculated as follows:

Tidal Range = HHWL-LLWL
= 1.10-0.20 = 0.9 meters
According to Kramadibrata (2002), the selection of pier type can be determined based on tidal range with the following values:
TP < 0.75 m = fixed pier type
TP > 0.75 m = non-fixed pier type
Based on the analysis results, the tidal range is 0.9 meters, so it is recommended that the appropriate type of pier is a non-permanent or flexible pier that can adjust to fluctuations in river water levels. In addition, based on the type of transportation served at the Rowosari pier, namely motorcycles, there is no need for a pier with a structure that is stronger against transportation loads.

Analysis Analysis of Berthing Facility Requirements

1) Pier dimensions.
   Based on the calculation of the pier dimensions, it was found that the pier is 9.36 meters long, 4.26 meters wide, and has a floor elevation of 0.8 meters.
2) The depth of the pool, can be calculated as follows:
   h = (0,8 s/d 1 m) + *draft max* = 1 + 0, 25 = 1,25 meters
   This is illustrated in Figures 4 and 5 below.

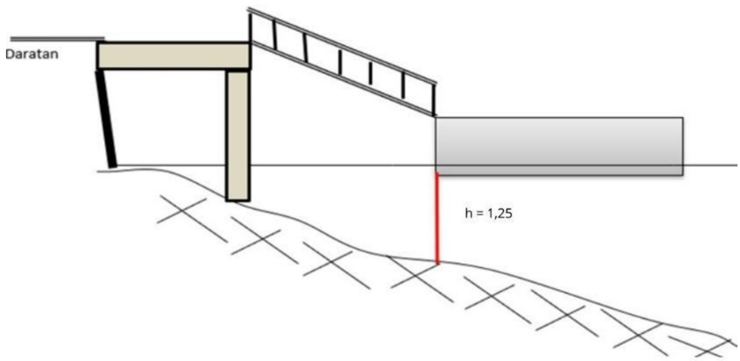

Figure 4.4 The Depth of The Pool In Pier Location

3) Need for a connecting bridge (trestle)

In determining the height of the trestle, the HHWL of the Rowosari River must be known. Based on data obtained from the Central Java Class I BPTD, HHWL data for 15 days was obtained, which was 1.1 meters, where the average peak height of the Rowosari River average height over 15 days in April was 0.6 meters with a guard height of 1 meter (0-1.5). Therefore, the trestle height can be calculated as follows:
Trestle hight = HHWL + Tinggi jagaan = 1, 1 + 1 = 2,1 meters

An illustration of the trestle height is shown in Figure 4.5.

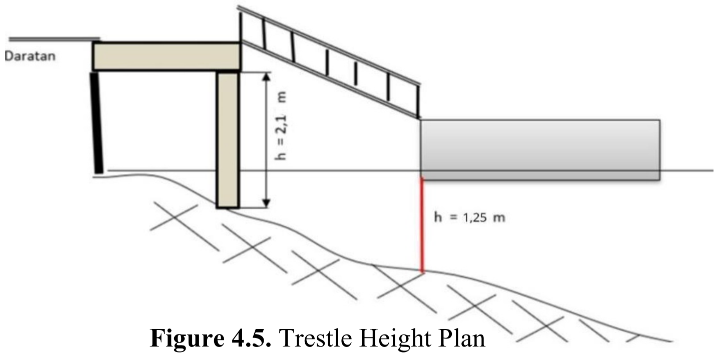

Figure 4.5. Trestle Height Plan

Trestle width. Based on observations, the type of vehicle used by passengers is a motorcycle with a standard width of 0.7-0.9 meters, but some vehicles are equipped with baskets on the left and right sides. To ensure that traffic on the connecting bridge remains comfortable, the width of the trestle is planned to be 3.0 meters.

Length of Moving Bridge. A flexible connecting bridge is needed at the floating dock to connect the road to the dock. The bridge has a slope of 20° to ensure passenger comfort in vehicles. Therefore, the length of the movable bridge can be calculated as follows:

$$Length\ MB = \frac{h_{trestle} - (Freeboard + LLWL)}{sinsin\ \alpha}$$

$$Length\ MB = \frac{2{,}1\ m - (0{,}8 + 0{,}2)}{sinsin\ 20°} = \frac{2{,}1 - 1{,}0}{0{,}342} = 3{,}21\ m$$

Length of the movable bridge = 3.21 meters

Illustration The length of the movable bridge is shown in Figure 4.6.

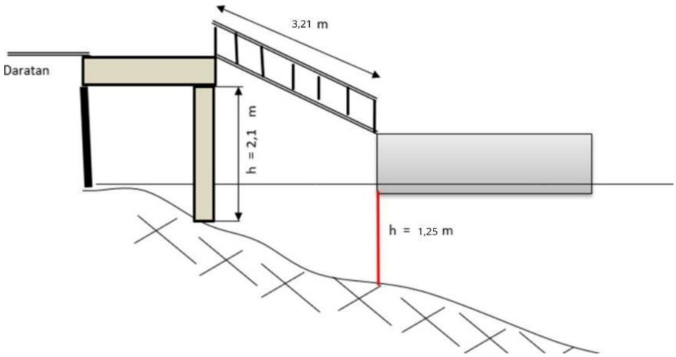

Figure 4.6. The Length of The Movable Bridge

Distance between the pontoon dock and the trestle. The calculation of the distance between the pier and the trestle must take into account the moving end of the bridge. Assuming that the moving end of the bridge is located above the pontoon at a distance of 0.5 meters from the edge of the pontoon pier, the distance between the pier and the trestle is as follows:

$$P + r = \frac{h_{trestle} - (Freeboard + LLWL)}{Tan\ 20°}$$
$$P + 0{,}5 = \frac{2{,}1 - (0{,}8 + 0{,}2)}{0{,}364}1$$
$$P + 0{,}5 = \frac{1{,}1}{0{,}364}$$
$$P = 3{,}02 - 0{,}5 = 2{,}52\ meter$$

An illustration of the distance between the pontoon and the trestle is shown in Figure 4.7.

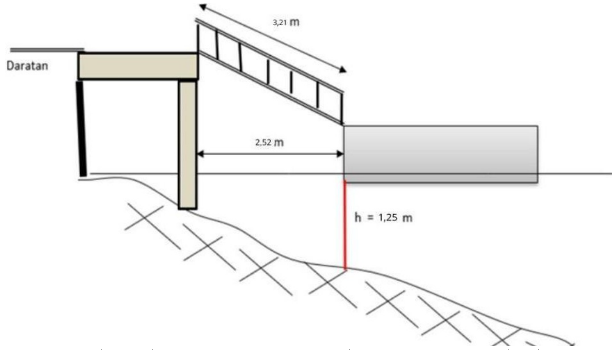

Figure 4.7 The Distance Between The Pontoon and The Trestle

The slope angle of the movable bridge during high tide. The slope angle of the movable bridge during high tide can be determined by the following calculation:

$$sin\ \alpha = \frac{h_{trestle} - (freeboard\ ponton + HHWL)}{movable\ birdge\ length}$$

$$sin\ \alpha = \frac{2{,}1 - (0{,}8 + 1{,}1)}{3{,}21} = \frac{0{,}2}{3{,}21} = 0{,}062$$
$$sin\ \alpha = 0{,}062$$
$$\alpha = 3{,}6°$$

An illustration of the slope of the movable bridge during high tide is shown in Figure 4.8.

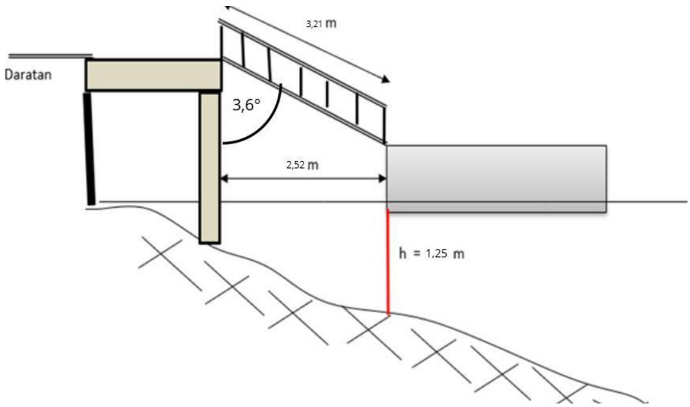

Figure 4.8 Slope of The Movable Bridge During High Tide

4) Fender Anaysis

All components are known, so the boats's berthing energy can be calculated using the following formula:

$$E = \frac{WV}{2g}\ x\ C_m\ x\ C_c\ x\ C_s\ x\ C_e$$
$$E = \frac{42{,}98\ x\ 0{,}41}{2\ x\ 9{,}8}\ x\ 1{,}09\ x\ 1{,}0\ x\ 1{,}0\ x\ 0{,}48 = \frac{17{,}58}{19{,}6}\ x\ 0{,}52$$
$$E = 0{,}466\ Ton/m$$

Based on the ship's berth energy value of 0.466 tons/m, it is recommended to use a cylinder-type fender with code FR 3 and an outer diameter of 25 cm, with an energy absorption capacity of 0.42 tons/m.
The berth type is planned according to present day conditions, which are parallel to the pier or the extended berth type. Therefore, the distance between fenders can be calculated as follows:
Distance between Fender = 0, 15 x LOA = 0, 15 x 7,8 = 1,17 meters
The number of fenders required can be calculated using the following formula:

$$Number\ of\ Fender = \frac{Pier\ Length}{distance\ between\ fender} = \frac{9{,}36}{1{,}17} = 8\ (units)$$

Based on the analysis results, the Fender requirements at Rowosari Pier are 8 units of Type FR 3 Cylinder Fenders (Show figure 4.9) with a distance of 1.17 meters between each Fender.

5) Bollard Analysis
Based on the type of berth, which is either longitudinal or parallel to the dock, the distance between boulders is calculated as follows:

$$Distance\ between\ bollard = \frac{1}{3}\ x\ Loa$$
$$Jarak\ antar\ bolder = \frac{1}{3}\ x\ 7{,}8\ m = 2{,}6\ m$$

The number of Bolder is calculated using the following formula and illustrated in figure 4.9:

$$Number\ of\ bolder = \frac{pier\ length}{distance\ between\ Bolder} = \frac{9{,}36}{2{,}6} = 3{,}6\ \approx 4\ Units$$

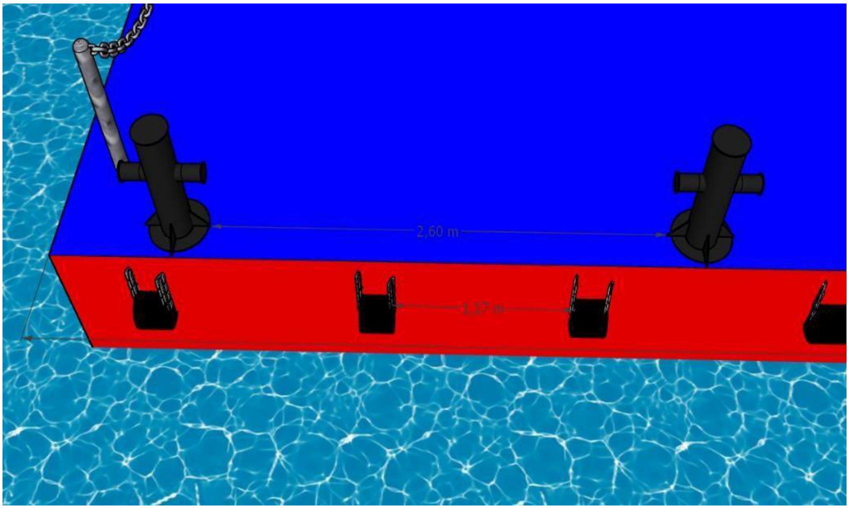

Figure 4.9 Plan of Bollard Number and Distance Between In Pier

5 Closing

5.1 Conclusion

Based on the results of the analysis, the following conclusions can be concluded:

1) The type of pier required based on the tidal range at Rowosari Pier is a non-permanent pier or floating pier (pontoon).
2) Supporting facilities required for ship berthing include a pier measuring 9.36 meters long, 4.26 meters wide, and with a floor elevation of 0.8 meters. The connecting bridge (trestle) is 2.1 meters high, and the distance between the dock and the trestle is 2.52 meters. The length of the movable bridge is 3.21 meters with a maximum slope of 20° and a slope of 3.6° at high tide, and the width of the trestle is 3.0 meters. In addition, FR 3 type fenders are required as impact energy absorbers with an energy capacity of 0.42 tons/m, with a total of 8 units and a distance between fenders of 1.17 meters. For mooring facilities, 4 units of single bitt bollards or cross bollards are required, with a distance between bollards of 2.6 meters.

5.2 Advices

Based on the frequency of ship departures and arrivals and the load factor value of the ships, which indicate that the ferry service is very active and much needed by the community around the Rowosari subdistrict, the following suggestions are offered:

1) Rejuvenation and modernization of ferry transportation facilities by converting manual propulsion systems to engine propulsion systems;
2) Socialization of shipping safety by providing safety equipment on board boats;
3) Modernization of the pier with improved structures and berthing facilities, including the installation of warning signs, directional signs, and prohibition signs around the pier to support more orderly traffic.

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