



Assessment of Wave Tranquility on The Breakwater Design Consideration at Pangandaran Port

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Abstract. Wave tranquility is a study that analyzes how a wave may propagate in specific locations. This study is intended to determine a location categorized as calm with a limit of wave height that occurs due to wave propagation around the location. Pangandaran Port is a place that was made to increase the potential of the Pangandaran district area. A problem in Pangandaran Port is the high wave occurrence around the location. That is caused by Pangandaran Port, located in southern Indonesia. That condition can disturb the tranquility of the basin. To keep the tranquility of the basin, a plan to solve this problem has been proposed, which is to build a breakwater that may calm the waves around the location. The study used a numeric model to transform a wave with MIKE 21 software to determine the wave condition in the basin. The study compared the condition of waves in the basin before and after the breakwater installation. The primary purpose of this study is to evaluate wave tranquility in the basin. It is becoming a reference to predict the number of days that ships could operate, and this study was done to know how optimal the breakwater keeps the wave tranquility.

Keywords: Breakwater, Wave Height, Wave Tranquility.

1 Introduction

One of the efforts in the transportation planning to support the transportation system is constructing the harbor facilities. The harbor is a place along a coast where ships or boats can take shelter if the atmospheric conditions are unsuitable for sailing [1]. In contrast, the port can be understood as a place where ships and boats are loading and

unloading. The harbor facilities' design should be considered safe at the operational time [2]. The safety of the harbor might be, in many ways, a view according to the parameters of the environment. Considering the environment's parameters, the harbor's layout must be a safe way to maintain wave tranquility [3-6]. Wave tranquility in a harbor plays an essential role in port operations, such as ship motion and cargo handling [7, 8]. Hence, the fundamental task is to establish the calculation of wave transformation from outside harbor into inner harbor berth locations.

In recent years, the effort of calculating wave transformation has been done in two general ways: physical and numerical models. Both ways are completing each other to find good and realistic results for predicting wave transformation. In engineering practice and design, having quick results of the wave transformation calculation seems to be one requirement for justifying the harbor's layout. The calculation results' speed information can help the decision maker of harbor design and construction to produce faster decisions. Therefore, numerical modelling is an efficient tool for determining the port condition based on optimizing the harbor layout [9, 10].

In earlier studies, it was mentioned that wave tranquility analysis must have a limitation that determines the calmness of the location due to a wave height that occurs. The study "Wave of Tranquility and Littoral Studies for Development of a Mini Fishing Harbor", analyzes the calm waves in the harbor basin using a wave height of 0.3 m [7]. The waves occurring in the basin are obtained from wave propagation using numerical modelling. The modelling results will determine whether the proposed port layout is fully operational.

Additionally, the study "Wave Agitation Criteria for Fishing Harbors in Atlantic Canada", analyses it by determining the wave height value in various seasons for ship operations with the purpose of port operations, which can avoid extreme circumstances [11]. This condition is done by daily observation of seasonal wave events and measurements using buoy, which can measure wave height in shallow waters to obtain new fish harbor criteria.

This study will conduct a wave tranquility analysis at the port of Pangandaran. The Pangandaran Port was constructed as part of the government's initiative to enhance the economic potential of the Pangandaran district. However, the port's location on South Beach exposes it to high wave conditions, disrupting the basin's tranquility [12]. This issue necessitated the construction of a breakwater to optimize the port's operations, including ship berthing and cargo handling.

Breakwaters, which can be submerged or detached, are crucial in reducing wave energy and ensuring calm waters in the harbor. For instance, submerged breakwaters have been shown to influence sediment distribution and mitigate wave impacts on surrounding areas [13-15]. Additionally, breakwaters protect the harbor basin from significant wave agitation, thereby enhancing the safety and operability of ships within the port [16]. Numerical models, such as those used for submerged breakwater systems [17], provide an effective method to predict wave heights and assess the efficiency of breakwaters in maintaining wave tranquility. This study aims to employ a numerical model to evaluate the wave conditions in Pangandaran's harbor basin, estimating how many operational days the ships can safely navigate and how effectively the breakwater ensures calmness.

2 Material and Methods

The wave data near the port was usually unavailable, so the wave data was retrieved from a hindcasting calculation using wind data near the shore [18, 19] MIKE 21 SW model in the located port was done to determine the wave condition in the basin with wave height transformation in the deep sea [20-23]. Wave transformation involves refraction, shoaling, reflection, diffraction and other factors affecting the wave transformation [24, 25]. The model was created using the mesh to represent reality [26]. The modelling was done by comparing the wave height transformation result before and after the breakwater installation. The wave height limit used is 0.5 m for the wave height criterion, which is said to be calm. The limit determines how many days the ship can operate with the wave height that occurs in the harbor basin and how optimal the proposed layout breakwater performance is.

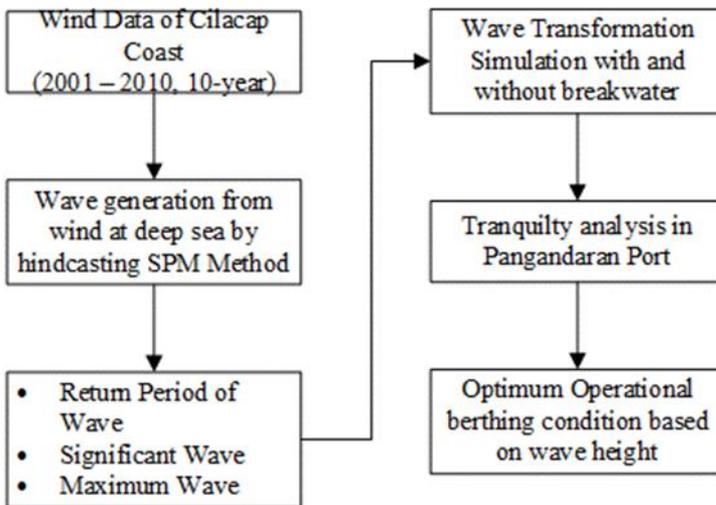


Fig. 1. Conceptual Frameworks of the Study

Pangandaran port is located in Bojong Salawe, Kalangjaladri, Parigi, Pangandaran, West Java. The location is on the South Coast, which has a high wave height [27]. (Fig.2).

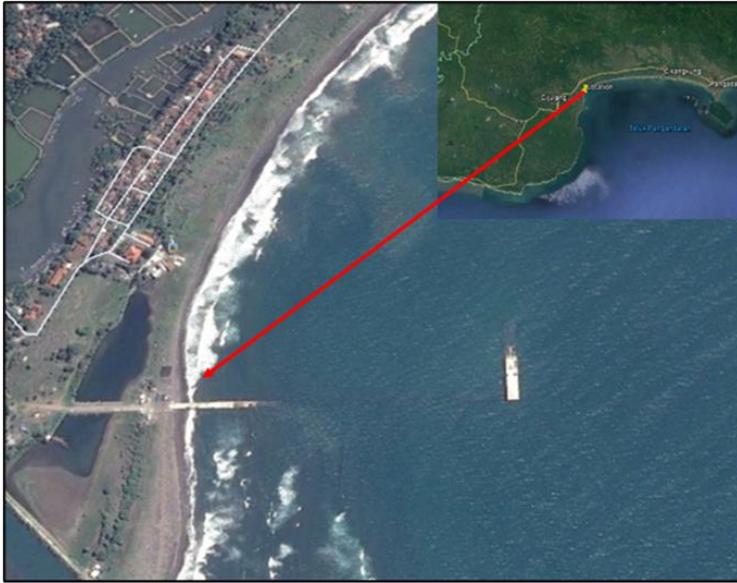


Fig. 2. Location of Study Area

The data analyzed are wave height for the past 10 years generated from the hindcasting calculation of wind data retrieved from BMKG Cilacap Observatory [27]. The wave was considered the most influenced by the basin's environmental conditions from the East, Southeast, and South [24]. Wind speed data was delivered in a windrose shape (Fig. 3 (a)), and the high wave data in a wave rose shape (Fig. 3 (b)).

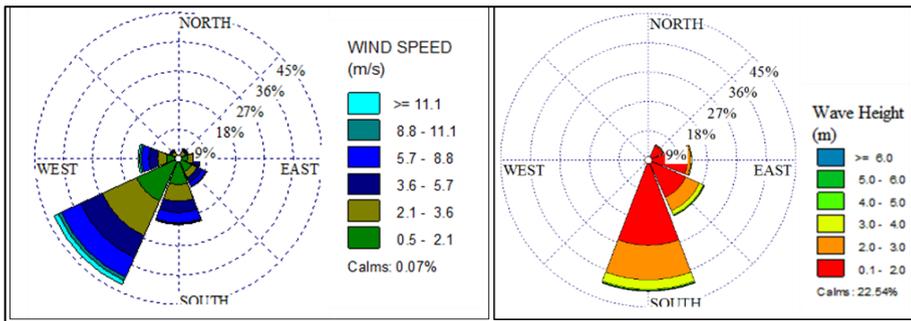


Fig. 3. Windrose Cilacap 10 years (Left), Wave Rose Pangandran 10 years (Right)

The wave height and period in the sea for 10 years were collected, and a chart relationship between H and T produced a simple equation $Y = [5.4065x]^{0.4204}$ or can be written as $T = [5.4065H]^{0.4204}$. The equation and chart can be seen in (Fig. 4).

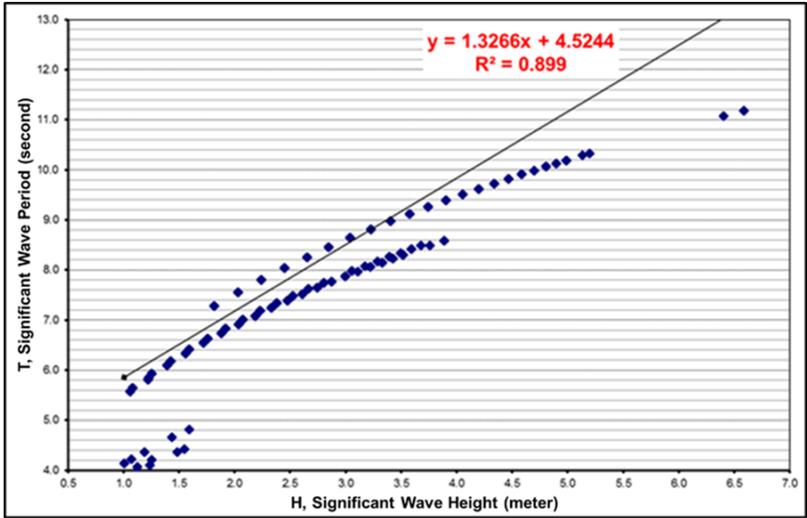


Fig. 4. Chart H & T

3 Results

Wave modelling was done in the previous condition after installing the breakwater with three input high wave scenarios, maximum high wave and significant high wave [28]. The result of the previous wave before the breakwater is seen in Fig. 5 and after the installed breakwater (Fig.6).

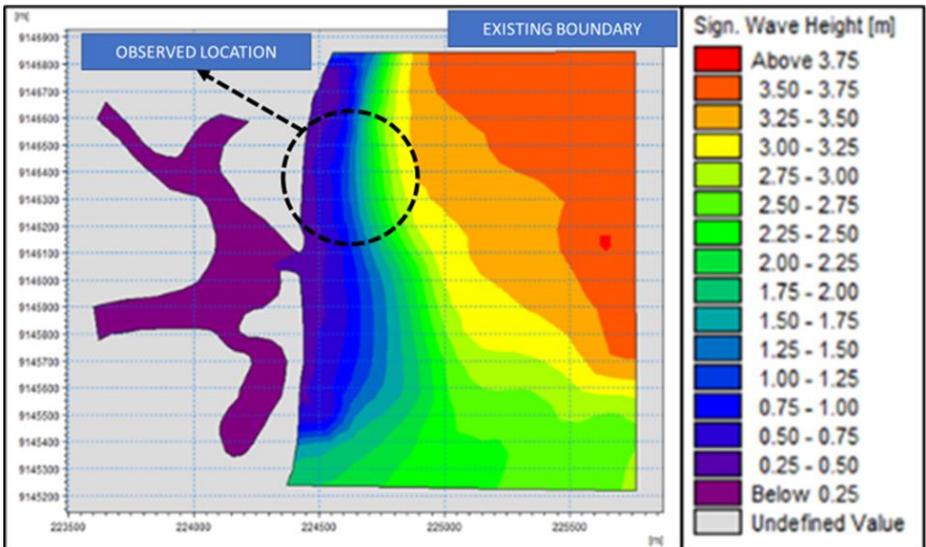


Fig. 5. Simulation Wave without Breakwater for Wave Tranquility Studies

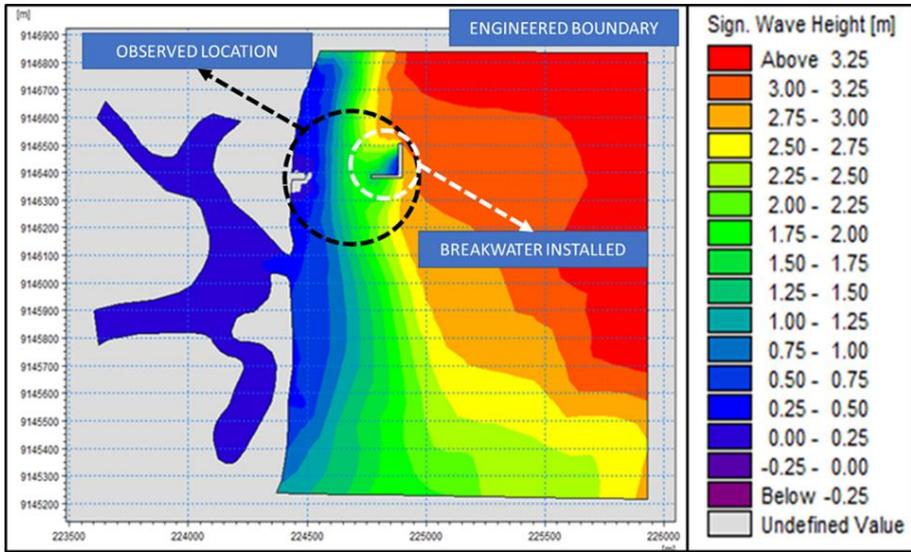


Fig. 6. Simulation Wave with Breakwater for Wave Tranquility Studies

The result from those modelling above was obtained in port basins with averagely high sea wave heights. Determination of many cases in many ships can be anchored is one of the results of sea wave data transformation from 1 year from the basin to the port. This data was presented in a recapitulation of the calculation format, and the presentation of ships that can berthing are in Tables 1, Table 2, and Table 3.

Table 1. The Calculation of Ship Berthing without Breakwater Layout

Month	Direction	Deep Water		Shallow Water			Berthing	Berthing / Month
		Height (m)	Period (second)	Height (m)	Events (day)	Event (per cent)		
January to March	East	3.50	8.30	0.2-0.6	13	13.95	No	Berthing
	Southeast	2.00	7.60	0.2-0.3	5	5.38	Yes	
	South	4.30	9.70	0.3-0.8	5	5.30	No	
				Calm	68	75.37%	Yes	
April to June	East	3.60	8.40	0.3-0.7	29	32.00	No	Not Berthing
	Southeast	5.00	10.20	0.2-1.2	15	16.80	No	
	South	3.00	8.60	0.2-0.6	21	23.20	No	
				Calm	26	28.00%	Yes	
July to September	East	3.60	8.40	0.2-0.6	3	2.90	No	Not Berthing
	Southeast	3.60	8.40	0.2-1.4	10	11.00	No	
	South	3.40	8.30	0.2-0.8	29	31.20	No	
				Calm	51	54.90%	Yes	
October to December	East	3.70	8.50	0.2-0.6	6	6.60	No	Berthing
	Southeast	5.40	10.40	0.2-1.6	8	8.90	No	
	South	5.00	10.20	0.2-0.8	21	22.78	No	
				Calm	56	61.72%	Yes	

Table 2. The Calculation of Ship Berthing with Breakwater Layout.

Month	Direction	Deep Water		Shallow Water			Berthing	Berthing / Month
		Height (m)	Period (second)	Height (m)	Events (day)	Event (per cent)		
January to March	East	3.50	8.30	0.1-0.4	12	13.00	Yes	Berthing
	Southeast	2.00	7.60	0.0-0.1	5	5.60	Yes	
	South	4.30	9.70	0.0	4	4.90	Yes	
	Calm				69	76.50%	Yes	
April to June	East	3.60	8.40	0.1-0.4	27	29.70	Yes	Berthing
	Southeast	5.00	10.20	0.0-0.1	15	15.80	Yes	
	South	3.00	8.60	0.0	20	21.70	Yes	
	Calm				30	32.80%	Yes	
July to September	East	3.60	8.40	0.1-0.2	3	2.90	Yes	Berthing
	Southeast	3.60	8.40	0.0-0.1	11	12.00	Yes	
	South	3.40	8.30	0.0	29	32.00	Yes	
	Calm				49	53.10%	Yes	
October to December	East	3.70	8.50	0.1-0.3	6	6.20	Yes	Berthing
	Southeast	5.40	10.40	0.0-0.1	8	8.30	Yes	
	South	5.00	10.20	0.0	20	22.10	Yes	
	Calm				58	63.40%	Yes	

Table 3. Recapitulation of the Calculation and the Percentage of Ships Berthing

No	Condition	Month	Berthing		Not Berthing	
			Events (days)	Events (%)	Events (days)	Events (%)
1	Without breakwater	January to March	22	24	68	74
		April to June	66	73	26	28
		July to September	41	46	51	55
		October to December	35	39	56	61
		Average	41	46	50	55
2	With breakwater	January to March	90	100	0	0
		April to June	92	100	0	0
		July to September	92	100	0	0
		October to December	92	100	0	0
		Average	91	100	0	0

4 Discussion

The repeated period can only be done through the H value. Meanwhile, for T obtained from equation $T = [5.4065H]^{0.4204}$. High and wave period for the maximum high sea wave with re-period 1-200 years [29]. For data input, MIKE 21-SW resulted from repeated period wave data 1 and 25 years for the significant sea high wave in Table 4 and maximum high wave in Table 5.

Table 4. Input Wave Maximum Condition for MIKE21-SW Model

Return Period	Maximum Wave Height (meter)			Wave Period (second)		
	year	E	SE	S	E	SE
1	1.3	1.6	2.5	6	6.6	8
25	4.9	5.7	5.8	10.5	11.2	11.3

Table 5. Input Wave Significant Condition for MIKE21-SW Model

Return Period	Maximum Wave Height (meter)			Wave Period (second)		
	year	E	SE	S	E	SE
1	0.8	0.5	1.2	5	4.2	5.8
25	2.5	4.3	3.7	7.9	10	9.4

The respiration of the presentation ships above shows that the condition before the breakwater was installed averaged just 55%. The possibility many ships could increase each month was less optimal. Meanwhile, for the condition after the breakwater installation, the possibility of ships can increase by 100%.

The result of port basin modelling with the maximum and significant high waves before the installed breakwater can be seen in Table 6 and Table 7.

Table 6. Wave Height at Harbor without Breakwater

Direction Waves Coming	Return Period (year)	Significant Wave in Deep Sea				Wave Around Harbor Height	
		Wave Height		Wave Period		Effect Hs	Effect H _{max}
		H _s (m)	H _{max} (m)	T _s (second)	T _{max} (second)	(m)	(m)
East	1	0.8	1.3	5.0	6.0	0.6-0.7	1.0-1.13
South East	1	0.5	1.6	4.2	6.6	0.4-0.5	0.5-0.6
South	1	1.2	2.5	5.8	8.0	0.6-0.7	1.0-1.4
East	25	2.5	4.9	7.9	10.5	2.1-2.15	2.1-2.3
South East	25	4.3	5.7	10.0	11.2	2.1-2.6	2.5-3.0
South	25	3.7	5.8	9.4	11.3	1.2-1.7	1.3-1.7

Table 7. Wave Height at Harbor with Breakwater

Direction Waves Coming	Return Period (year)	Significant Wave in Deep Sea				Wave Around Harbor Height	
		Wave Height		Wave Period		Effect Hs	Effect H _{max}
		H _s (m)	H _{max} (m)	T _s (second)	T _{max} (second)	(m)	(m)
East	1	0.8	1.3	5.0	6.0	0.01-0.02	0.05-0.06
South East	1	0.5	1.6	4.2	6.6	0.01-0.02	0.04-0.05

Direction Waves Coming	Return Period (year)	Significant Wave in Deep Sea				Wave Around Harbor Height	
		Wave Height		Wave Period		Effect Hs (m)	Effect H _{max} (m)
		Hs (m)	H _{max} (m)	Ts (second)	T _{max} (second)		
South	1	1.2	2.5	5.8	8.0	0.01- 0.04	0.01- 0.03
East	25	2.5	4.9	7.9	10.5	0.06- 0.07	0.11- 0.012
South East	25	4.3	5.7	10.0	11.2	0.05- 0.07	0.06- 0.07
South	25	3.7	5.8	9.4	11.3	0.01- 0.05	0.01- 0.04

5 Conclusions

Transformation of sea wave study, which was done, and the result can be used to know the condition of tranquility in sea waves. The result of sea wave transformation shows that most sea wave directions are to the East, Southeast and South. The conclusions obtained from the wave modelling are a) The result of numeric modelling for wave tranquility in the basin after a transformation of the inside of the sea wave. From the high that allowed 0.5 m obtained in the condition after breakwater installed wave height in the basin are calmer; b) First scenario with data of sea wave height from 1 year was produced the average presentation about 55% in the condition without installed breakwater and the average presentation about 100% for the condition with breakwater installed c) Second scenario with the significant wave height from 1 year repeated constantly period produced the wave height with the higher result was between 0.6-0.7 m for the condition without breakwater, meanwhile for the condition with there was a breakwater in there was less than the limit 0.5 m; d) Third scenario with the maximum wave height from 1 year repeated constantly period produced the higher wave between 1.0-1.4 m for the condition without a breakwater, meanwhile for the condition with a breakwater in there less than limit 0.5 ml; and e) Tranquility sea wave study shows that port wave in the port basin was more calmly in the sea wave condition after installed a breakwater, so the further planning for installed a breakwater must be do.

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