The impact of parameter changes of a detached breakwater on coastal morphodynamic at cohesive shore: A simulation

A Fitri 1*, L Yao 2

1 School of Civil and Architectural Engineering, Nanchang Institute of Technology, Nanchang, 330099, China, arnizafitri@gmail.com
2 College of Water Conservancy and Ecological Engineering, Nanchang Institute of Technology, National and Provincial Joint Engineering Laboratory for the Hydraulic Engineering Safety and Efficient Utilization of Water Resources of Poyang Lake Basin, Nanchang, 330099, China, yaoli0817@nit.edu.cn

*Email: arnizafitri@gmail.com

Abstract. Coastal defence structures such as detached breakwaters have been used alternatively to reduce the coastal erosion problems in the world. Behind their efficiency, detached breakwater causes complex changes to the coastal hydro-morphologies because of variation in the sediment type, climate condition and design of the structures. This study aims to evaluate the impact of parameter changes of a detached breakwater on coastal morphologic changes. Three model cases of detached breakwater with different lengths and positions have been set up. MIKE 21 Mud Transport model interrelated with MIKE 21 Hydrodynamic model was performed to simulate the deposition-erosion patterns in the locality of detached breakwater for different lengths and positions of the breakwater. The results show that the detached breakwater with available empty gap gives lowest negative impact to the cohesive coastal areas with considerable reduction of the erosion problems.

1. Introduction
Detached breakwater is a barrier structure placed in the shallow nearshore region to protect any landward area from the direct attack of storm surges such as wave, currents and tides [1-2]. Detached breakwater has been using worldwide in the intertidal zones of coasts, to provide protection measures and mitigate erosion problems [3-5]. However, all coastal protection structures including detached breakwater, can change the coastal hydro-morphodynamic, which could then impacts deposition-erosion patterns in the coastal zone [6-7]. Breakwaters can reduce the incident wave energy and allow sediment deposition on the shoreward sides of the structure [8]. The changes of the coastal hydro-morphodynamic caused by a detached breakwater are site-specific while it is affected by several parameters including sediment characteristics, climate conditions, structural configurations such as design and dimension [2,5]. Previous studies done on coastal morphodynamic changes due to the presence of detached breakwaters have mainly focused on sand coasts [9-11], while for a cohesive shore, the hydro-morphodynamic response to the presence of a detached breakwater is not much studied earlier.
The cohesive shore of Carey Island, Malaysia has been experiencing erosion problems due to human interventions in the coastal zone since 1995. In order to reduce erosion problems, a detached breakwater was proposed to be constructed in the intertidal zone of Carey Island (near to the erosion area) for coastal protection. However, there were not many studies earlier about the impact of the detached breakwater on deposition-erosion patterns on the cohesive shore. Besides, the proper dimension and position of the breakwater need to be carried out for optimization of the function of the breakwater construction in reducing the erosion problem at Carey Island. Hence, this study attempts to evaluate the impact of different lengths and position of a detached breakwater on coastal morphodynamic changes. MIKE 21 Mud Transport interrelated with MIKE 21 Hydrodynamic was used to simulate the patterns of deposition-erosion in the locality of the detached breakwater for different lengths and positions.

2. Study Area
This study was carried out at intertidal area of Carey Island coast, Peninsular Malaysia approximately within longitude of 02°49′26″N to 02°49′29″N and latitude of 101°20′22″E to 101°20′27″E (figure 1). The Carey Island coast is a mangrove forest reserve, with a semi-diurnal tidal system that receives daily tidal inundations while cohesive sediments covered most part of the bottom coastal area. Dyke has been built along the coastline of Carey Island by Department of Irrigation and Drainage (DID), Malaysia for protection palm cultivation area from the salt-water intrusion. There is a big river; namely, Langat River which is located approximately 8 km from the study site (Figure 1).
Figure 1. Schematic location of the study area
3. Methods

3.1. Data collection and preparation
The data used in this study consist of sediment characteristics such as soil particle size and soil density; bathymetry data; climate data such as wind and wave parameters; suspended sediment concentration; tide; and total suspended sediment (TSS) and water discharge from the Langat River.

Ten sediment samples were collected along the coastal of Carey Island to determine the sediment characteristics at study site. Bathymetry data were surveyed in the field using a boat equipped by an echo-sounder and a DGPS during the spring tide. Suspended sediment concentrations were recorded at the site using optical backscatter sensors (OBS-3A) for 2 week period. Water samplings and water velocity were collected at the mouth of Langat River to determine the TSS values and water discharge from Langat River. Tidal data were obtained from the Malaysian Survey and Mapping Department (JUPEM) while wind and wave data were obtained from the Malaysian Department of Meteorology.

3.2. Model case setup for detached breakwater
In this study, the detached breakwater is designed to have “mainbody” and “circulation gap” sections with their width are 3 m and 2.5 m, respectively. The detached breakwater is rubble mound. Three different lengths and positions of the detached breakwater were setup in order to evaluate the impact of the length and position changes of the breakwater to the coastal morphology. The detail description of the detached breakwater for each case is illustrated in the Table 1.

### Table 1. Detail description of the detached breakwater for each case

| Case No | Case Illustration/Sketch | Description |
|---------|--------------------------|-------------|
| 1       | ![Diagram](image)         | The breakwater consist of mainbody and gap circulation sections. The lengths of the mainbodies section are 30m, 40m, 30m, and 30m respectively. The length of gap circulation setion is 5 m. There is a empty gap available between the third and fourth sections of the mainbody. |
The breakwater consist of mainbody and gap circulation sections. The lengths of the mainbodies section are 30m, 40m, 30m, respectively. The length of gap circulation section is 5 m.

3.3. Numerical modelling
In this study, MIKE 21 Mud transport model interrelated with MIKE 21 Hydrodynamic module was performed to simulate the deposition-erosion patterns near the detached breakwater. The simulation was run for 2 weeks period based on available data. MIKE 21 Mud Transport model is a numerical model used to determine the erosion, transport and deposition processes of fine-grained material (< 63 µm) under the action of currents and waves. The model solves an advection-dispersion equation, based on Mehta [12] and the impact of waves and currents are introduced with bed shear stress. Figure 2 presents the flow chart of the Sediment Transport Simulations.
4. Results and Discussion

Figure 3 presents the deposition-erosion patterns in the vicinity of the detached breakwater from each case for two weeks simulations. Based on figure 3, simulation results demonstrated that there are increments of the sediment accumulation in the study site (at breakwater surrounding area) with the higher amount found at landward area of the breakwater structure. It means that the presence of the detached breakwater has successful in slowly reducing the erosion problem at study site especially behind the structure of the breakwater.

The amount of sediment accumulations are found to be higher for the longer dimension of detached breakwater (case 2 and case 3) while case 3 give highest increment of the sediment accumulations after two weeks installation of the breakwater at study site. However, there is erosion appeared at the seaward side of the breakwater structure for case 3. It is suspected due to the higher reflection and refraction occurred at the front of breakwater which has very long dimension (more than 100 m). The simulation results also show that the longer breakwater with available break (empty gap) after 100 m (case 2) results no erosion appeared at breakwater surrounding area. Therefore, the detached breakwater with case 2 model gives the best impact for the coastal of Carey Island. For case 2 model, the presence of the breakwater increases the bed elevation slowly without any other erosion problem occurred at surrounding area.
5. Conclusion
The presence of a detached breakwater could help increasing the bed elevation on cohesive shore of Carey Island as well as reducing slowly the erosion problem at the site approximately around its structure. The results show that the length of a single detached breakwater cannot be made more than 100 m to give lowest negative impact caused by construction of breakwater itself.

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