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Prediction of Coastal Erosion/Accretion and Sediment Properties at Batu Pahat Coastal Area

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ABSTRACT

Coastal erosion and accretion may be defined to be natural processes for which predicting the coastal magnitude is essential for a better coastal monitoring. The purpose of this study is to investigate the shoreline sediment properties and prediction of coastal erosion in an eroded region in Batu Pahat. Pantai Punggur was chosen as one of the research locations because of the condition of the beaches, which were designated as eroded regions as it is experiencing erosion. Sampling points were separated into four zones to better understand sediment transport: Zones A, B, C, and D. The sediment parameters of the studied samples were determined and described as a result of this research. Moisture content, specific gravity, grain size distribution, pH value, shear strength, and organic content were the studied parameters. Further studies, such as settling velocity and erosion and accretion prediction, were calculated based on those properties. From the analysis, Zones A, B, and D were projected to erode, whereas Zone C was predicted to accrete. The results of this study are useful in terms of comprehending morphological traits, which will aid in the knowledge of sediment transport. Furthermore, these findings are significant for information in the management of coastal concerns.

Keywords: Coastal erosion, accretion, sediment properties, shoreline

1. INTRODUCTION

Coastal erosion is a natural phenomenon resulting from the interactions between processes and the system. Coastline changes may occur due to two main factors which include natural factors and also by the factors of human activities in the coastal areas. Sea level rise, erosion and sedimentation are among the factors that contribute to the natural changes in the coastline, while the reclamation and development in coastal areas are factors of coastline changes due to human activities. Batu Pahat is an area with significant changes of coastline [1].

Coastal erosion is frequently caused by the combination of natural processes and human activities, particularly in places that are geologically and geomorphologically vulnerable and are not sufficiently protected. The existence of the port and other human activities on the coastal strip, activate the primary erosional processes found in their research region, including water extraction from the subsoil, which causes subsidence, and the use of sediments as inert material [2].

According to certain research, the seasonal monsoon is a key element that amplifies the natural phenomena that cause beach alterations. During the seasonal monsoons, [3] investigated beach morphodynamic categorization throughout the Terengganu coast. According to the findings, calm conditions were produced during the southwest monsoon (SWM), but storm conditions were

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observed during the northeast monsoon (NEM), resulting in erosion owing to a greater wave energy environment. Similar results found in a study of beach morphology changes between NEM and SWM at Mantanani Besar Island in Sabah [4]. These research findings are useful in formulating and piloting an effective coastal zone management plan for monsoon-dominated coasts, as well as serving as a guide for any future development of shoreline management plans.

Coastal erosion has a potential to directly impact coastal and island regions. Due to this issue, a study on shear stresses and sediment properties was carried out at Kampung Sungai Lurus, Batu Pahat shoreline. They found that erosion process occurred at the study area with shear stress of sediment being higher than critical shear stress. It also showed that the erosion process constantly happens and damages the toe of revetment [5].

The shoreline of Batu Pahat practically has no beaches and mostly mudflats which have limited accessible beaches [1, 6]. Various coastal tidal flats, particularly those that are tide-dominated, are muddy [7]. However, when compared to sandy beaches, the number of studies on the profile form and surficial sediment distribution of muddy tidal flats is uncertain. Lack of studies on such condition motivated the conducting of this study.

2. METHODOLOGY

2.1 Study Area

This study is focused on the west coast of Malaysia, at Pantai Punggur, Batu Pahat of Johor which is shown in Figure 1 (a) – (c). Pantai Punggur is listed as one of the critically eroded sites. Batu Pahat experienced severe coastal erosion. Their research showed that 85.84%of Batu Pahat is experiencing extreme erosion that occurred only within 3 years (2011-2013) [6].

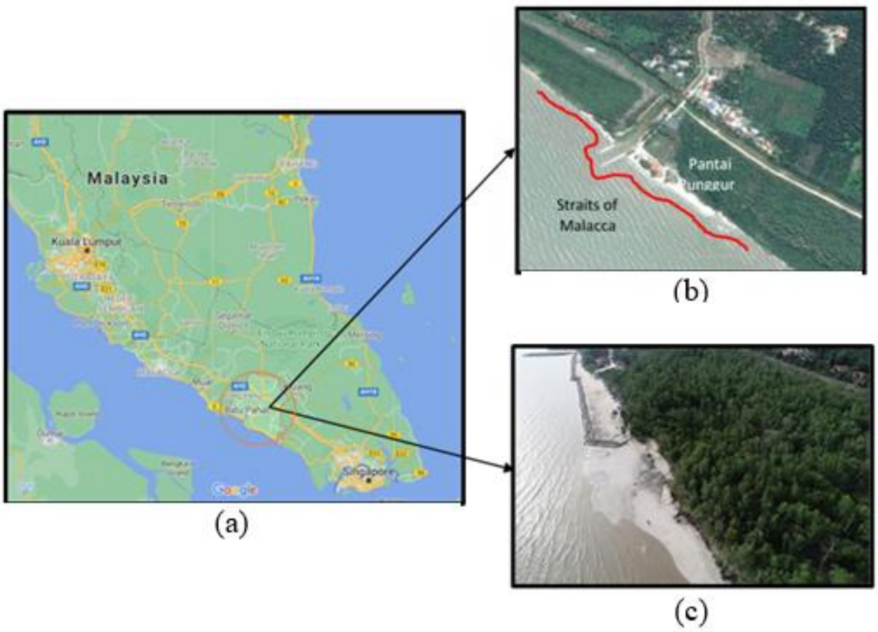

Figure 1. (a) Location of Pantai Punggur, Batu Pahat (image from Google Maps), (b) Image of Pantai Punggur retrieved from Google Earth, (c) Aerial view of study area at Pantai Punggur.

Several site visits to the study area were carried out, which was a preliminary survey in early 2019 – early 2020 as shown in Figure 2. From the site visits and a comparison photographs taken one year apart, it was observed that some Labuan Blocks had collapsed which imply early identification of sea level rise and erosion which need a further investigation.

(a) 2019

(b) 2020

Figure 2. Condition of the Revetments (Labuan Blocks) Sungai Punggur in (a) 2019 and (b) 2020.

2.2 Sampling Points and Works

Coastal morphology addresses the evolution of coastal features such as sediment (sand and silt-clay) and their interaction with hydrodynamics, which is an important subject in coastal studies. One of the most essential steps in soil testing is soil sampling. The soil sampling is the earliest part of the soil testing process and the foundation for information derived from laboratory analyses, soil test interpretations, and recommendations.

In order to study the sediment transport, sampling points were divided into four zones, namely Zone A (no revetment area), Zone B and Zone C (revetment area), and Zone D (no revetment and located near mangrove area). Figure 3 shows sampling stations that consist of four zones with the position of high tide (HT), mean tide (MT) and low tide (LT).

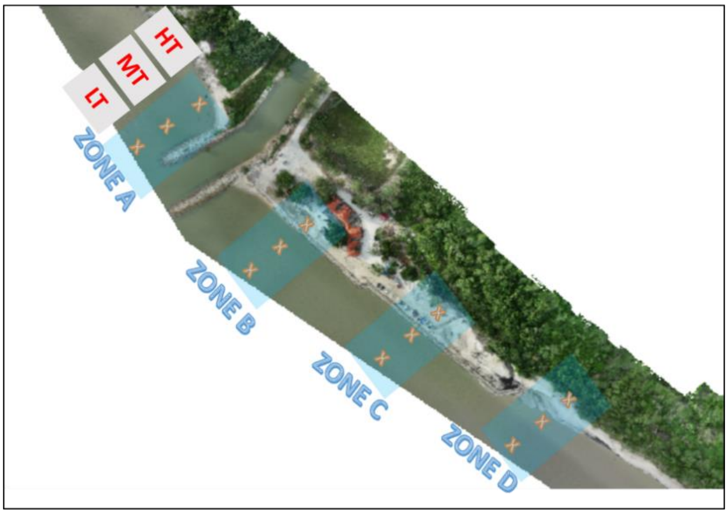

Figure 3. Sampling stations that consist of 4 zones with overall 12 sampling points.

The term "disrupted sample" refers to a sample in which the soil structure has been significantly disturbed by the operation of boring tools or excavation equipment [8]. Disturbed and undisturbed samples were collected from sampling points using hand auger. The freshly retrieved soil samples were first wrapped with layers of cling film, then tightly bound in plastic bags to prevent moisture loss during transportation and storage. For disturbed samples, the soil can be extracted neatly using hand auger. However, for undisturbed samples, sediment core extraction method is necessary. Core samples serve as an excellent tool for establishing the sedimentation rate, the history of contaminant in the water system, and the accounts of impurities [9].

A polyvinyl chloride (PVC) tube was used as a core container to keep the samples in a cylindrical shape. The PVC tube has an outside diameter of 88.24 mm, 83.85 mm inside diameter and 200 mm height. As described by [9], in practice, tube diameters of about 5 cm and 12 cm are commonly used. The tube diameter should be as large as is practical in order to provide sufficient material for analysis, to minimize the impact of smearing along the core edge, and to minimize the possibility of core compression.

For undisturbed core samples, it is important to collect the original layers of the sediment without disturbance and avoid losing important parts of the core. Soil layer depth for subsoil is 0.51 – 1.00 meter and is suitable to be used in determining soil loss [10]. The process of collecting the soil samples started with augering the soil 0.5m from the soil surface. After the depth of 0.5 m was reached, the PVC tube then is pushed into the soil. If the top layer of sediment contains significantly higher concentrations of the analyst of interest, it may be necessary to eliminate a potential smearing problem by discarding the outer rim of material in contact with the PVC tube.

Disturbances such as in situ changes the condition will always happen. The magnitude of the disturbance depends on soil condition, sampling method and expertise. All samplings will usually include less material, required more time, and tools used for sampling is more specific. In addition, when operated with intact samples, it is important to always remember to protect the water content, and exposure to vibrations and temperature should be limited. For undisturbed samples, the soil samples were sealed by waxing at both side of the tube and wrapped with the plastic foil.

2.3 Sampling Points and Works

Laboratory work was carried out to determine the physical properties of sediment in Pantai Punggur. Laboratory work performed in this study were moisture content, specific gravity, hydrometer, pH, vane shear test (VST) and loss on ignition (LOI). All the tests were conducted according to the standard procedures given in BS 1377: 1990 [11]. The determination of shoreline sediment properties is needed to understand the soil behavior and further analysis can be conducted to determine the settling velocity and prediction of coastal erosion sedimentation.

3. RESULTS AND DISCUSSION

3.1 Sediment Properties

Moisture content test was conducted to determine the percentage of water content in the soil samples. The results of moisture content test are as shown in Figure 4. Low moisture content was reported at HT area which ranged 27% - 37%. The location of the sampling point B which was near to the dykes and area with Labuan Blocks could be one of the factors that contributed to the lower value of moisture content compared to the other zones. Moisture content of samples at LT and MT ranged from 95% (Zone B) to highest at 130% (Zone C). These results agreed well with [12] which reviewed that marine clay moisture content varied from 39% to about 175%

depending on the depth and location from which the soil was obtained.

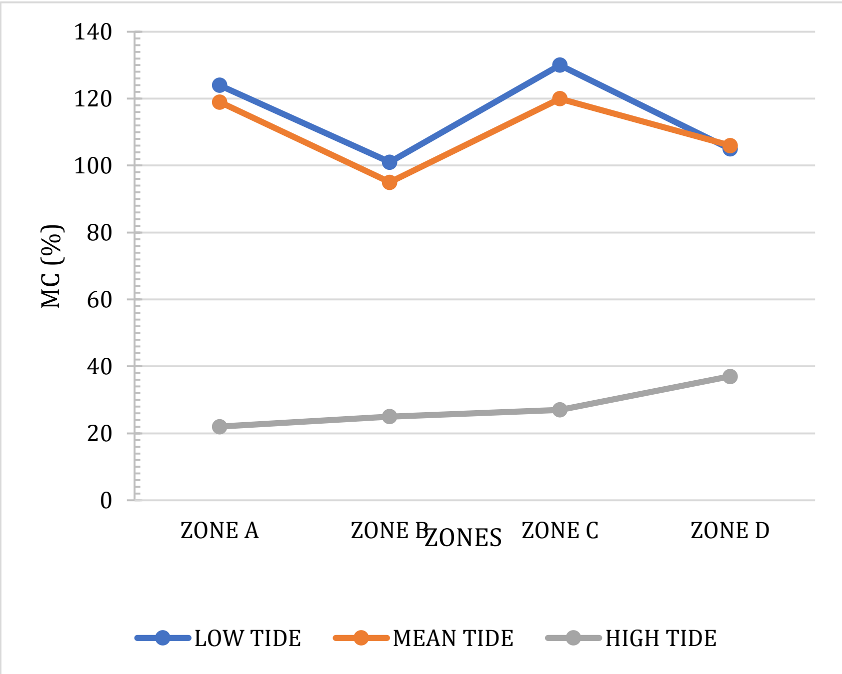

Figure 4. Moisture content results.

Figure 5 shows loss on ignition test results, which quantify the organic content. Organic content in soil samples ranged from 1.55% to 8.21% and samples at HT and MT were mostly higher than LT, which were above 5.4%. Similar findings have been reported by [13] where the authors claimed that organic matter has been moved from from the sea and deposited landward during tidal and wave flow.

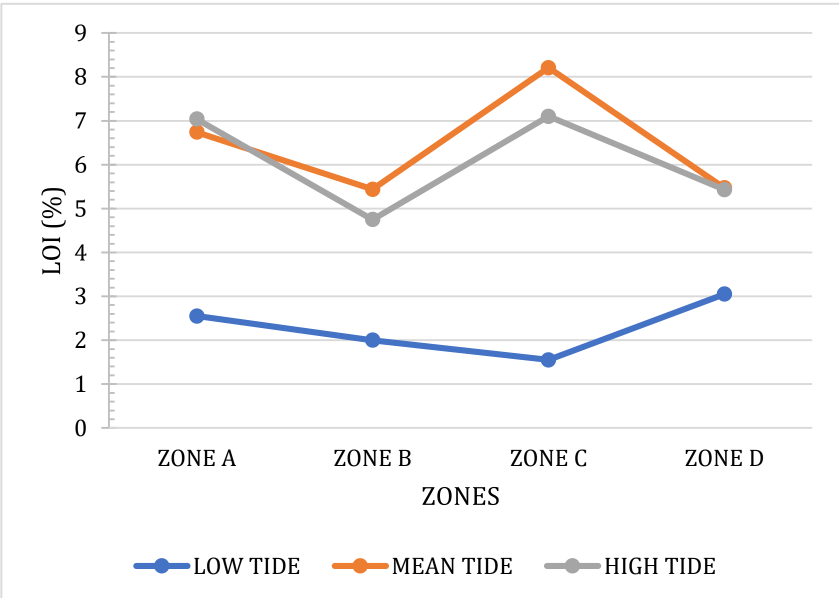

Figure 5. Loss on ignition test results.

Figures 6 and 7 show the results of specific gravity and pH respectively. It was found that specific gravity ranged between 2.628 to 2.73 and these agreed with [14] where specific gravity between 2.6 until 2.9 is considered as silt and clay. Based on the pH value results that ranged from 6.33 to 7.34, it was found that the sediments of the samples were an alkaline soil at almost all Zones B, C and D. Zone A ranged below than 7.00 which indicated existence of acidic sediment materials. These show that Zone A has a low value of specific gravity and contains an acidic sediment material and that these two parameters may affect in eroding the soil.

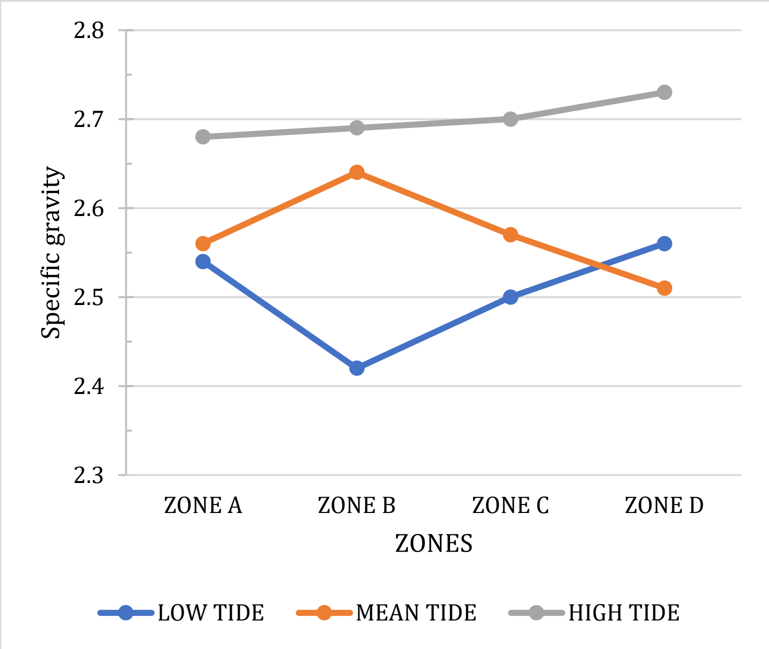

Figure 6. Specific gravity results.

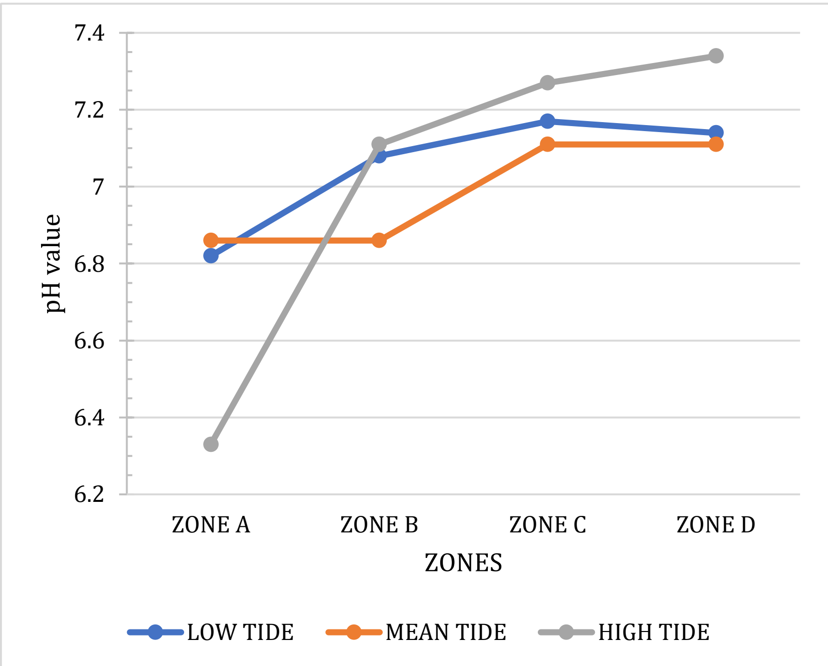

Figure 7. pH values.

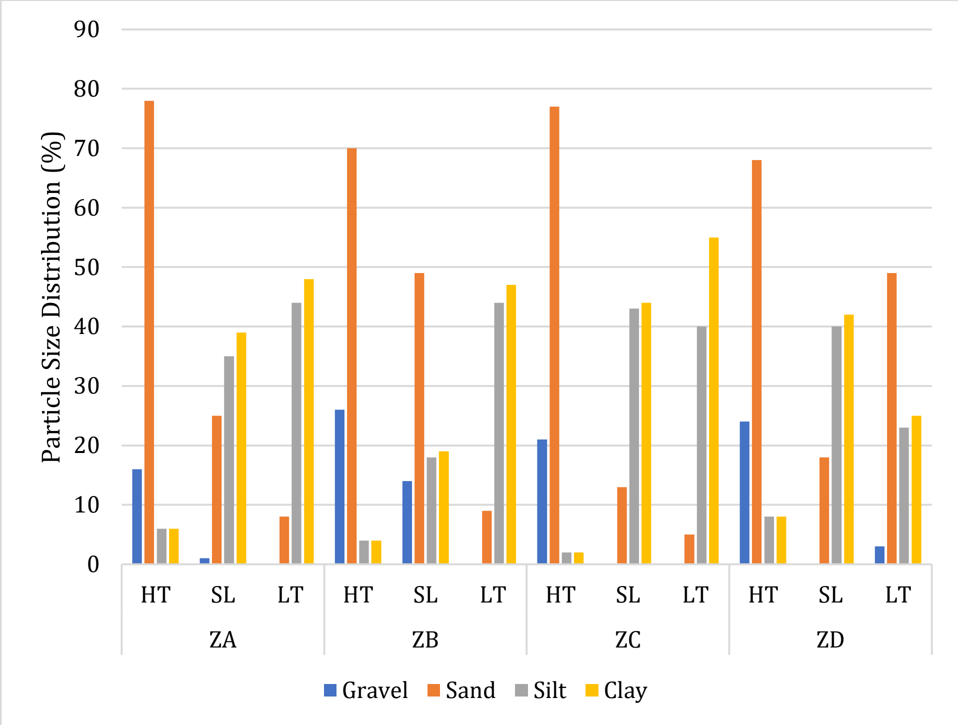

Figure 8. Particle size distribution of collected sediment samples.

The grain size distribution of collected sediment samples are as shown in Figure 8. Gravel percentage at HT points at all zones ranged from 16% - 26% and 14% at MT in Zone B. However, at other points the gravel percentages were as low as 0 – 3%. The highest percentage of sand was 78% at Zone A (HT) and lowest was 5% at Zone C (LT). For clay and silt, the highest clay (48%) and silt (44%) were both at Zone A (LT). The lowest clay and silt were at Zone C (HT) which was 2%. Particle size distribution shows that HT points at all zones are dominated with sandy gravel. For MT points at Zone A is silty clay, Zone B is sandy silt while for Zones C and D both are clayey silt. However, at LT area all zones are clayey silt except at Zone D which is sandy clay.

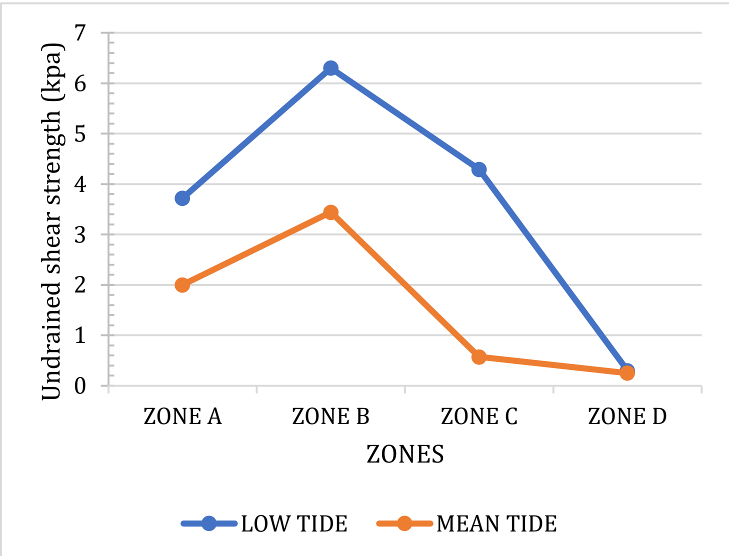

Figure 9. Undrained shear strength test results.

Results for undrained shear strength are as shown in Figure 9. The graph trend for MT is similar to LT points. It can be observed that highest strength is at Zone B and lowest at Zone D. From the test, it clearly shows that shear strengths of all samples are not larger than 10 kPa. This shows that the clay strength is extremely low which cannot even stand its self-weight. Cohesion strength value for marine clay is reported as 3.5 kPa [15].

3.2 Prediction of Coastal Erosion and Accretion

Prediction of coastal erosion and accretion is important, as it can be a risk assessment as per a basis for guiding coastal management. Erosion and accretion prediction in this research are based on a dimensionless parameter called the Dean number produced by [16] as described in [17]. The Dean number is calculated as $N = H/wT$, where H is the significant wave height, w is the settling velocity and T is the wave period. If $N > 3.2$ erosion is predicted whereas if $N < 3.2$, accretion is predicted. Figure 10 shows Dean number and settling velocity results for all zones. Note that N values more than 3.2 serve as an indicator in predicting the erosion. Almost all zones predicted occurrence of erosion except for Zone C. Although N value at Zone C did not reach 3.2, the value is considerably close to 3.2, which was 3.14. Note that highest settling velocity also occurred at Zone C.

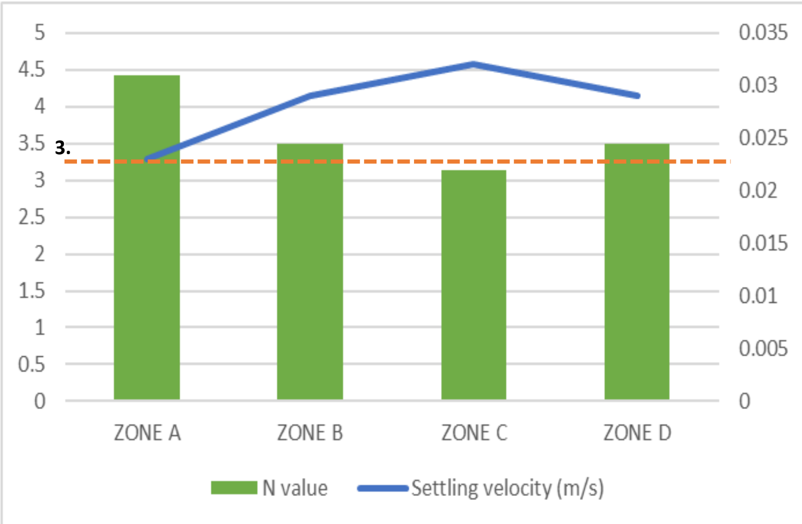

Figure 10. *N* value from Dean number and settling velocity results.

Sediment size is one of the factors affect the fall velocity of soil particles. The velocity will decrease with increasing concentration of fine sediment dispersed in water and vice versa [18]. This explains why Zone C had the highest settling velocity compared to other zones. As described in particle size distribution (Figure 8), the lowest clay and silt are at Zone C (HT) which is 2%. It clearly shows that the low concentration of fine materials increased the settling velocity. Meanwhile Zone A had the lowest settling velocity and the highest N value which indicate that the erosion probably occurs. This situation is in line with the high concentration of fine sediment at Zone A. Furthermore, th rate of sediment transport could be increased with the presence of fine particles in the structure.

The prediction of erosion and accretion clearly shows a relationship with the sediment size and the prediction agrees well with [19]. The authors used Kraus's equation to predict the erosion/accretion and they concluded that the relatively large sediment grain size will experience sedimentation and the smaller grains will be easily carried away by the waves and currents (also known as sediment transport) which led to the prediction of soil erosion.

4. CONCLUSION

In this study, sediment properties of the study areas were determined and described. The studied sediment properties were moisture content, specific gravity, grain size distribution, pH value, shear strength and organic content. From these properties, further analyses such as settling velocity and prediction of erosion and accretion were determined. The results showed that Zone A, B and D were predicted to experience erosion and Zone C was predicted to experience accretion. The presence of fine particles in the system decreased the settling rate and increased the probability for the area to erode.

The findings showed that Zone A is at a high-rate value for erosion prediction followed by Zone D. Note that both zones had no presence of any revetment protection and this explains why the predictions were as such. Zone B and Zone C are situated at the revetment area. Nevertheless, only Zone C was not predicted to experience erosion. This situation showed that although revetment was used as protection against erosion which was evidenced at Zone C, the failure might occur particularly at the area experiencing erosion (Zone B).

The findings obtained from this study provide valuable information in terms of understanding morphological characteristics that will assist in understanding of sediment transport. In addition, these findings are essential for the information in managing coastal problems, and for the sake of future improvement in the study of solving the coastal erosion issue.

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