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Research Article

An evaluation of a new offshore breakwater at Sattahip Port, Thailand

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Abstract
Careful planning for a port development is vital. Offshore breakwater is known to reduce wave height approaching a port, but it is not always the case. Different ports have different characteristics. This article chose to analyse Sattahip Port. Necessary information, such as annual wave climate, long-term tidal records, and a bathymetric map were collected and synthesized. Numerical simulations were carried out by the MIKE21 PMS software package. The simulation results showed that the existing breakwater at the port could only protect some parts of it. If the whole area of the port were to be sheltered, a new offshore breakwater would have to be installed at a certain location. The existing breakwater could not be extended because it would interfere with the existing navigational channel. A new breakwater at the nearest island was another option, but it was proven by the simulation results that the new breakwater could not reduce the wave height as planned. If the wave simulation had not been undertaken, decision makers might have proceeded in the wrong direction, and millions of dollars would have been wasted.

1. Introduction

Offshore breakwaters are common for deep water ports (Ali & Diwedar, 2014; Guler et al., 2015). A primary function of the breakwater is to reduce wave height within the port. If the waves within the port are too high, many types of port operation cannot be undertaken. Ships at berth may heave up and down, and cranes installed along the berth will be unable to lift cargoes from the ships (Van der Molen et al., 2003). Furthermore, the ships may roll and hit the berth, leading to damages to the ships themselves (Schelfn & Östergaard, 1995). Ship maneuvering within the port may be difficult, because the high waves interfere with navigational safety (Tsujimoto & Orihara, 2018; Zhang et al., 2017). Therefore, an off-shore breakwater must be designed to achieve its objectives.

A construction of an offshore breakwater involves expensive capital investment. An off-shore breakwater's major components include rocks heavy enough to withstand wave force and geotextiles to increase the breakwater's overall stability (Saengsupavanich, 2013). Some breakwaters are constructed from concrete units (Bruce et al., 2009; Yagci et al., 2004), since big rocks are not available in certain locations. Offshore breakwaters that are located far away from shoreline incur much higher costs compared to those situated close to shore. Careful planning helps decision makers decide whether the new construction of an offshore breakwater is necessary.

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Moreover, an appropriately-designed breakwater helps ensure that the money invested to construct it will not be wasted. This article presents a case study of Sattahip port, Thailand, where coastal engineering plays a vital role in evaluating the appropriateness of a breakwater.

2. Study site

Sattahip Port is located in Chonburi Province, Thailand (**Figure 1**). It is one of the deep water ports of Thailand. It has an existing offshore breakwater to protect it from incoming waves. There is a navigational channel running straight from the offshore zone to the port. However, the author found that some parts of the port still experienced high waves during monsoon season. In order to maintain a calm sea state for the whole port area, the author attempted to study any possibility, including that of a new offshore breakwater. The reason for this is to try to decrease downtime and increase the length of operational periods, as well as to provide the possibility of expanding the port area to a nearby beach.

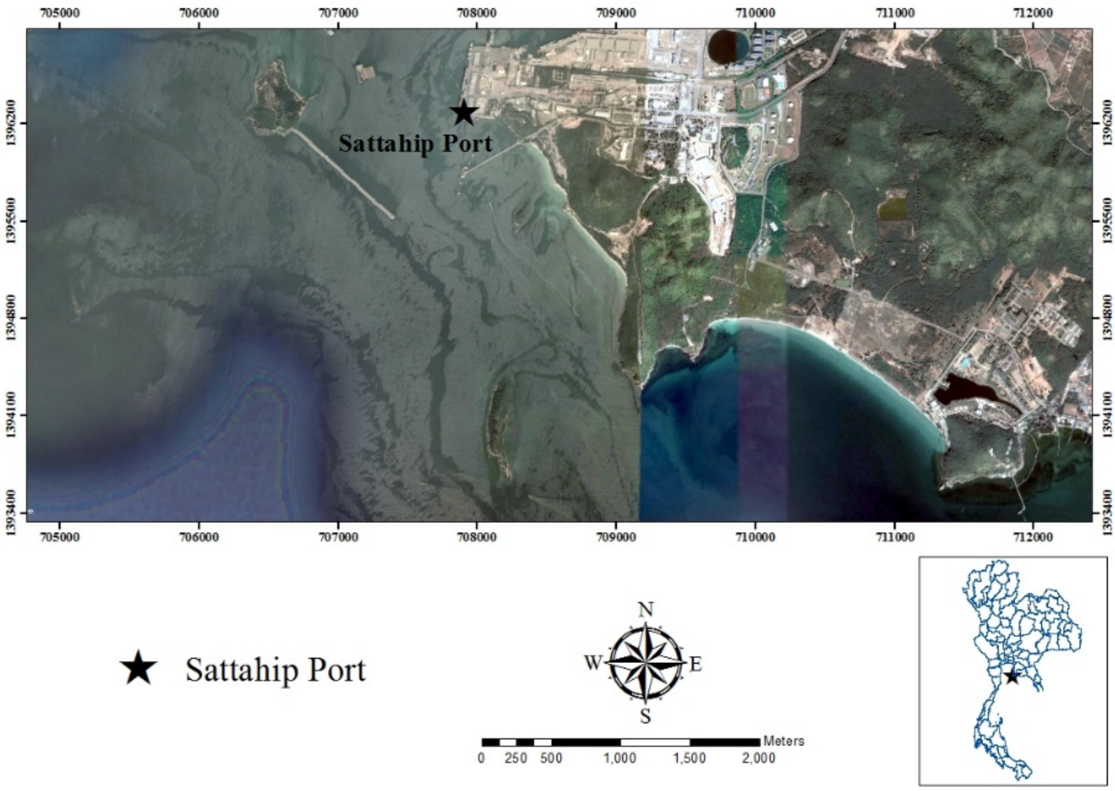

Figure 1 Study area.

The Bathymetric map was collected from public nautical charts, as well as information requested from the General Bathymetric Chart of the Oceans (GEBCO) (GEBCO, 2018) (**Figure 2**). The author found that the existing navigational channel had a depth of around 12 to 14 m. The existing breakwater protruded from the island to the edge of the navigational channel. Therefore, it was not practical for the existing breakwater to be extended for its length, since the extended part of the breakwater would overlap with the navigational channel.

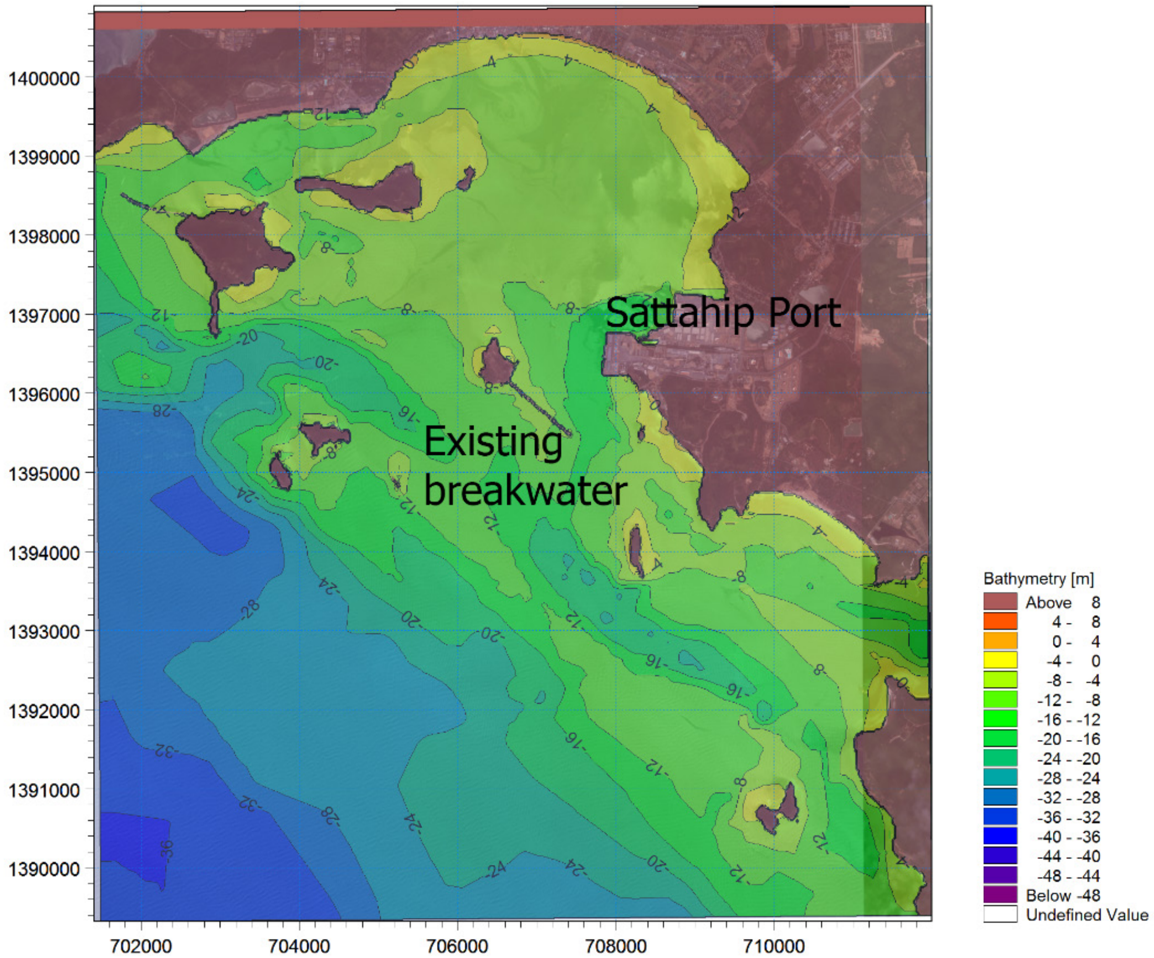

Figure 2 Bathymetric map of the study site.

The author found that waves approaching the port mainly came from the south. High waves tended to occur from the southwest (SW) and south-southwest (SSW) directions (**Figure 3**). During June to July, waves with magnitudes of 3 m were present. There was a 63.46 % calm period where wave heights were less than 0.20 m. A long-term wave analysis by Weibull distribution (Kamphuis, 2000) found that the 50-yr return period wave height was 4.32 m, and the 50-yr return period wave period was 11.1 s (**Table 1**). The author collected tidal information from the Marine Department, Thailand. The nearest tidal station where information could be requested and accessible was Rayong station (located at 12^0 39’ 30” N 101^0 16’ 28” E), being approximately 40 km from the study area. It was found that the local mean sea level of the study site was +0.09 m above Thailand’s national mean sea level (MSL). The mean high water spring (MHWS) at the study area was +0.68 m MSL, while the highest high water level of the study area was +1.44 m MSL (**Table 2**).

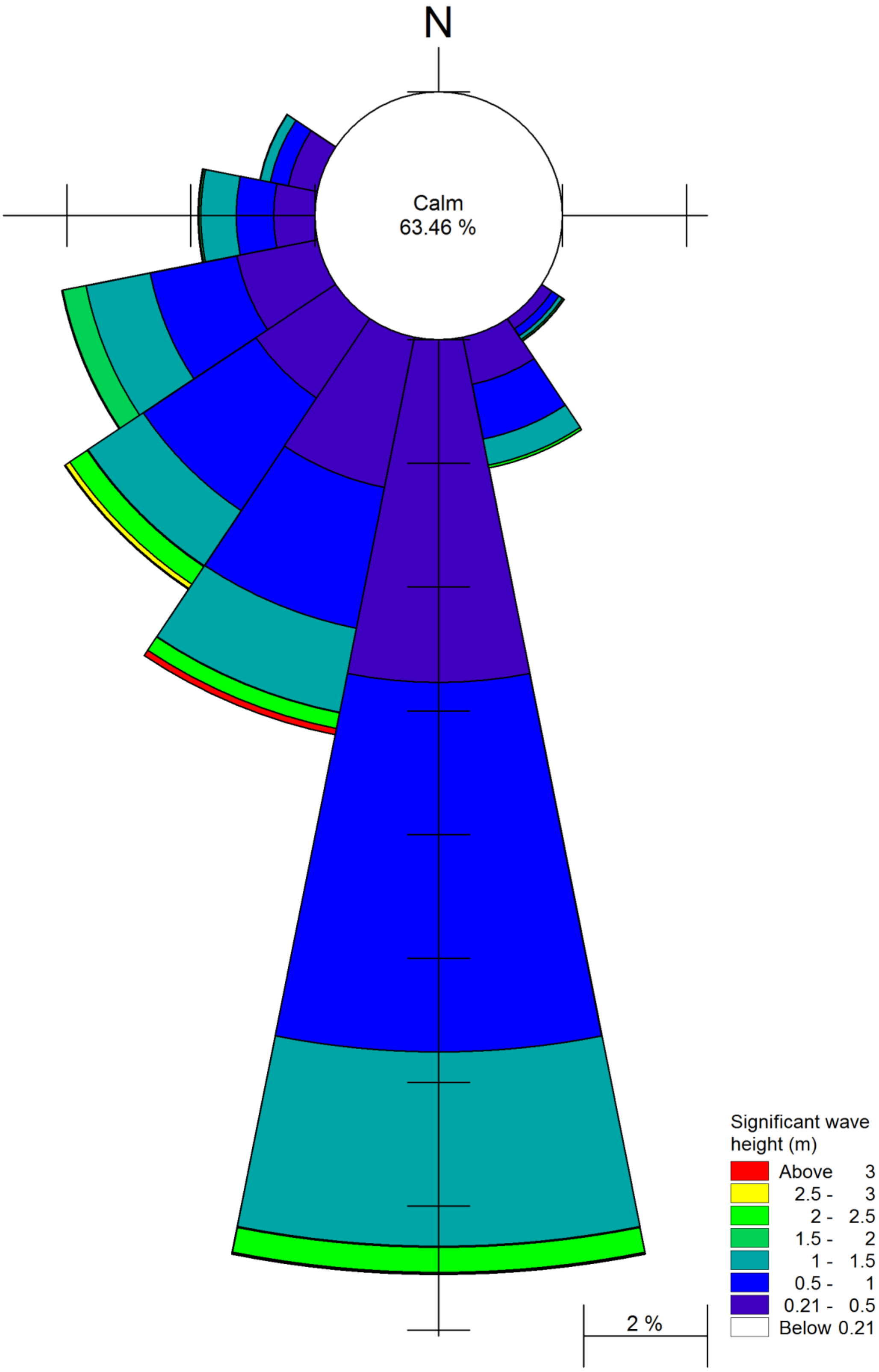

Figure 3 Annual wave height at the study site.

Table 1 Long-term waves at the study area.

Return period (year)	H_s (m)	T_p (m)
5	3.33	9.40
10	3.63	9.92
15	3.80	10.23
20	3.92	10.44
25	4.02	10.60
50	4.32	11.10

Table 2 Tidal information at Rayong station (located at 120 39' 30" N 1010 16' 28" E), being approximately 40 km from the study area.

	Elevation from Thailand's national mean sea level (m)
Mean high water spring	0.68
Mean high water	0.65
Mean high water neap	0.63
Local mean sea level	0.09
Mean low water neap	-0.52
Mean low water	-0.61
Mean low water spring	-0.73
Highest high water	1.44
Lowest low water	-1.58

3. Methodology

An evaluation of a new offshore breakwater at Sattahip Port was undertaken by a software package named the MIKE21 PMS. It is based on a parabolic approximation to the elliptic mild slope equation, and can simulate refraction, diffraction, and reflection of linear time harmonic waves on a gently sloping bottom (DHI, 2018). The MIKE21 PMS has been widely applied to various coastal engineering works as well as researches (Jakobsen et al., 1998; Simeoni et al., 2009; Sloth et al., 2012; Sorourian & Banijamali, 2010).

The simulations began with the construction of a calculation domain, having a grid size of 10×10 m^2. Two scenarios were simulated. The first simulation was taken for the existing conditions in order to evaluate how the 50-year return period waves could migrate into the port. The incoming waves were set to come from the SSW direction. As mentioned earlier, the existing breakwater was constructed adjacent to the edge of the existing navigational channel. Therefore, it was not practical for the existing breakwater to be extended for its length, since the extended part of the breakwater would overlap with the navigational channel. The second alternative was to construct a new offshore breakwater at another island. In order to reduce as much wave height as possible, the tip of the new breakwater should be placed as close as possible to the verge of the navigational channel. The change of wave height was then compared with the first case.

4. Results

The simulation results showed that the existing breakwater could reduce the incoming waves to some extent. A certain area of the port still experienced high waves. Wave height reaching the port was approximately 2.8 m, indicating that the existing breakwater might not be sufficiently protective for ships berthing along the southern side of the port (**Figure 4**). If the wave height was to be decreased, a new breakwater had to be constructed. The new offshore breakwater was installed at another island closest to the port. Although the tip of the new breakwater was placed at the border of the navigational channel, the simulation results indicated that the new breakwater did not meet its objective. The new breakwater could create a calm area at its lee, but failed to reduce the wave height at the port. The wave height at the port was still 2.8 m (**Figure 5**). The reason for this was that the gap between the existing and the new breakwaters were so wide that the wave could penetrate through it. Placing both breakwaters closer together was impractical, since the navigational channel was between them. Therefore, it was concluded that the new breakwater was not helpful in reducing the waves at the port.

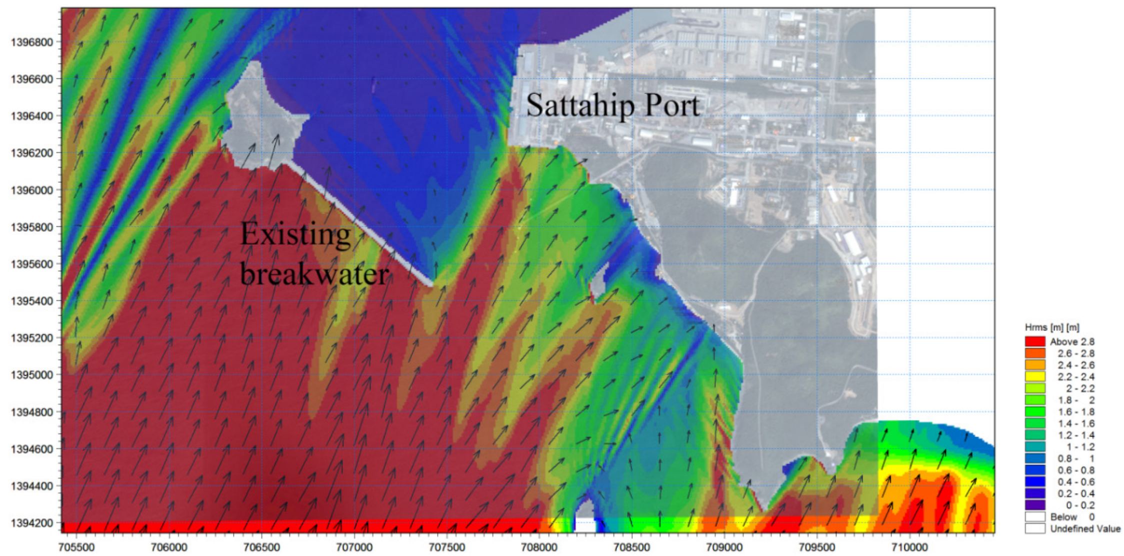

Figure 4 Waves approaching the port (existing conditions).

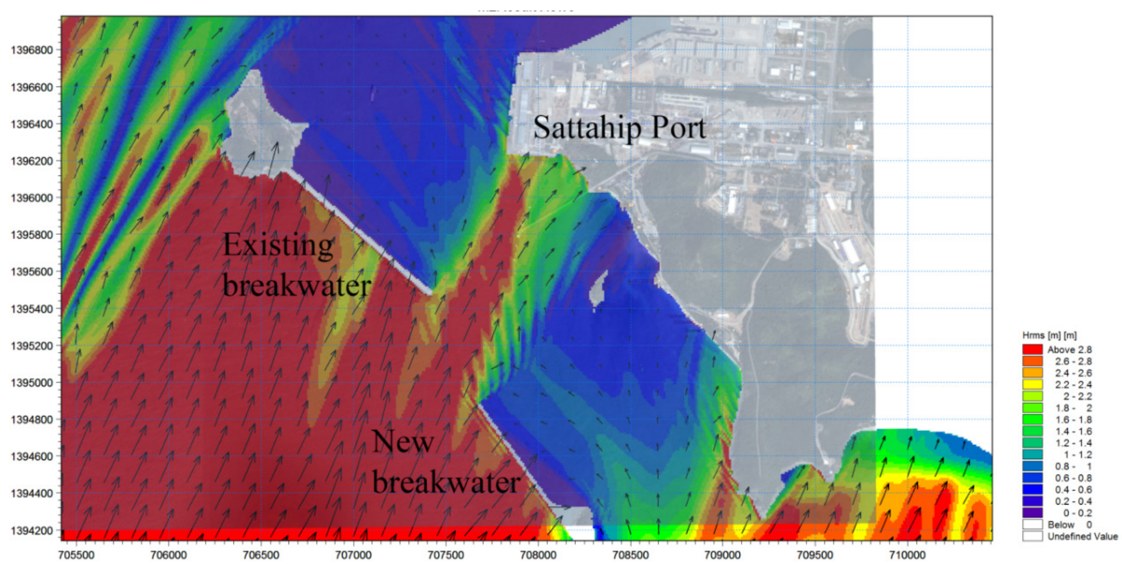

Figure 5 Waves approaching the port (a new offshore breakwater at the closest island).

5. Discussion and conclusions

Appropriate planning of an offshore breakwater is key. If there was no careful consideration, millions of dollar could be wasted. This case study attempted to increase the duration of the port's operational period and find a possibility to expand the port area to a nearby beach by constructing a new offshore breakwater. Generally, offshore breakwaters could reduce wave heights. However, this case study indicated that other existing coastal structures, as well as site-specific limitations such as a navigational channel, could change the outcome. MIKE21 PMS was a useful tool to help make a decision. Simulations using the 50-year return period scenario were undertaken in order to represent the extreme cases, and to prove the effectiveness of the existing and the new breakwaters. The less extreme cases (for example, the 1-year return period) were ignored, because the extreme cases could provide a better evaluation. Although a new offshore breakwater was to be constructed at Sattahip port, the wave height was not reduced at all. Therefore the new breakwater was not necessary. If the wave height approaching the port was to be decreased, other options other than constructing the new breakwater at the closest island should be considered.

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