STUDY ON COASTAL MORPHODYNAMICS IN THE VICINITY OF COASTAL BREAKWATER OF KUALA BESUT DURING PRE AND POST MONSOON

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Abstract: A study on surface sediment distribution and seafloor morphology with the effect of monsoon phenomena was conducted near the breakwater of Kuala Besut, Terengganu. In this study, a standard bathymetry application was used and sediment was collected along the coastal area. The seafloor morphologies during pre and post monsoon had shown relative changes due to the Northeast monsoon while sediment movement provide significant data in term of mean size, sorting, skewness and kurtosis. The grain size analysis shows finer sediment dominated at both areas (nearshore and estuary) during the pre-monsoon period with the mean size values ranged of 2.00 – 7.00 φ (nearshore) and 0.30 – 7.01 φ (estuary). Lower mean size values obtained during post-monsoon period ranged 0.28 – 5.20 φ (nearshore) and 0.21 – 6.86 φ (estuary) indicate that coarser sediment obtained at the study area. Bathymetry shows distinct changes in depth; 0.64 – 7.62 m (pre-monsoon) and 0.73 – 7.05 m (post-monsoon) respectively.The irregular sedimentation pattern observed based on the bathymetry data. The data evident that during the pre-monsoon survey, the left-side experienced noticeable erosion while the right-side had the opposite effect. However, survey conducted during post-monsoon revealed that both sides were eroded at the upper-part (landward) while process of accumulation occurred further down (seaward).

I. INTRODUCTION

The contributory factors of sediment distribution at the coastal environment are cyclic in nature and highly controlled by the natural activity including wind, waves, tides and currents. Waves induce the longshore current and rip current; longshore current transport the sediment along the shoreline while rip current carry the sediment towards or away from the shore. Both processes results an alternation of erosion and sedimentation [1].

As the coastal close to the estuarial mouth, the sediment is regularly classified as marine origin. In areas where the open seacoasts are sandy, it is general to find the bed in the mouth or entrance channel to consist mainly of sand. Sediment transport is influenced strongly by the hydrodynamics of flood and ebb shoals neighbouring to the channel. Rivers are the most probable source of sediment to the study area during the non-monsoon season. On the other hand, for beaches further from the river mouths, sediment transport during the non-monsoon season is powered primarily by waves and the sediment being transported is derived from the beach itself. The larger the amount of sediment discharged by the river to the near-shore area, the longer the disruption to the sedimentological trend on the beaches alongside river [2].

Man-induced activities considered as one of the factors affecting sediment size distribution [3]. Usually artificial marvel such as the coastal engineering near the coastal area will disrupt the natural readjustment process and causes erosion. Coastal-engineered construction such as breakwater and jetty are build to help deepen and stabilize the channel to prevent shoaling by littoral drift and to protect the waterway entrance from storm waves. Whereas the breakwater is attached to the coast at one or both ends with a gap for boat entrance in purpose to defend the portion of shoreline area and provide a harbour or anchorage protected from waves.

However, breakwater diminishes the wave energy at the shoreline and thus reduces the capability for waves to transport the sand alongshore. As sand moves alongshore under the normal processes of waves breaking oblique to the shoreline, the drift have to stop when it reach a barrier place across the littoral zone. As a result the sand accumulates on the updrift side of breakwater and the same processes scour the sand away from the downdrift side. Waves play a vital role in the shoreline configuration.

The Kuala Besut river-estuary system is known as serving facilities for the tourists to visit PulauPerhentian as well as a hub for fishery activities. As Kuala Besut facing directly to the South China Sea, the Northeast Monsoon plays a great role in the sedimentation process. Therefore, a breakwater was built in order to reduce the wave forces to the surrounding area. However, this had created some problems to the nearest shoreline and river area in terms of the inconsistency in the sedimentary cycles (erosion and accretion processes) and thus more obvious during and after the monsoon season. Hence, the dredging activities are more often applied to move out the sediment from being deposited around the breakwater and distracting the water movements. The purpose of this study is to study the distribution of the sediment at Kuala Besut and comparison was made for the both period of before and after monsoon season. This seasonal variation study will help to understand more about the changes happen in shoreline and seafloor due to construction of breakwater at the river mouth.

II. MATERIALS AND METHODS

The study comprisesof twomajor parts; sediment distribution and bathymetry (seafloor morphology), taking into account the seasonal changes during before and after monsoon activity.The initial sampling was carried out during September 2008 (pre-monsoon) while the second sampling was conducted in March 2009. Data acquisition consists of bathymetry survey (using echo sounder), sediment collection and some physical parameters measurement (e.g. current velocity and tidal level). Comparison was made from the data collected in order to identify and analyzethe related changes in conjunction with seasonal variation.

1) The study area

The study area is a district of Besut, which bordering the Kelantan state, covers an area of 123,367 acres and constitutes of 9.52% of the Terengganu area. The estimated population is about 145,324 that is the third highest population in Terengganu state.The topography are varies where the northern region is steeper while the southern region, the setting is considered as wavy. This topographical condition thus causes the low land to form valleysnear the Besut riverbank. The town of Besut is situated at Kuala Besut,close to the BesutRiver estuary.

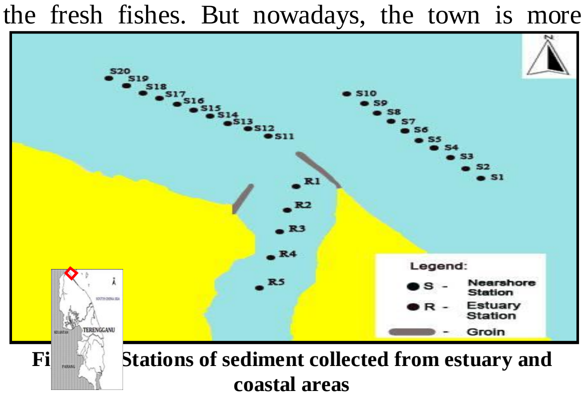
Formerly, Kuala Besut is known as hub for marketing the fresh fishes. But nowadays, the town is more popular in servicing the tourists who wish to go to Perhentian Island. This includes providing the accommodation and transportation facilities. The rapid development and usage of the Kuala Besutriver-estuary system causes the area facing serious sedimentation problems.

In 2008, a breakwater was built at this area to improve the quality of life in the flood-prone areas during monsoon season (usually during November to February). The flooding condition thus causes considerable damages to the crops and personal properties, also posing threat to the public health. Therefore, since the development of the breakwater, lesser impact and more benefits experienced by the locals with better environments.

However, the existence of the breakwater little much caused disturbance in sediment transportation and net shore drift mechanisms. The Drainage and Irrigation Department (DID) had categorized the problem as significant (Category 2), which means the erosion is serious but the economic interest only will be affected in 5 to 10 years later. To overcome this, the local governmentapplied several engineering methods in order to reduce the erosional rate for instance by installing the groin that parallel to the shoreline.

2) Sediment collection

The sediment samples were collected from multiple points,accordingly to the bathymetry survey-line. The interval between each point to another was approximately 100 m.A total of 20 samples from the nearshore zone (in front of the breakwater) and 5 samples fromthe estuary area were collected usingPonar grab. Samples were placed inthe plastic bags, labelled, and brought back to the laboratory for further analysis. The electronic equipment such as GPS (Global Positioning System) was used to define the coordinate of the samples collected (Figure 1).



Fi Stations of sediment collected from estuary and coastal areas

3) Grain-size analysis

The dry sieving method was applied for coarser grain samples (size larger than 63µm) and the most widely used for most grain-size analysis. Samples were dried in the oven at 70–80 °C for about 24 hours in the oven. A portion of sample, approximately 100g was weighed, and sieved and shaken using a shaker machine for about 10 – 15 minutes. The mesh size of sieve series were arranged consecutively finer downwards from 4000 – 63µm.Samples retain in each mesh size were weighed and the values were recorded in a spreadsheet. The statistical analysis applied the moment method suggested by [4,5,6].

Meanwhile, finer samples (< 63µm) were analyzed using the laser diffraction method. Samples were initially heated on a hotplate at temperature of 40 – 60 ºC and few drops of hydrogen peroxide (H_2O_2) were added gradually until the reaction stops (the aim was to remove all the organic matters in the samples). Samples were added with dispersing agent known as Calgon solution (*Sodium hexametaphosphate*) to aid the break-up of flocks that may formed by clays. The samples were left overnight before analyzed with the laser diffractometer machine.

4) Bathymetry

The study comprises of two major parts; sediment distribution and bathymetry (seafloor morphology), taking into account the seasonal changes during before and after monsoon activity. The initial sampling was carried out during September 2008 (pre-monsoon) while the second sampling was conducted in March 2009. Data acquisition consists of bathymetry survey (using echo sounder), sediment collection and some physical parameters measurement (e.g. current velocity and tidal level). Comparison was made from the data collected in order to identify and analyze the related changes in conjunction with seasonal variation.

The bathymetry survey was applied to map the seafloor morphology and to determine any changes using the comparison technique of multi-date survey. Survey equipments usedincludes combination of multiple transducers and software such as echo-sounder, DGPS (DifferentialGlobal Positioning System), HypackMax and notebook computers. The transducer (echo-sounder) was mounted directly to the boat and joint with the DGPS antenna (Figure 2). A total of 50 transect lines (40 at the nearshore area, and 10 at the estuary area) were covered with an even interval of about 50m. The total length of each line was approximately 1km. The survey output was generated in three-dimensional form (3D) using Surfer software.

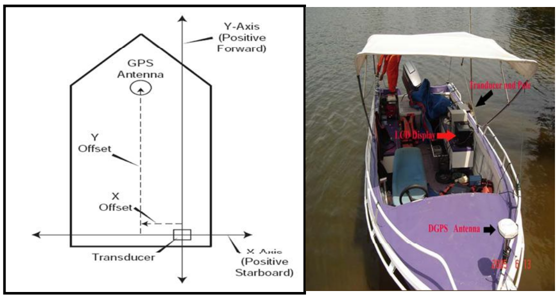


Figure 2: The boat equipped with the survey equipments

III. RESULTS AND DISCUSSIONS

1) Sediment characteristics

a) Mean size

The higher mean values indicate finer grain sediment and the lower mean values indicate a coarser grain. From the results obtain, the range of mean size value of sediment for nearshore zone were 2.00 - 7.00 phi (φ) (pre-monsoon) and 0.28 - 5.20 φ (post-monsoon) (Figure 3).While for estuary area, the mean size rangedbetween 0.30and 7.01 φ during pre-monsoon, and 0.21 to 6.86 φ during post-monsoon season (Figure 4). In general, the nearshore samples were classified as fine sand, coarse silt and medium silt. The estuary samples however, were classified as coarse sand, medium silt and fine silt.

It could be noted that finer sediments were dominated during pre-monsoon period at most stations for both nearshore and estuary areas.

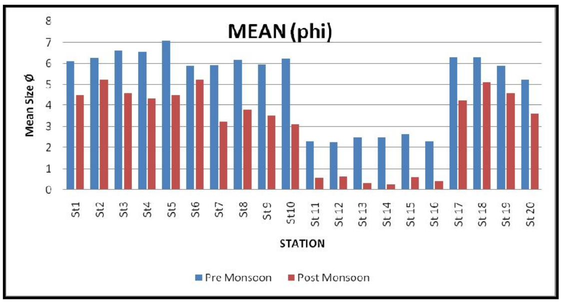


Figure 3: Sediment mean size (φ) value during pre and post monsoon of the nearshore area

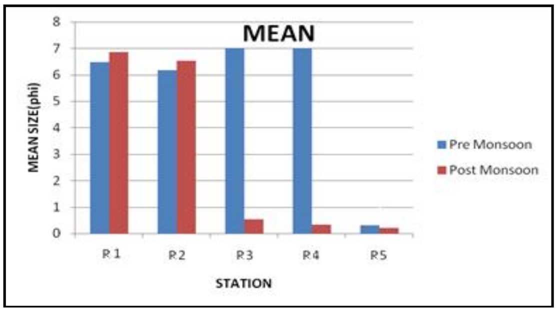


Figure 4: Sediment mean size (φ) value during pre and post monsoon ofthe estuary area

Based on Figure 5 and Figure 6, the distributions of the sediment mean size value were influenced by northeast monsoon. According to Wong [7] 73% of waves of more than 0.46 m observed during December to February compared to only 48% in May to September. During monsoon, the waves and current generated are at the maximum forces causing higher effect towards shoreline. The construction of breakwater act as dams to littoral drift causing a built-up of beach on updrift side and at the same time, serious erosion occurred to the downdrift direction. The sediment movement in estuary during monsoon season causes the sediment from upstream to be dumped at the coastal area due to existence of breakwater, which slows down the current velocity causing coarser sediment on seabed.

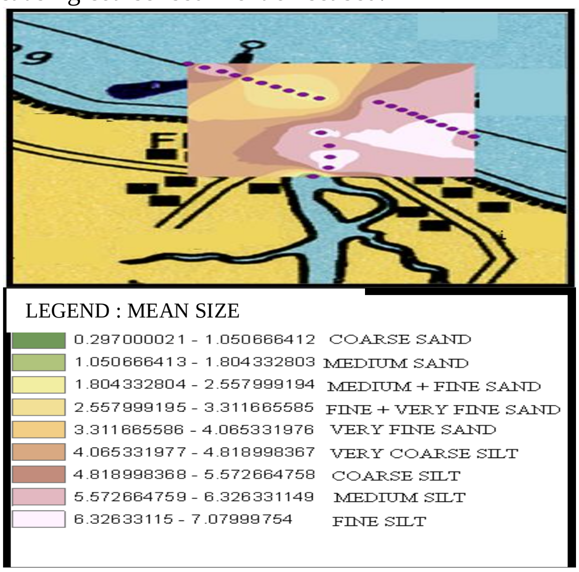


Figure 5: Sediment mean size distribution during pre-monsoon period

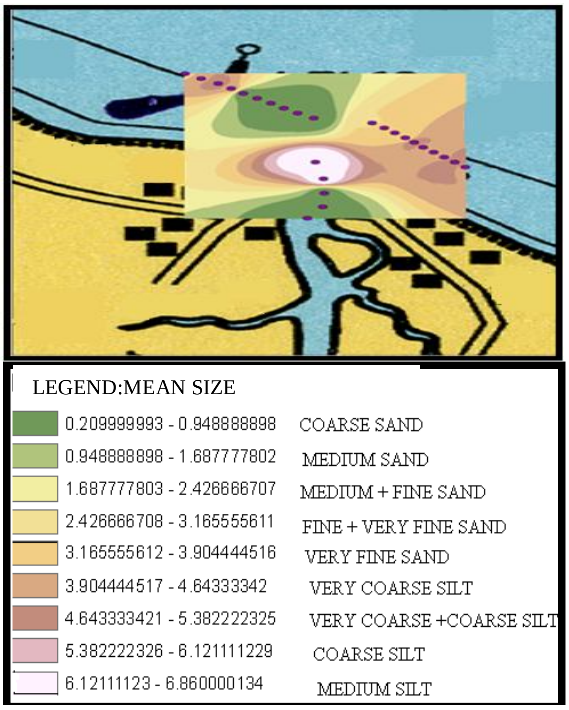


Figure 6: Sediment mean size distribution during post monsoon period

b) Sorting

Sorting, also known as standard deviation indicates the range of forces which determine the sediment size distribution [8]. High sorting value means poorly sorted sediment while low value of sorting indicates well sorted. Based on the analysis, sorting value for the nearshore area ranged from 0.36φ (station 16) to 1.88φ (station 20) during pre-monsoon (Figure 7). The average sorting value was considered as poorly sorted (1.24φ).

However, during post-monsoon season, the average sediment sorting was moderately well-sorted (0.64φ) and ranged between 0.13φ (station 13) and 1.02 φ (station 3). Meanwhile, the average sorting type at the estuary area was poorly sorted and ranged between 1.05φ (station R5) to 1.74φ (station R1) during pre-monsoon. The same sorting type obtained during post-monsoon except for station R4 (moderately well sorted) and station R5 (moderately sorted). The range of sorting value was between 0.53 to 1.82 φ (Figure 8).

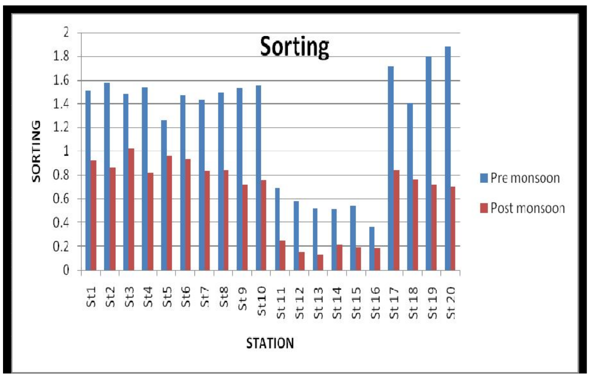


Figure 7: Sediment sorting (φ) value during pre and post monsoon of the nearshore area

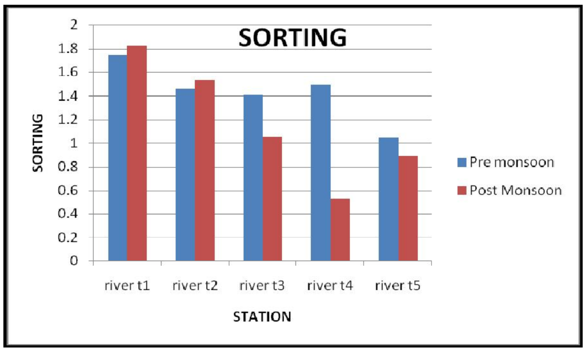


Figure 8: Sediment sorting (φ) value during pre and post monsoon of the estuary area

According to Rosnan et al.[9] sediments in the South China Sea ranged from poorly sorted to very poorly sorted and sediments from the north-western part tend to be coarser toward the coastal region, as a result of the accumulation of larger grains as they roll toward the land area due to the effect of currents.Figure 9 and Figure 10 show the sorting distribution for both nearshore and estuary areas respectively.

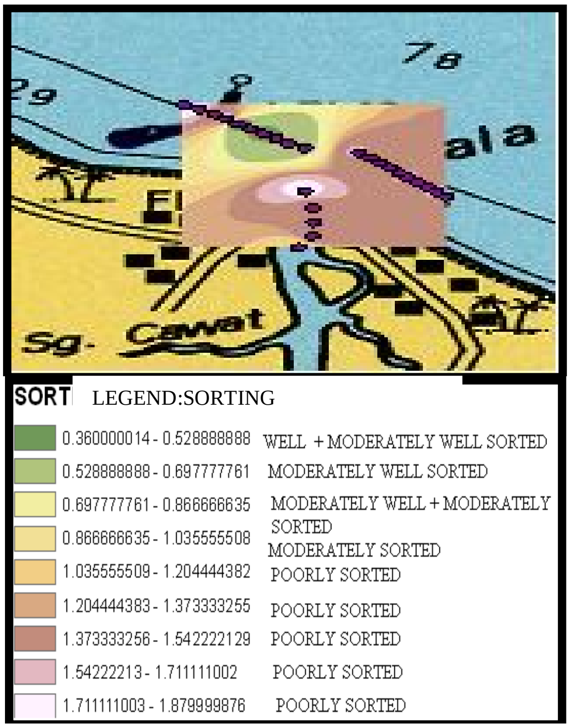


Figure 9: Sediment sorting distribution during pre-monsoon period

Overall, the sediment sorting were disturbed by the monsoon activity where most of the sediment were confined of moderately sorted at the upstream and further downstream which is near to river-mouth, and moderately well sorted at further downstream region. Sediment at the estuary area consists of poorly sorted (river-mouth) and well sorted (coarse grain) at the middle part of the river. This indicates that smaller particles were transported away from the shore and leaved the coarser grain settled down. Sediment near the breakwater was poorly sorted, due to current flow was slowed down by the breakwater structures that caused sediment dumped near the river-mouth. The breakwater will alter the water circulation and the sediment will be redistributed to downdrift region during non-monsoon season.

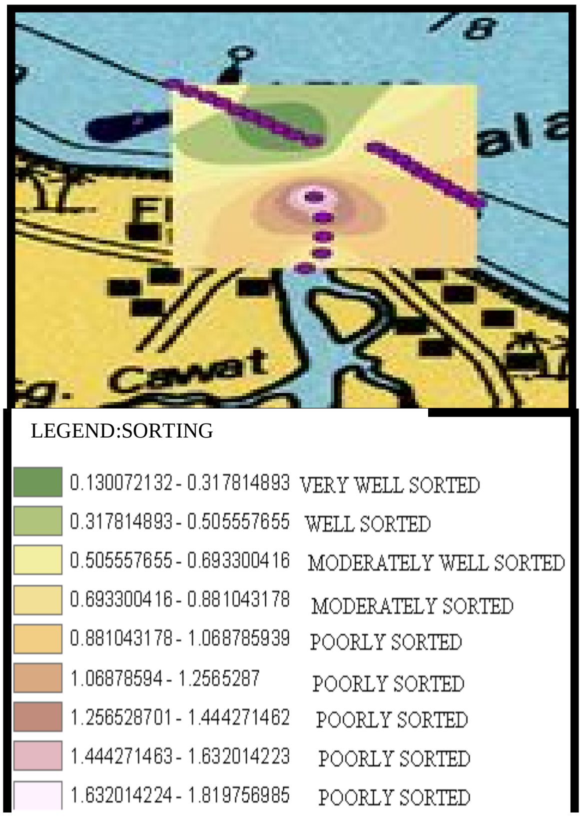


Figure 10: Sediment sorting distribution post-monsoon period

b) Bathymetry

Figure 11 shows the 3D image of bathymetry obtained during pre-monsoon survey. The left region had undergone significant erosion while the other region experienced accretion of sediment. The variability of sediment load supplied to the river-channel and intensity of the two opposing forces within seasons resulted in seasonal changes to the river channel geometry [10]. The river depth ranged of 1 – 4 m due to high sedimentation rate at the nearshore area and minimal flow of current velocity in the river system, causes in deposition of sediment at the rivermouth.

The alternation process (between erosion and deposition) was mostly affected by the breakwater installation. During post-monsoon period, the morphology of seafloor of Kuala Besut revealed that the left-region undergone more serious erosion but further down, sediments were accumulated as closer to the groin structure at shore (Figure 12). At the right region, the same situation happens where sediments were eroded at the upper side and accumulation occurred as further down the area. Meanwhile, at the estuary area, positive effect was observed through decreasing of depth value which means accretion process was active at that area.

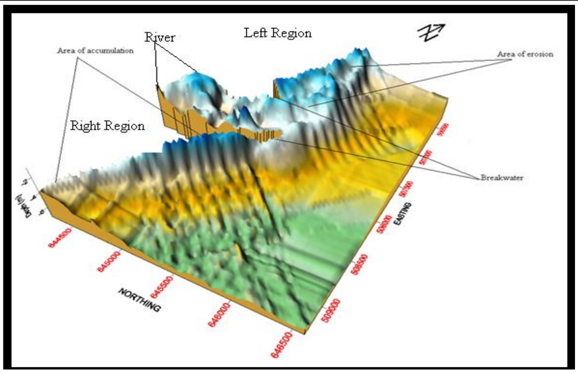


Figure 11: Bathymetry mapping of Kuala Besut (pre-monsoon)

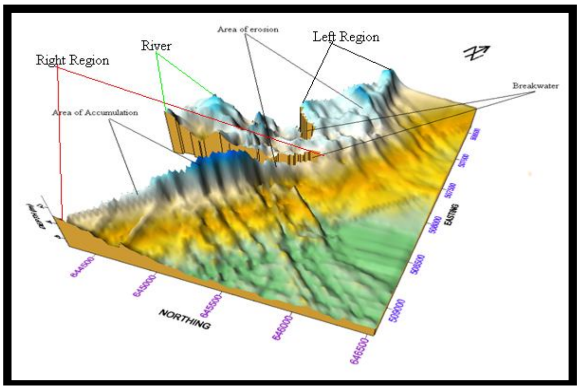


Figure 12: Bathymetry mapping of Kuala Besut (post-monsoon)

The northeast monsoon plays a great role in distributing the sediments at the study area. Among the main factor that contributes to the seafloor changes is the littoral drift that transports the sediment along-side and across the coast. Also, the man-induced activities such as sand mining project thus cause the sediment to distribute unevenly and disturb the natural behaviour of the sediment transport. The sand dredging activity is conducted regularly at this area in order for deepening the river and estuary for the navigational purposes. This is because Kuala Besutis known as the terminal for tourist to visit Perhentian Island, and also as the fish landing base. It was estimated that the bed load transport at the river-mouth of Kuala Besut varied from 75,000 to 100,000 m^3/year (RanhillBersekutu, 1994).

CONCLUSION

From the study, the sediment distribution at the nearshore and estuary areas shows changes in term of their characteristic. The grain size analysis shows some changes on the mean size during pre monsoon season in the range of 2.00 –7.00 φ while during the post monsoon season, lower mean size range obtained from 0.28 – 5.20 φ. During pre-monsoon, the average sorting values was considered as poorly sorted (1.24φ) ranged from 0.36 – 1.88 φ. Meanwhile, during post-monsoon, the sorting values ranged between 0.13 – 1.02 φ with an average value of 0.64 φ (moderately well-sorted). The northeast monsoon thus causes changes in sediment distribution due to higher rainfall and wave energy resulted finer sediment transported further offshore, leaving the larger particle behind. Based on analysis of bathymetry, changes in depth was due to impact from the monsoon activity, which brings larger waves and higher current forces to the shore. The different in depth ranges indicates that monsoon had altered theseafloor topography. The factor causes changes of seafloor and eroding sediment due to splashing of waves at the shoreline,and resulted sediment suspended in water column and finally dumped at the breakwater. The breakwater, which was installed to ease boat navigation at initial purpose, had caused problems in term of sediment transportation and distribution.

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