GROSTLOG 2024
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

# Evaluation of Existing Coal Unloading Jetty Capacity Due to Increased Coal Vessel Size for Pacitan Coal Fired-Steam Power Plant

**Muhamad Kemal Idris[a], Maria Angelin Naiborhu[b], Diana Choerunniza[c], Benedicta P. Pelealu[d],**
[a,b,c,d] Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia
*Corresponding author: idriskemal1@gmail.com*

**Abstract**: In 2018, the breakwater at Sudimoro Coal Fired-Steam Power Plant (CFSPP) was severely damaged, allowing wave directly penetrate inside the harbor basin area. The harbor and coal unloading jetty structure of the CFSPP was designed to serve 27,000 Dead Weight Tonnage (DWT) dry bulk carriers, with maximum allowed wave height of 1.0 m. However, due to the breakwater damage, the wave height inside the harbor basin area, has increased to 1.5-2.0 m. It may risk the vessel and jetty structure during the berthing and unloading process as the vessel motions were larger than allowed in the initial design. To address this issue, increasing the vessel's capacity to 40,000 DWT was considered, with the expectation that the larger vessel would withstand higher waves. Vessel size increasement have to be evaluated against the existing harbor infrastructures, such as the capacity of existing coal unloading jetty structure, turning basin radius and depth. This study aims to evaluate the feasibility of the existing harbor jetty and harbor basin at the Sudimoro CFSPP to accomodate larger vessels. Bollards and fenders upgrades were required. However, the major key is in the existing pile capacity of the existing coal unloading jetty structure, as the results indicate that the current pile capacity of coal unloading jetty structure cannot support the 680,1484-ton axial load from a 40,000 DWT ship, as it exceeds the allowable bearing capacity.
**Keywords:** *bollard, coal unloading jetty, structural evaluation*

## 1 Introduction

The Sudimoro CFSPP in Pacitan, East Java, is one such critical infrastructure facility that relies heavily on its coal unloading jetty for the coal supply as the main fuel of the plant. The CFSPP was operated since 2014 and has its own harbor facilities for coal unloading jetty and is located at the coast of South Java Seas, which has a harsh wave climate. The coal unloading jetty was originally designed to accommodate bulk carrier ships with a capacity of 27,000 DWT and protected by breakwater as shown in Figure 1.a to keep wave heights within the harbor basin to a maximum of 1.0 m. However, significant damage to the breakwater in 2018 (see Figure 1.b) destabilized the berthing area, making it unsafe for berthing and unloading process as the wave height inside the basin has increased to 1.5-2.0 m. Such condition has led to considerations for increasing the vessel’s capacity to 40,000 DWT to ensure smooth coal unloading process while the breakwater is repaired.

This paper aims to evaluate the structural integrity of the existing jetty at Sudimoro in response to new operational demands, particularly the increased vessel capacity and higher wave conditions. The evaluation focuses on the strength of the jetty’s pile foundation, the adequacy of the fender and bollard systems, and the necessary modifications to the depth and radius of existing turning basin. The findings from this study are expected to provide insights into the required structural upgrades to ensure the continued functionality and safety of the jetty.

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

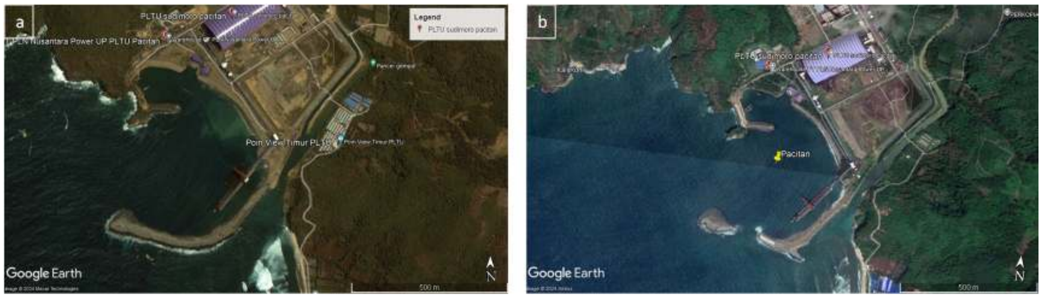


**Figure 1. The Condition of the Breakwater Before Damage (a), The Condition of Damaged Breakwater (b)**
*Source : Google Earth, 2024*

## 2 Literature review

According to Triatmodjo (2010), waves play a significant role in the design of harbor structures, as it can impose horizontal forces on vessels and associated infrastructure, affecting vessel stability during loading and unloading operations. It is important to limit the wave height inside the harbor basin.

Some jetties are constructed as open structures, extend into the sea to provide sufficient water depth for berthing vessels. The integrity of these structures depends on the strength of their pile foundations, which must support the loads imposed by berthed vessels (OCDI, 2002). Breakwaters are often employed to protect berthing areas from wave action, as highlighted by Kramadibrata (2002), but damage to these protective structures can significantly destabilize the berthing area, as seen in the case of the Sudimoro, Pacitan CFSPP jetty.

In maritime engineering, the capacity of fenders and bollards is critical for absorbing the kinetic energy of berthing vessels and securing them during operations. PIANC (2002) provides guidelines for the design of fender systems, emphasizing the need to match fender capacity with the vessel's displacement to prevent structural damage during berthing. Similarly, bollards, which secure the vessel to the jetty, must be capable of withstanding forces from both the vessel and environmental conditions such as wind and current (British Standard 6349: Part 1, 2000).

The current study was conducted by applying these principles to evaluate the capacity of the existing Sudimoro CFSPP' coal unloading jetty. The evaluation considers the limit of pile foundation bearing capacity, existing fender capacity and bollard systems, and modifying the berthing area to accommodate larger vessels.

## 3 Research Method

### *3.1 Data Collection*

a. Secondary Data
The study primarily utilizes secondary data, including existing jetty design specifications, soil data from Standard Penetration Tests (SPT), and environmental data related to wave heights and maritime conditions at the Sudimoro, Pacitan power plant site.

b. Design Parameters
Vessel parameters, such as the deadweight tonnage (DWT), length overall (LOA), beam, and draft, are obtained to simulate the impact on the jetty structure. There are two different vessels were used are 27,000 DWT vessel (existing) and 40,000 DWT vessel (proposed).

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

*3.2 Wave Condition*

According to ECMWF, the average wave height based on 10 years of measurement data from 2014 to 2023 of significant high, mean wave, and swell in the Southern part of the Java Seas, particularly in the Pacitan area, shows that the deep-sea wave height is 3.681 m. Figure 2.a shows the coordinate location of the data in ECMWF.The frequency of wave heights and wave speeds in various directions are shown in Figure 2.b, with 71.9% coming from the Southwest direction at the deep-sea location coordinates indicated at the ECMWF coordinates point (8.5 Southern latitude and 111.5 Eastern longitude).

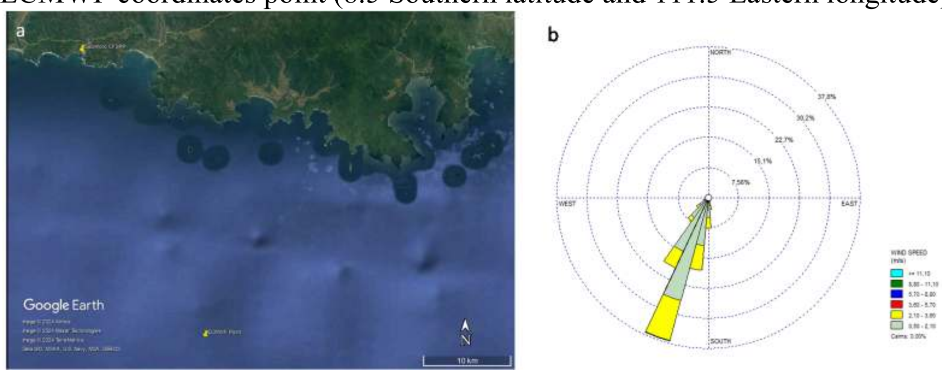


**Figure 2. ECMWF Data Location (a), Wave Rose (b)**
*Source: researcher analysis and Google Earth, 2024*

*3.3 Structural Modelling*

a. Modelling Software

The jetty structure as shown in Figure 3 was analysed using SAP2000, a structural analysis software, to simulate the loading conditions imposed by the larger vessel capacity. The model includes the jetty's pile foundations, the fender system, and the bollard capacity.

b. Load Analysis

Various loads, such as axial loads, lateral loads from berthing forces, mooring forces, and seismic forces, are applied to assess the structural performance of the jetty. The analysis considers both static and dynamic loading scenarios. Loads combinations used for the SAP2000 analysis based on Unified Facilities Criteria (UFC), Design: Piers and Wharves 2012. The load combinations are presented in Table 1 as follows:

**Table 1** Loads Combination

| Vacant Condition | |
|---|---|
| Combination 1 | 1,4 DL |
| Combination 2 | 1,2 DL + 1,6 LL |
| Combination 3 | 1,2 DL + 0,5 LL + EQ |
| Combination 4 | 1,2 DL + 1,0 LL +1,6 W |
| Combination 5 | 1,2 DL + 1,0 LL + 1,6 C |
| Combination 6 | 1,2 DL + 1,0 LL + 1,6 A |
| Berthing Condition | |
| Combination 7 | 1,2 DL + 1,6 LL + 1,6 B |
| Combination 8 | 1,2 DL + 1,0 LL + 1,0 B + 1,0 EQ |
| Combination 9 | 1,2 DL + 1,0 LL + 1,0 B + 1,6 W |

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

| | |
|---|---|
| Combination 10 | 1,2 DL + 1,0 LL + 1,0 B + 1,6 C |
| Combination 11 | 1,2 DL + 1,0 LL + 1,0 B + 1,6 A |
| Mooring Condition | |
| Combination 12 | 1,2 DL + 1,6 LL + 1,6 M |
| Combination 13 | 1,2 DL + 1,0 LL + 1,0 M + 1,0 EQ |
| Combination 14 | 1,2 DL + 1,0 LL + 1,0 M + 1,6 W |
| Combination 15 | 1,2 DL + 1,0 LL + 1,0 M + 1,6 C |
| Combination 16 | 1,2 DL + 1,0 LL + 1,0 M + 1,6 A |

where:
DL = Dead load
LL = Live load
EQ = Earthquake load
W = Wave load
C = Current load
A = Wind Load
B = Berthing Load
M = Mooring load

### 3.4 *Evaluation Criteria*

a. Pile Foundation Strength

The axial bearing capacities of the jetty's pile foundations is evaluated and compared with the increased loads from the 40,000 DWT vessel. The bearing capacity is determined using the Meyerhof method, considering the soil conditions and pile dimensions. The longitudinal section of the jetty structure is shown in Figure 3.

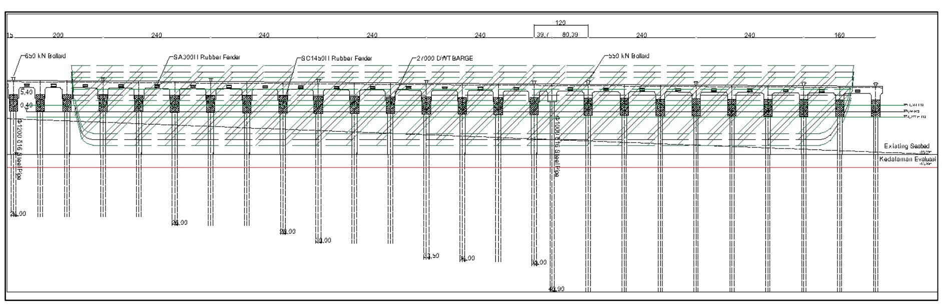

**Figure 3. Longitudinal Section of Jetty Structure**

*Source: researcher analysis, 2024*

b. Fender and Bollard Capacity

The fender system's energy absorption capacity and the bollard's load-bearing capacity are assessed based on PIANC (2002) and British Standard 6349 part 1-4 (2000) guidelines. The necessary upgrades to accommodate the larger vessel were identified.

### 3.5 *Berthing Area Modification*

The depth of the berthing area and the turning basin radius are evaluated to ensure they meet the requirements of the larger vessel. The study considers dredging as a potential solution.

### 3.6 *Data Analysis*

The simulation results from SAP2000 were analysed to determine the structural

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

adequacy of the existing jetty. The findings were used to identify any necessary reinforcements or modifications to the jetty structure.

## 4 Results and Discussion

Table 2 shows the summary results for jetty evaluation, which are further explained in the sub-sections below.

**Tabel 2** Summary Result for Jetty Evaluation Using 40,000 DWT

| | Parameters | Evaluation | Existing | Unit |
|---|---|---|---|---|
| **Pile, diameter 1000 mm** | End bearing capacity | 557.35 | | ton |
| | Ultimate bearing capacity | 601.92 | - | ton |
| | Allowable bearing capacity | 401.28 | | ton |
| **Pile, diameter 1200 mm** | End bearing capacity | 802.58 | | ton |
| | Ultimate bearing capacity | 856.07 | - | ton |
| | Allowable bearing capacity | 570.71 | | ton |
| | Bollard capacity | 80 | 55 | ton |
| | Fender capacity | 801 | 596 | ton |
| | Depth of berthing area and turning basin, from LWS | 13.28 | 10.40 | m |
| | Width of outer channel | 148.25 | 133.82 | m |
| | Turning basin radius | 390 | 350 | m |
| | Wave height | 1.83 | 1.50 | m |

### *4.1 Wave Height*

The wave height analysis at the existing location was conducted using significant wave height data from ECMWF, based on a 10 years wave data record from 2014 to 2023. The analyzed wave height at the Jetty 2 location (see Figure 4) with the coordinate of 8.26 Southern latitude and 111.37 Eastern longitude, is found to be 1.83 m, which exceeds the initial design for maximum allowable wave height inside the harbor basin. The model did not account for wave intrusion into the harbor basin as a result of the breakwater damaged. The wave model based on the latest data shows that even without breakwater damaged, the wave height inside the harbor basin has increased compared to the initial design. This condition may impact the stability of berthing vessels and disrupt coal unloading process.


**Figure 4. Wave Point Model Observation**
*Source: Google Earth, 2024*

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/altr

The following Table 3 presents the analysis of maximum wave heights conducted at each coordinate point using reanalysis data of significant high, mean wave, and swell from ECMWF.

**Tabel 3** Summary of Maximum Wave Height

| Location | Max. Wave Height | Unit |
|---|---|---|
| Jetty 1 | 1.58599 | m |
| Jetty 2 | 1.83163 | m |
| Jetty 3 | 1.74863 | m |
| BW 3 | 6.39712 | m |
| BW 4 | 5.87686 | m |
| BW 5 | 5.8824 | m |

*4.2 Structural Evaluation of the Jetty*

The structural analysis conducted using SAP2000 reveals that the existing jetty at Sudimoro, Pacitan CFSPP is not adequately designed to support the increased load from a 40,000 DWT vessel. The axial load generated by this larger vessel is calculated to be 680.1484 tons, which exceeds the allowable bearing capacity of the current pile foundation. This indicates a significant risk of structural failure under the proposed operational conditions.

*4.3 Fender and Bollard Capacity*

The existing fender system is designed for maximum energy absorption of 27,000 DWT vessels. To accommodate larger 40,000 DWT vessels, the fender system will have to be upgraded to model SC1600 with an energy absorption capacity of 801 kN/m. In addition, the bollards, which are critical to securing the vessel when berthing, should be upgraded from the current capacity of 55 tonnes to 80 tonnes to ensure that they can withstand the greater force exerted by the larger vessel.

*4.4 Depth of Berthing Area and Turning Basin*

The current depth of the berthing area and the turning basin at Sudimoro, Pacitan CFSPP are insufficient for safely accommodating the 40,000 DWT vessel. The study indicates that the berthing area requires dredging to a depth of -13,28 m LWS to provide the necessary clearance. Based on the evaluation of the turning basin, the existing turning basin is not suitable for the maneuvering of 40,000 DWT vessels. A turning basin diameter of 390 m is required, however as the existing water area is limited by the breakwater, hence it is not possible to enlarge the turning basin. To address this issue, a 40,000 DWT vessel will require pilot vessels for berthing assistance.

*4.5 Channel Width*

The width of the shipping channel required for 40,000 DWT vessels based on the evaluation results is 148,25 m. Therefore, the width of the shipping channel at the existing location is not sufficient for 40,000 DWT vessels.

*4.6 Impact of Environmental Conditions*

The study also considers the impact of environmental conditions, such as wave height and current, on the stability of the jetty and the mooring forces. The high wave activity in the region, especially following the damage to the breakwater in 2018, effected the vessel instability at the berthing area. This underscores the need for breakwater repairs to maintain the stability of the berthing area.

## 5 Conclusion

Based on the evaluation of pile foundation strength, the feasibility of the fender and bollard systems, the calculated radius of turning basin area, the width of the navigation channel, and the depth of the berthing area towards the increase in vessel capacity to 40,000 DWT, and the significant increase wave height at the Pacitan CFSPP, it can be concluded that the piles are inadequate to serve a 40,000 DWT vessel as the axial forces exerted by the vessel exceeds the allowable axial bearing capacity of the piles.

Modifications to the fender and bollard capacities must be made according to the recommendations shown in the Table 2. Additionally, dredging to a depth of -13.28 m LLWS for the berthing area is required to accommodate and ensure the 40,000 DWT vessel can safely berth at the jetty.

In term of wave condition, the latest wave data resulting higher wave condition within wave basin compared to the initial design.

## 6 Implications

The findings of this study have important implications for the operational efficiency and safety of the Sudimoro CFSPP and similar coastal infrastructure. The inability of the existing jetty to accommodate larger vessels without structural modifications highlights the critical need for ongoing assessments of marine infrastructure, particularly in regions with high wave activity and changing environmental conditions.

## 7 References

British Standard (BS) 6349-1: Maritime structures - Part 1: Code of practice for general criteria, 2000

British Standard (BS) 6349-4: Maritime structures - Part 4: Code of practice for design of fendering and mooring systems, (1994).

PIANC. *Guidelines for the Design of Fender Systems*. MarCom Report of WG33, 2002.

Soedjono Kramadibrata. *Perencanaan Pelabuhan*. Jl. Ganesa 10 Bandung, Institut Teknologi Bandung, 2002.

Technical Standards For Port and Harbour Facilities in Japan 1980. Japan. Bureau of Ports and Harbours, Ministry of Transport, 1980

Triatmodjo, B. Perencanaan Pelabuhan. Beta Offset Yogyakarta, 2010

Unified Facilities Criteria (UFC) Design: Piers And Wharves Approved For Public Release; Distribution Unlimited *550587* Sdms Doc Id 550587, 2005.