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Beach Volume Changes and Shoreline Sediment Properties at Eroded Area in Batu Pahat

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Abstract: This research is about the correlation between the beach volume changes and shoreline sediment properties at eroded area in Batu Pahat. Pantai Punggur is selected as the study area as it indicates signed erosion to critical erosion. The objectives of this research are to study the beach volume changes and shoreline sediment properties thus correlate both parameters. The identification of beach volume changes is essential to evaluate the changes in volume at the coastal area whereas the study of shoreline sediment properties is compulsory to assess the beach condition. Shoreline sediment properties has been identified by carried out several soils testing, whereas the analyzation of beach volume changes has been done by processing the aerial image in Pix4D Mapper and the analyzation of beach volume changes were carried out by Global Mapper Software. This research indicates that the volume changes of the beach portray a significant change within one month interval. Based on the result obtained, the minimum and maximum average moisture content range between 70.1-122.6%, whereas the specific gravity data lies within 2.54 to 2.77. For the particle size distribution, the percentage of sand is higher at HT (High Tide) and the percentage of silt is dominant at MT (Mid Tide) at each coastal zone. In addition, the sampling point away from the shoreline showed, the lower the bulk density. In summary, the data obtained shows that Zone A and E are more prone to erosion compared to the other zone since there are no revetment at Zone A and Zone E. This proves that shoreline sediment properties have a correlation with beach volume changes that may resulted to an erosion condition.

Keywords: Beach Volume, Volume Changes, Sediment Properties, Coastal Erosion.

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1. Introduction

Beaches are often related to coastline which corresponds to the definition of coastline itself which refers to the interface between land and water. Beaches are assigned as an area with high morpho dynamic activities due to its vulnerability upon changes due to erosional and depositional process[1]. The erosion that takes palace will then affect the sediment volume change as both are corresponding with one another This phenomenon has contributed to the changes of soil properties which may lead to the difference of the soil behavior physically and chemically. Beach volume changes can be used to evaluate the beach response when experience coastal process mainly the coastal erosion. The observation of beach volume changes and shoreline sediment properties is crucial so that the understanding about the factors that contribute to the changes as well as the condition of the beaches can be studied.

The objective of this research is to identify volumetric change in shoreline area by using Unmanned Aerial Vehicle (UAV), to investigate the physical properties that contribute to the changes of sediment properties and lastly to correlate beach volume changes with shoreline sediment properties at eroded area. Pantai Punggur, Batu Pahat has been classified as one of the worst eroded areas in Batu Pahat. The study of shoreline sediment properties is compulsory to analyze the condition of the beaches so that the suitable nourishment plan can be implement in that area[2].As the technologies tend to develop rapidly, the demand of technologies and approach for research are relatively high. Therefore, in order to meet the demand, the process of identifying volumetric of shoreline area can be done by using Unmanned Aerial Vehicle with the aid of Pix4D Mapper and Global Mapper as a medium to analyze the beach volume changes. For the shoreline sediment properties, the implementation of laboratory works is used as a medium to gather the data.

2. Coastal Geomorphology

Coastal geomorphology studies the effects of large bodies of water, such as seas and oceans, and big lakes. The study of the morphological evolution of the shore under the impact of wind, waves, currents, and sea-level fluctuations [3]. In simpler words, physical processes interact to erode, move, and deposit sediment to build landforms. The cross-shore sand transport limit and profile equilibrium delineation are key concepts in coastal geomorphology. The increasingly developed nature of the country's coastline will undoubtedly increase demand for beach nourishment.

2.1 Beach Volume Changes

Beach volumes refer to the volume of sand seaward of a benchmark and above the original defined of the vertical datum. Variations of beach volume changes have been implemented at the coastal area to quantify the changes in volume as well as study the beach response that can be done with geometric and volumetric comparison of beaches profile sets. The comparison is paramount to understand the beaches response towards the coastal process[4]. The beach volume changes are essential to monitor in recent years as the coastal zone will experience changes due to environmental factor including wave speed, wind speed and tidal height. The identification of beach volume changes is essential to evaluate the changes in volume at the coastal area so that the changes can be quantify.

2.2 Coastal Erosion

Coastal area describes as the interfaces between land and water. This area is highly vulnerable towards a natural hazard of the climate changes mainly during the occurrence of storm and sea level rise (SLR) problems [5]. Coastal erosion is one of the coastal process that frequently occurred at the coastal area. This can be proved by the data from National Coastal Erosion Malaysia Study (NCES) on 1985 that conclude about 29% of shoreline is eroding. Pantai Punggur is one of the area experience critical erosion in Batu Pahat [6]. The erosion that takes places at the coastal area were categorize into the category that lies within critical, significant, and acceptable category[7]. Coastal erosion is defined as the loss of coastal land due to net removal of sediments from the shoreline and this process are also called as shoreline retreat [3]. The erosion occur at the coastal area are mainly by occurrence of natural disaster and anthropogenic impact.

2.3 Coastal Sediment

Coastal sediment is composed of solid particles that move with the tides or waves but do not float. Coastal sediments come in a variety of origins, forms, sizes, and chemical compositions. Weathering of rocks, shell pieces, organic debris, and chemical precipitation create coastal silt. River currents or flows may bring sand to the coast. The coastal margin is a good place for coastal silt to deposit because river currents slow down as material reaches the ocean [8].Waves, currents, and tides re-distribute material collected on the beach. Conversely, sand accumulations may impact water flows, providing required feedback for coastal landform change. A lack of sediment movement out of the ocean causes horizontal accumulation, resulting in soft coastlines, including beaches and low-relief coastal landforms like foredunes and coastal terraces. Coastal sediment deposits are naturally dynamic, responding to variations in water levels, winds, and waves. Affected initially by natural or man-made changes, coastal silt is one of the most sensitive coastal features. This highlights the necessity of analyzing coastal geomorphology, which is linked to other natural processes.

2.4 Sediment Transport

Sediment properties are classified into two categories which are single sediment and bulk sediment. These two distinct groups of sediment properties need distinct types of research. When considering the single sediment properties of the sediment transport, the particle size, shape, density, specific weight, and fall should be considered, whereas when considering the bulk sediment properties, the size distribution, specific weight, and porosity of the bed materials will be considered [3]. Physical sediment qualities are critical since they influence the erodibility of cohesive sediment. As a result, sediment properties can be determined in order to fully understand shoreline sediment transport, as these two parameters are related. According to previous research, changes in sediment transport are related to changes in flow rates, water levels, climate, and human activity [9]. It is crucial to study the sediment properties at the coastal area as erosion of coastline does influence by the type of soil at the coastal region.

3. Material and Methods

Sampling points were divided into five zones, namely Zone A (no revetment area), Zone B and Zone C (revetment area) and Zone D & E (no revetment and located near mangrove area). The location of each zone were determined due to the variety of topography at the coastal area. Figure 1 shows sampling point at four tide level on each zone. There is total twenty sampling location were determined at Pantai Pungur. Each zone consists of four sampling location based on tide level composed mainly at Maximum High Tide (MHT), Hight Tide (HT), Medium Tide (MT), and Low Tide (LT). Therefore, in summary there is three soil sample were taken at each tide level. The location of the sample station is determined by numerous parameters, including the distance between the lowest subsoil and high tide, as well as the availability of unobstructed measuring facilities due to roots, barriers, or roadways.

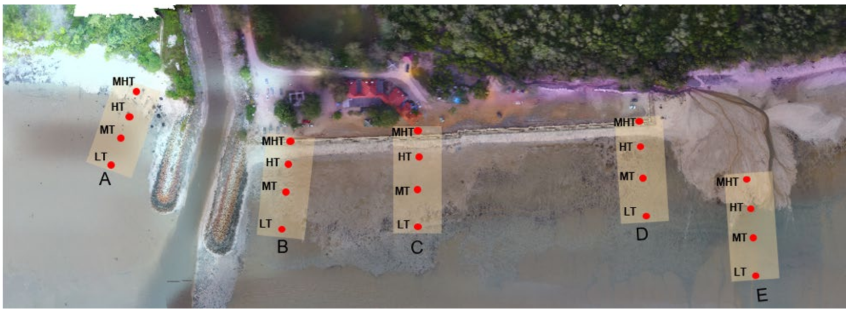

Figure 1: Sampling Point at Pantai Punggur

As for the research, soil sample was carefully extracted to avoid disruption to undisturbed soil sample. The soil sample was extracted 0.5m from surface. There is total 60 sample of disturb and undisturbed soil that were extracted for November and another 10 sample in December. The laboratory testing was carried out to analyses the extracted sample. Figure 2 shows the soil extraction process at Mid Tide (MT) whereas Figure 3 shows the soil sample that has been extracted at coastal area. In order to secure the moisture content, the sample is wrap tightly using a plastic wrap.

Figure 2: Soil Sample Extraction at Mid Tide

Figure 3: Soil Sample

The soil sample extracted at the coastal zone is then undergo several testings to determine the shoreline sediment properties which are moisture content, specific gravity, hydrometer test for particle size distribution and bulk density. Those properties must be analysed and perform a further research to observe any significant findings that appropriate for the sediment loss at Pantai Punggur. In addition, for beach volume changes, the implementation of Pix4D Mapper and Global Mapper software were used as a medium to quantify the beach volume changes. UAV (Unmanned Aerial Vehicle) is used a as tool to capture aerial image of Pantai Punggur with high resolution image to be process by the software. This research implements physical and visual approach to correlate the beach volume changes and shoreline sediment properties.

4. Results and Discussion

Based on the test that were carried out for the extracted sample in the coastal area, the data of moisture content, specific gravity, particle size distribution and bulk density were obtain successfully. Table 1 shows the summary result of moisture content at each zone. The average moisture content for each zone is above 100% at point D and E. Points A, B, and C are all below 100%, yet the values are quite comparable. Zones A, B, and C have two coastal structures that might influence erosion and accretion, resulting in a different moisture content than Zones D and E. For this research, the minimum and maximum average moisture content ranging between 70.1-126.5%. Similar range of moisture content is reported by (Ali,2015), the Authors stated that the lowest and maximum moisture content in this coastal region ranges from 75.8 – 122.6 % with the average moisture content 99.2 % [10].

Table 1: Moisture Content Summary Result

Zone	Average Moisture Content (%)
A	70.1
B	70.7
C	77.2
D	126.5
E	100.1

Table 2 shows the specific gravity data for each tide level. In summary, the specific gravity lies within 2.58 to 2.78. The higher value of specific gravity on each zone lies within the MHT and HT whereas lower value lies at MT and LT one each zone. The pattern for specific gravity data is almost similar on each zone and does not portray a huge difference.

Table 2: Result of Specific Gravity at Each Tide Level

Zone	Tide	Specific Gravity	Type of soil
A	MHT	2.77	Soil with mica
	HT	2.78	Soil with mica
	MT	2.59	Organic Soil
	LT	2.55	Organic Soil
B	MHT	2.76	Soil with mica
	HT	2.73	Inorganic clay
	MT	2.78	Inorganic clay
	LT	2.75	Inorganic clay
C	MHT	2.73	Soil with mica
	HT	2.74	Inorganic clay
	MT	2.58	Organic Soil
	LT	2.59	Organic Soil
D	MHT	2.77	Soil with mica
	HT	2.69	Silty sand
	MT	2.59	Organic soil
	LT	2.59	Organic Soil
E	MHT	2.76	Soil with mica
	HT	2.69	Silty sand
	MT	2.61	Organic soil
	LT	2.54	Organic soil

Particle size distribution analysis is a mechanical study used to determine the particle size of a soil sample. In order to determine the particles size distribution of the soil sample by undergo sieve analysis with hydrometer test. The graph of sieve analysis with hydrometer for particle size distribution is shown in **APPENDIX A.**

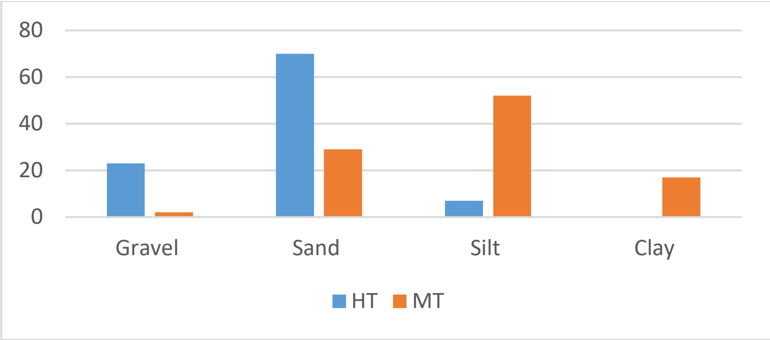

Figure 4: Graph of Particle Size Distribution for Zone A

Figure 4 shows the graph of particle size distribution for zone A, the highest percentage of sand followed by gravel are at the HT whereas the higher percentage of silt and clay are high at MT compared to HT. As for this zone, the further the sampling point from the shoreline, the higher the percentage of silt and clay.

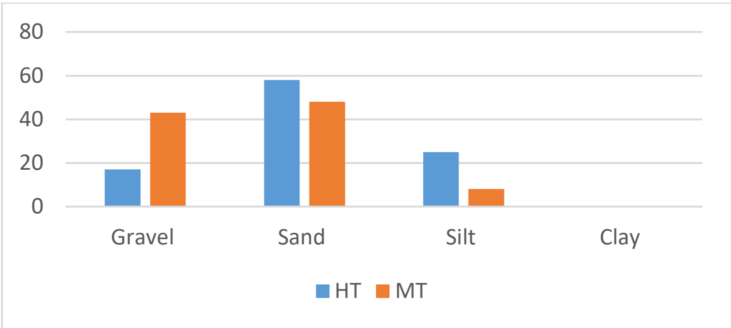

Figure 5: Graph of Particle Size Distribution for Zone B

Figure 5 shows the graph of particle size distribution for zone B. Its shows that the percentage of sand is higher at HT followed by MT whereas for gravel the percentage is higher at MT compared to HT. The location of Zone B could be one of the factors that contribute to the particle size distribution.

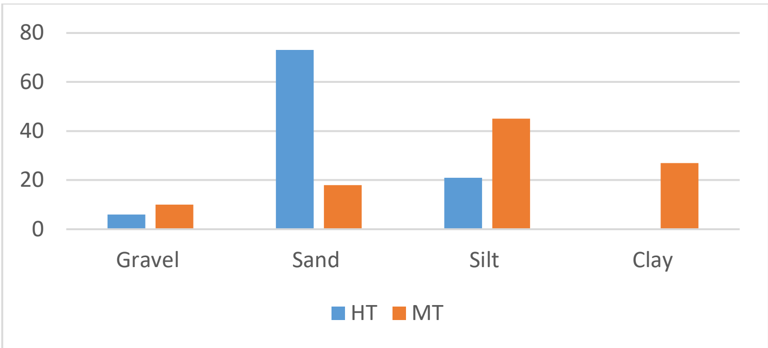

Figure 6.: Graph of Particle Size Distribution for Zone C

Furthermore, Figure 6 shows the graph of particle size distribution for Zone C. At this zone, both HT and MT show the least percentage of gravel which is less than 10%. However, at HT the percentage of sand is higher, triple the percentage of sand at MT. The sampling point for Zone C is hinger in the percentage of silt and clay.

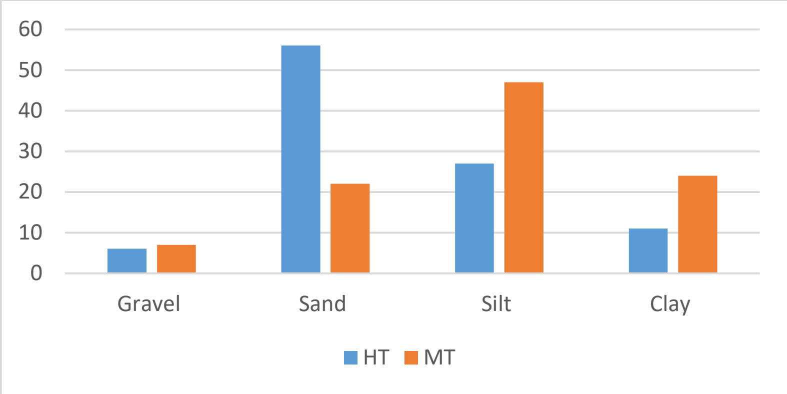

Figure 7: Graph of Particle Size Distribution of Zone D

Figure 7 shows the graph of particle distribution for Zone D where the percentage of gravel is quite similar for both sampling point.This graph shows the similar pattern that the further the sampling point from the shoreline, the higher the percentage of silt and clay in the soil sample.

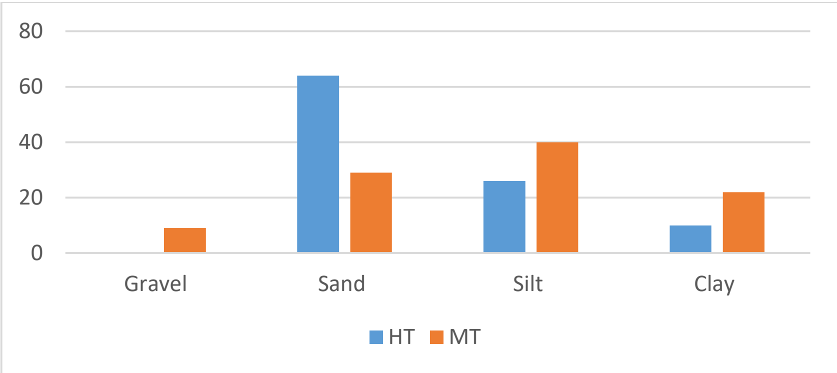

Figure 8: Graph of Particle Size Distribution for Zone E

Figure 8 shows the summary data for particle size distribution for Zone E. The percentage of gravel only found in MT followed by the highest percentage of silt. Follow the other pattern of pervious zone, at HT is will shows high percentage of sand if compared with soil at MT. This can be concluded that soil sample that is extracted at HT will shows the similar pattern which is high in percentage of soil as the sampling point near the shoreline of the coastal area.

Table 3 shows the average bulk density on each zone at the coastal area. In conclusion, the average bulk density in Zones D and E is lower than the average bulk density in Zones A, B, and C. According to the results, the bulk density decrement value is related to the high proportion of clay and silt in comparison to the other three zones.

Table 3: Average Bulk Density at Each Zone

Zone	Average Bulk Density (g/cm^3)
A	1.52
B	1.61
C	1.59
D	1.31
E	1.47

In order to evaluate the difference of bulk density, additional sample were taken in December at HT and MT to undergo bulk density test. Table 4 shows the difference of bulk density in December and November in each tide. Based on the data listed in the table between two months November and December, its shows difference value. This means that, within one month interval, the changes could still be seen. However, the different is small as it is less than 0.20 g/cm$^{3.}$

Table 4: The difference of Bulk Density in December and November

Zone	Tide	Bulk Density (g/cm^3) Dec	Bulk Density (g/cm^3) Nov	Difference Bulk Density (g/cm^3)
A	HTA	1.86	2.01	-0.15
	MTA	1.47	1.57	-0.1
B	HTB	1.46	1.49	-0.03
	MTB	1.62	1.63	-0.01
C	HTC	1.79	1.76	0.03
	MTC	1.5	1.39	0.11
D	HTD	1.57	1.6	-0.03
	MTD	1.41	1.17	0.24
E	HTE	1.5	1.56	-0.06
	MTE	1.39	1.21	0.18

As for this research, the beach volume changes analyzation were carried out by using the images processed by Pix4D Mapper into Global Mapper. Using the feature in the Global Mapper, the location of sampling and the area of each zone is being drawn in the software.

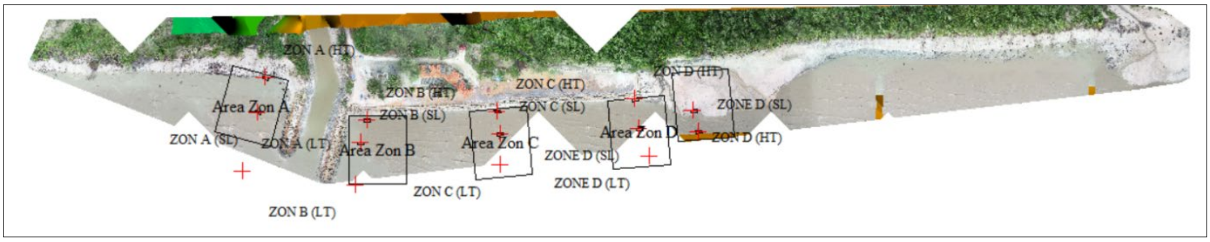

Figure 9: The analyzation of beach volume changes in Global Mapper.

By setting the volume feature, the software generates the data of total enclosed area and volume of each zone and each sampling point mainly at High Tide and Mid Tide. The analyzation of beach volume changes was carried out at all zone in relation with the analyzation of sediment properties. Figure 9 shows the analyzation of beach volume changes in Global Mapper.

Tables 5 below shows the beach volume changes in one month interval of each tide. The analyzation of each tide is focused only on High Tide (HT) and Low Tide (LT) at each zone. The beach volume on a small scale such as in each tide also shows the changes below than 0.5 cm^3.The analyzation on volume changes for each tide shows that sediment loss is more likely occur compared to accretion process. The increment of volume only occurs at High Tide on Zone A and D. The other tide for another zone portrays decrement of volume.

Table 5: Beach Volume Changes in One Month Interval of Each Tide

ZONE	Tide	Total Enclosed Area (sq km)	Perimeter (m)	Total Volume cm^3 (November)	Total Volume cm^3 (December)	Volume Changes cm^3
A	HT	0.000013	15.852	0.4464	0.0173	-0.4291
	MT	0.000013	15.852	0.4464	0.0050	-0.4414
B	HT	0.000013	15.852	0.3058	0.6395	0.3337
	MT	0.000013	15.852	0.3058	0.0146	-0.2912
C	HT	0.000013	15.852	0.1965	0.2308	0.0343
	MT	0.000013	15.852	0.1258	0.0187	-0.1071
D	HT	0.000013	15.852	0.1458	0.1461	0.0004
	MT	0.000013	15.852	0.0616	0.0095	-0.0521
E	HT	0.000013	15.852	0.1431	0.0070	-0.1361
	MT	0.000013	15.852	0.1068	0.0081	-0.0987

Table 6 shows the data of the correlation for parameters of sediment properties and volume changes. In summary the outcome of the result showing the similar pattern that could help in prediction sediment loss throughout the natural coastal process such as erosion and accretion in the meantime. The tables indicates that the prediction of volume changes can be determine by evaluating the bulk density as its shows the similar patterns with the data that has been extracted from the global mapper. In addition, the data within one month interval shows the significant changes at the sampling point at different tide as well as the overall volume for each zone. The sediment loss is higher at Zone A followed by Zone E, D and C. Previous research stated that soils with a high pore space to solids ratio have greater bulk densities than those that are more compact and have less pore space [11] .This is attributable to the fact that the amount of clay and silt in the soil reduces the bulk density of the soil. Therefore, it can be concluded when the volume decrease, the value of specific gravity and bulk density decrease whereas the moisture content value increase.

Table 6: The Correlation of Beach Volume and Sediment Properties

Zone	Tide	Moisture Content (%)	Specific Gravity	Difference Bulk Density (g/cm^3)	Particle Size Distribution				Volume Changes cm^3
					Gravel	Sand	Silt	Clay	
A	HT	26.5	2.78	-0.15	23	70	7	0	-0.4291
	MT	103.2	2.59	-0.10	2	29	52	17	-0.4414
B	HT	65.9	2.73	-0.03	17	58	25	0	0.3337
	MT	75.1	2.78	-0.01	43	48	8	0	-0.2912
C	HT	60.8	2.74	0.03	6	73	21	0	0.0343
	MT	96	2.58	0.11	10	18	45	27	-0.1071
D	HT	74.6	2.69	-0.03	6	56	27	11	0.0004
	MT	228.4	2.59	0.24	7	22	47	24	-0.0521
E	HT	68.3	2.69	-0.06	0	64	26	10	-0.0840
	MT	127.1	2.61	0.18	9	29	40	22	-0.1000

The sediment loss is highest at Zone A ranging from 0.4291 cm^3 to 0.4414 cm^3 compared to Zone B, C, D and E that lies within the range of 0.0521 cm^3 to 0.2912 cm^3. The value varies due to the composition of particle size distribution at the area. However, the sediment loss at each zone is higher when the percentage of gravel and sand is higher at the area. For example, the composition of gravel and sand that is higher at Zone A resulted in high sediment loss compared to Zone E which mainly composed by sand and silt. This proves that the sediment loss experience by the coastal area is influenced by the composition of the particle size distribution at the area. When the area is mainly composed by the cohesive soil such as silt and clay, the sediment loss is small compared to the area that composed mainly of gravel and sand. Based on the results, it can be summarized that the particle size distribution influences the volume change at the study area.

5. Conclusion

As for the conclusion the main composition of soil at Pantai Punggur composed mainly by sand and silt. The percentage of silt and clay are high at low tide and mid tide. Whereas at maximum high tide and high tide, the percentage of gravel and sand is higher based on the particle size distribution result. In relation with bulk density, the further the distance of sampling point from the shoreline, the lower the bulk density due to higher composition of silt and clay at the area. In terms of beach volume changes, it exhibits a changing pattern at each tide and zone during a one-month period. The data gathered in the previous chapter shows that Zone A and E are more prone to erosion compared to the other zone as location is an area with no revetment. Based on the output at the end of this research, the objective of this research was successfully achieved which are to identify volumetric changes in shoreline area using Unmanned Aerial Vehicle (UAV) with Global Mapper and Pix4D Mapper Software, to investigate the physical properties that contribute to the changes of sediment properties and to correlate beach volume changes with shoreline sediment properties at eroded area. Based on the research, it can be stated that there is a significant changes of beach volume, therefore further action should be taken to reduce and control the sediment loss at the coastal area. Sand nourishment is the mechanical placement of sand in the nearshore zone with the goal of advancing the coastline or maintaining the littoral system's sand volume[12]. Therefore, as a result of the data acquired from this study, authorities should consider this as a warning to implement costal structures or any other way suited for nourishing the beaches. The revetment in this region helps to reduce erosion, but it is still important and should be given greater attention.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, UniversitiTun Hussein Onn Malaysia for its support.

Appendix A

Data Particle Size Distribution

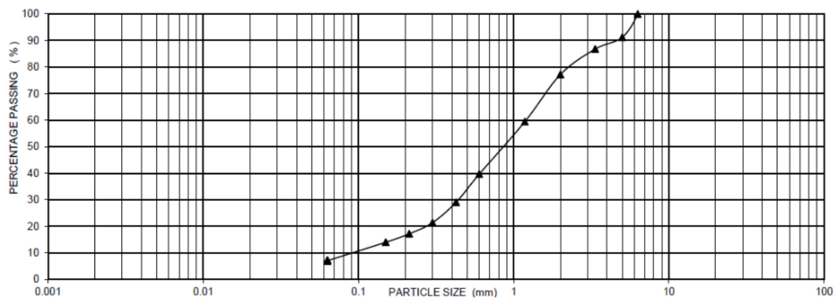

Figure 1: Particle Size Distribution Curve of HTA

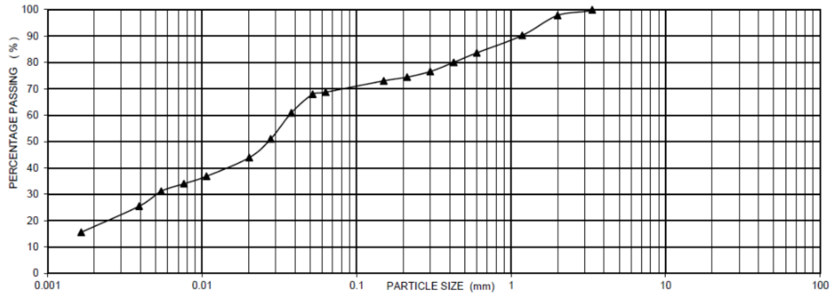

Figure 2: Particle Size Distribution Curve of MTA

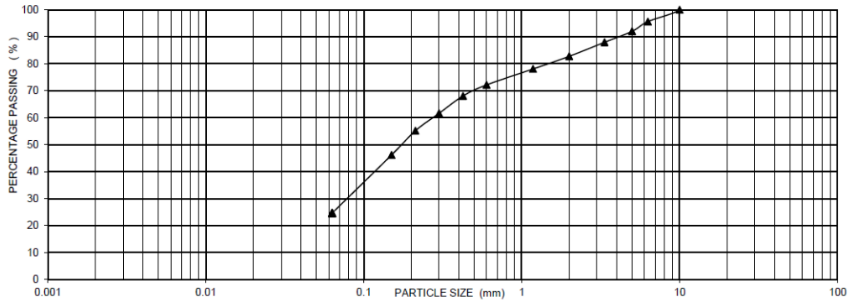

Figure 3: Particle Size Distribution Curve of HTB

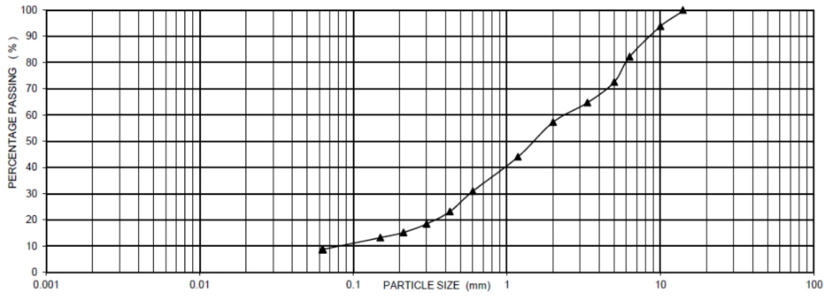

Figure 4: Particle Size Distribution Curve of MTB

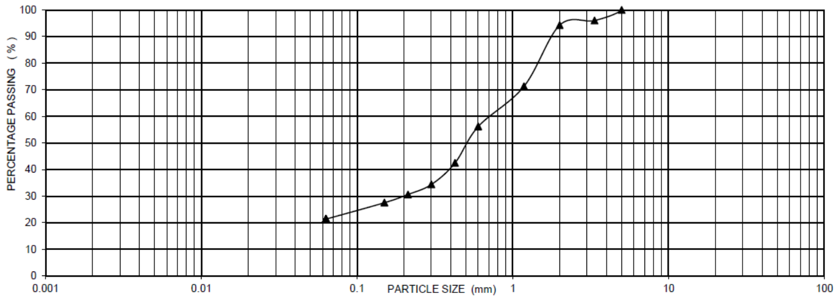

Figure 5: Particle Size Distribution Curve of HTC

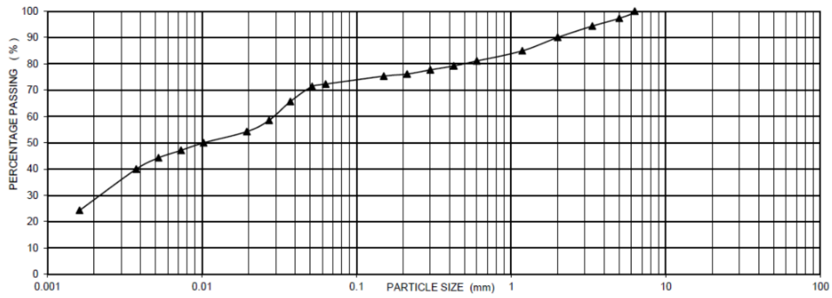

Figure 6: Particle Size Distribution Curve of MTC

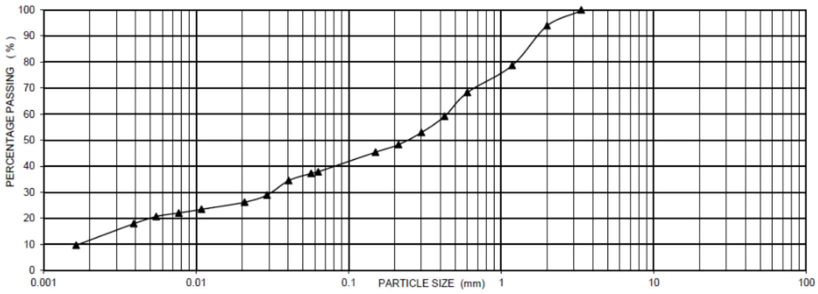

Figure 7: Particle Size Distribution Curve of HTD

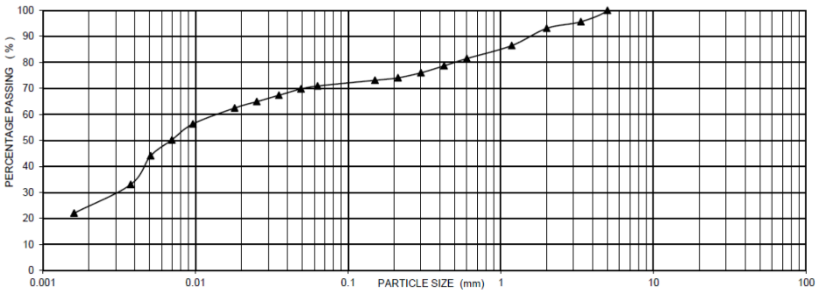

Figure 8: Particle Size Distribution Curve of MTD

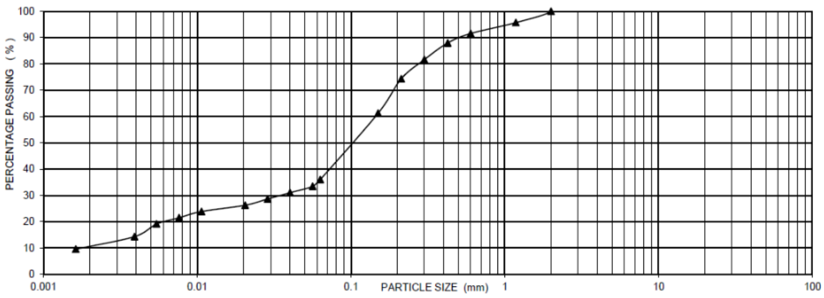

Figure 9: Particle Size Distribution Curve of HTE

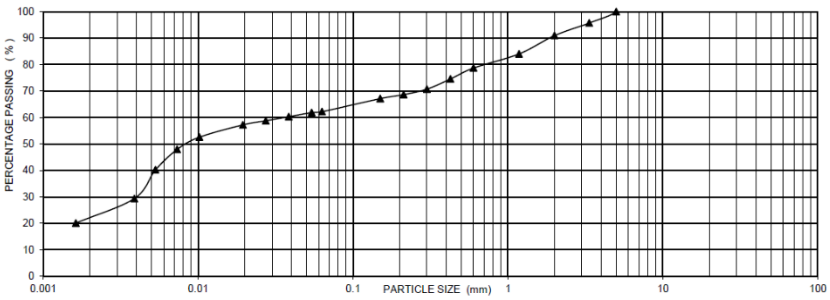

Figure 10: Particle Size Distribution Curve of MTE

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