The effect of porous zigzag-type breakwaters on the coastline changes in Neuheun village, Aceh

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Abstract. The process of changing the coastline has always been a challenge for coastal communities. Beach erosion has been a threat with the coastline withdrawing from its previous position. Coastal protection buildings are needed to overcome coastal erosion problems, and alternative construction also needs to be developed. The zig-zag type porous breakwater is quite effective in reducing erosion based on several small-scale physical models that have been developed. Therefore a prototype was built and tested to observe its usefulness, and how it was applied in the field. This study aims to assess the effect of installing zigzag type porous breakwaters on coastline changes. This research began with the installation of construction and continued with observing changes in the coastline. Observations are carried out periodically at any time, to see changes in the contour of the beach that occurs. Observations were made by leveling the beach surface against several transverse profiles. Changes in coastline due to construction will be analyzed by looking at the relation to the wind direction. The results obtained from several observations show that the construction of a zig-zag type porous breakwater has a positive effect in reducing erosion, as long as the breakwater distance with the coastline does not exceed the breakwater length.

1. Introduction
The coastline is a meeting point between land and sea, tides, wind, and waves attacking land and where the land responds to attacks with various acts of giving and taking that are effectively aimed at removing energy from the sea [1]. As a result of these conditions, coastline changes are a common thing. Coastline changes are generally caused by erosion and sedimentation. Erosion during certain wind seasons and sedimentation in other seasons is a common cycle because erosion and sedimentation are part of the dynamism that occurs on the coast.

To deal with the problem of erosion and sedimentation, a coastal security building is generally made. The coastal protective buildings show effective results in resisting coastal erosion. Based on these problems, a study was carried out in the form of prototyping of coastal security structures in the form of porous breakwaters installed in zigzag ways [2].

The selection of breakwaters as the object of research is because these buildings are already commonly used in protecting beaches, breakwaters built in parallel on the coast have proven to be effective ways to reduce coastal erosion [2]. The existence of pores or holes in the breakwater building functions to absorb some of the incoming wave energy. In a previous study carried out in a laboratory
concluded that an increase in breakwater porosity reduces the reflected wave height and the effect of porosity becomes significant in reducing wave energy when the breakwater is made higher [3]. Besides that, the porous breakwater structures can attract marine life and ultimately improve environmental quality [4].

The selection of zigzag type breakwaters is done because this type of building is considered to be more effective in resisting erosion rates, it is based on previous research conducted by conducting a study of physical models of breakwater not submerged porous zigzag types against wave diffraction patterns [5]. In that study the breakwater model with width (L) 28.3-56.6 cm was able to reduce wave energy by 52.5-65.18%, the value of the diffraction coefficient increased with reduced wave steepness, whereas the diffraction coefficient value decreased with increasing wave steepness. The relationship of the wave period with the diffraction coefficient is directly proportional.

The study of a porous zigzag type breakwater model to change the velocity distribution and wave-current pressure had been carried out [6]. The research was carried out by using a breakwater model with a porosity of 47%, 46% and 45% and the waves arranged with wave height (H) of 10 cm and wave period (T) 1,268 seconds. From the simulation results, it can be concluded that porosity in the breakwater building can affect the speed and pressure generated by the wave currents. The average current velocity before the construction of a porous zigzag type breakwater model is 0.2832 m/s and the current velocity after construction is 0.2141 m/s, this indicates that the construction of porous zigzag type breakwaters can reduce the velocity distribution of currents that will hit the coast.

2. Methodology

This research was conducted at ADB Beach, which is located in Gampong Neuheun of Masjid Raya District Aceh Besar Regency. This location is chosen because the beach has dynamic characteristics, so it is considered suitable as the location of the prototype of a built-in-pore breakwater building zigzag that aims to see how big the building influences Change of coastline. It is hoped that the building will be able to withstand the rate of erosion effectively to help the coastal protection process.

The offshore breakwater is one of the alternative constructions to protect the coastal. The breakwater to be installed has a porosity rate of 47% [7]. This study was done in three stages; installation of offshore porous zigzag breakwater prototype, observation (measurement) of coastal morphology change, and data analysis.

Figure 1. Study area, Neuheun Village, Aceh Besar district.
2.1. Zigzag and porous breakwater installation

The installation of the breakwater was done by using the excavator by first moving the breakwater units measuring 1.0x1.0x1.0 m from the temporary placement location (Fig 2) to the point Installation. The lifting of a breakwater using an excavator is done by tying a breakwater or clasp with a two tons strong strap belt which is then attributed to the excavator bucket. After all breakwater and hooks are located around the mounting point then the installation according to the research plan is done. This research, the breakwater is installed only one breakwater building, not a series consisting of several breakwaters. This is done due to the limited funds available.

![Figure 2. Units breakwater at the temporary site.](image)

Before the installation is done first to expand the geotextile in the installation location. Geotextile installation aims to allow if the built-in breakwater decreased due to unstable soil or sand then the decline becomes uniform so that the breakwater arrangement is expected to remain as early as Installation. The breakwater installation was done by compiling the breakwater in a zigzag line with ten lines in which each row was filled by three breakwater units. One unit of the breakwater with the other is associated with a hook that has been made to prevent it from being installed later. The retrofitted breakwater has a length of 17.0 m, width of 2.8 m, and height of 1.0 m as can be seen in figure 3.

![Figure 3. Breakwater when it is installed in the field.](image)

2.2. Observation and data collection

The data collected includes secondary and primary data. Secondary data used include data on wind speed and direction sourced from Blang Bintang BMKG Station. Primary data collected includes topographic
and bathymetry maps. Topographic surveys aim to make topographic maps that contain the latest information on the state of the surface of the mapped coast, the information presented includes the state of relief (high and low) on the surface of the land or area of the measurement area. Topographic measurements were carried out onshore and land at the research location. The area of measurement is 60 m x 80 m, which is 60 m along the coast and 80 m perpendicular to the coast. The area of measurement is divided into five cross profiles. The elevation measurements for each transverse profile are carried out starting from the mainland towards the sea using a water pass. The results of the water pass readings for each measurement of the transverse profile are recorded on the measurement form and then analyzed to obtain an elevation value for each transverse profile. The elevation value is then poured into the image to produce a map of the location of the research site. Topographic measurements are carried out in the initial conditions on 29 October 2017, then measurements are taken periodically at certain times. The breakwater layout after being installed from the measurement results can be seen in figure 4.

Figure 4. Breakwater installation layout.

2.3. Data analysis
Wind data were analyzed to determine the velocity and dominant wind direction during observation. The analyzed wind data were presented in a wind rose diagram. From the wind rose diagram you get information about the winter season that occurs in the measurement period, so it is useful to see how it affects the coastline change. The topography measurement is done several times in a certain period, it aims to see how much the coastline changes occur from one-time measurement to the next measurement. Based on the results of topographical measurements obtained the data in the form of reading threads on the topographical measuring device which is then analyzed resulting in the value of elevation. The value of elevation is then poured into the image so that it becomes the topographical map of research locations and images of transverse pieces of the beach. From the image of the topographical measurements can be calculated how much sedimentary movement occurs both erosion and sedimentation.

3. Results and discussion

3.1. Coastline changes during observation
The coastline was changed after breakwater installation compared to the initial condition on October 29th, 2017. The deterioration of the coastline from the initial conditions occurred from the measurements
on December 10, 2017, until the most severe on May 12, 2018, which was an average of 40.9 m behind the coastline at the initial conditions. On the July 31st measurement of 2018, the coastline is still behind the initial condition of an average of 2.8 m, but the conditions have been progressing the coastline from the previous measurements on 12 May 2018, which is 38.1 m. At the measurement conducted on 8 October 2018, the coastline was progressing from the initial condition with an average distance of 6.1 m. The coastline returned to a decline of an average of 6.4 m on the measurement conducted on 22 December 2018. Figure 5 shows the shape of coastline changes during observation. The distance of coastline changes during the observation can be seen in Table 1.

![Figure 5. Coastline changes during observation.](image)

**Table 1.** The distance of coastline changes during observation.

| Measurement time       | Left side | Backside | Right site | Average |
|------------------------|-----------|----------|------------|---------|
| 10 December 2017       | 2.0 - 3.5 | 0.0 - 2.0 | 7.0 - 8.0  | 3.8     |
| 17 December 2017       | 4.3 - 5.1 | 2.0 - 6.5 | 9.0 - 14.0 | 6.8     |
| 25 December 2017       | 15.0 - 19.0 | 20.0 - 24.0 | 26.0 - 30.0 | 22.3 |
| 09 January 2018        | 16.5 - 24.0 | 23.0 - 25.0 | 27.0 - 30.0 | 24.3 |
| 15 March 2018          | 35.0 - 38.0 | 36.0 - 38.0 | 40.0 - 42.0 | 38.2 |
| 12 May 2018            | 38.5 - 39.0 | 38.0 - 41.0 | 43.4 - 45.5 | 40.9 |
| 31 July 2018           | 2.8 - 3.2  | 1.7 - 5.5  | 1.5 - 2.3  | 2.8    |
| **08 October 2018**    | **-6.6** - **-8.7** | **-6.2** - **-6.6** | **-3.3** - **-5.0** | **-6.1** |
| 22 December 2018       | 0.2 - 4.6  | 5.6 - 6.4  | 9.0 - 12.8 | 6.4    |

*) The coastline is more advanced than the initial conditions
3.2. Coastline change due to construction impact

Based on observation can be seen the impact of the porous breakwater that is mounted zigzag against the change of coastline. This is evidenced by the measurement results carried out on December 10 and 17, 2017. From the results of the measurements made on December 10, 2017, the coastline behind the breakwater did not multiply the setbacks in the left and right positions. Similarly, when measurements were made on 17 December 2017. Here the breakwater was able to maintain the coastline position during the distance between the coastline to the breakwater does not exceed the breakwater length. Unlike the measurements on December 25, 2017, onwards, where the breakwater is no longer able to defend the coastline from setbacks due to the distance between the breakwater and the coastline has been very long breakwater. The effect of the breakwater on changing coastline can be seen in figure 6.

![Figure 6](image1.png)

**Figure 6.** Breakwater impact on changing coastlines during observations.

![Figure 7](image2.png)

**Figure 7.** Coastline change from existing conditions 29 October 2017 until 12 May 2018 which is in the East wind season.
3.3. Changes in coastline due to the wind season
The deterioration of the coastline from the initial conditions occurred from the initial observation condition of 29 October 2017 until 12 May 2018 as seen in figure 7. In this period the winds are in the eastern season, generally blowing from east to west. From the observation done in the blend with the wind rose can be concluded that in the east season the coast is erosion evidenced by the pullback coastline with significant distances as seen in table 1.

Different from the coastline changes that occurred between the measurements made from 12 May 2018 to 8 October 2018 where the coastline goes forward as seen in Figure 8. During this period the wind was in the West season, generally blowing from west to east. From the observation done in the blend with the wind rose can be concluded that in the eastern season the coast was subjected to sedimentation evidenced by the coastline with a significant distance.

![Figure 8. Coastline change from May 12, 2018, to 8 October 2018 which is in the West wind season.](image)

4. Conclusion
Based on observations that have been done, the impact of the breakwater that was installed with a length of 17.0 m, the width of 2.8 m and a height of 1.0 m against the coastline change is only seen when the distance breakwater with the coastline does not exceed the length of breakwater. In this condition breakwater was able to withstand the decline of the coast amounted to 0.0 – 2.0 m compared to the beach without a breakwater that has decreased by 2.0 – 8.0 m. Breakwater becomes no impact on the coastline change when the distance between Breakwater with the coastline exceeds the length of breakwater. In the observation site, the influence of the wind seasons is more dominant against the coastline change. During the east wind, there is a large erosion that causes the coastline to reach an average of 40.9 m. During the West wind, sedimentation was caused by the coastline up to an average of 47.0 m. The impact of the breakwater in accelerating the occurrence of sedimentation is not seen due to the formation of tombolo or salient on the coastline behind the breakwater, although in general sedimentation occurs in the west wind season.

In this study, the constructions were mounted only one row of the breakwater building so that the effect of the breakwater on changing coastline is not very noticeable. It is hoped that the future-related research can be made in the form of a series consisting of several breakwater buildings so expect the influence of breakwater to change coastline can be more noticeable. The high breakwater in this study
is only 1.0 m so it is not very effective in holding the wave compared to the higher buildings, expected in future related research can be made higher so that it will be more to protect the coastline.

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