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Surficial Sediment and Littoral Environment Data Along the Shoreface of Batu Pahat, Johor Coastal

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ABSTRACT

The coastline of Peninsular Malaysia is experiencing severe erosion can result in economic stagnation and life-threatening conditions. The shoreline is the interface between water and land area which can be shifted due to numerous coastal processes that influence such as the geotechnical properties and the physical form of the beach. Hence, this paper aims to observe the characteristics of the coastal area and perform a particle size distribution test of Batu Pahat, Johor coast. Data collection for this study is divided into two (2): data collection for Littoral Environment Observation (LEO) and data collection for soil sampling. Selection of coastal area at Pantai Parit Hailam, Pantai Punggur and Pantai Perpat particularly at beach habitats on Malaysia's west coast. A comprehensive dataset of eight (8) surficial sediment samples retrieved from three coastal areas of Batu Pahat, Johor, is presented. Samples were collected between June and July of 2023 at 0.2 m depth of surface using hand auger method. The minimum and maximum average wind speed ranged between 0.89 m/s to 2.5 m/s. The sediment samples consist of Pantai Parit Hailam ranging from loamy sand to silt loam, Pantai Punggur showing mostly sandy loam with some gravelly loam and Pantai Perpat consistently exhibiting sandy loam. The findings obtained from this study provide valuable information in terms of understanding morphological characteristics that will assist in understanding of sediment transport.

1. Introduction

Coastal areas refer to a section of land that borders an ocean or other body of water and is subject to the effects of the marine environment and coastal processes [1]. A variety of habitats, including rocky shorelines, sandy beaches, estuaries, bays, lagoons and coral reefs, may be found in coastal locations. The shoreline is the interface between water and land area which can be shifted due to numerous coastal processes that influence such as the geotechnical properties and the physical form of the beach [2]. Early erosion detection will result from the coastline changes [3]. These areas are

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shaped by a complex interplay of physical, chemical and biological processes that are influenced by the dynamics of the ocean, the atmosphere and the land [4]. An integrated strategy that considers the complexity and dynamic character of these systems while balancing the requirements of people and the environment is necessary for the effective management and protection of coastal regions.

Particle size analysis is used to identify the different sizes of rocks or sand that make up sediment in coastal locations [5]. The creation of coastal sediments is intrinsically dynamic due to the daily fluctuations in waves, winds, currents and sea level. The first areas of the shore to be affected by an environmental shift, whether due to natural or man-made factors, are the coastal sediments. The most significant characteristics of coastal sediment are the grain size distribution and particle size distribution of the sediment, along with density, form, sedimentation rate and resistance to erosion [6]. Solid particles that move with the tides and waves but do not float make up coastal silt. Sand may be carried to the coast by river flows or currents [7]. Coastal silt deposits benefit from the slowing of river currents as the material approaches the ocean, which makes a coastal edge an ideal location.

The objective of this study is to observe and determine the Littoral Environment Observation (LEO) data, perform a particle size distribution test and examine the median grain size (D50) for each sample. Much like other littoral regions, the coastal area of Batu Pahat faces significant erosion challenges. These processes significantly impact both natural resources and human habitation [8]. Pantai Punggur, Batu Pahat has been classified as one of the eroded areas in Batu Pahat. This can be proved by the data from the National Coastal Erosion Malaysia Study (NCES) in 2015 that concluded about 29% of the shoreline is eroding. Pantai Punggur is one of the areas that experience critical erosions in Batu Pahat [9].

The study focused on data from Littoral Environment Observation (LEO) and sediment particle distribution at Batu Pahat coastal area. Selection of coastal areas is at Pantai Parit Hailam, Pantai Punggur and Pantai Perpat, particularly at beach habitats on Malaysia's west coast. The aim of this study is to report on the characteristics of sediment on shoreline areas, due to the importance of site-specific sediment properties and the understanding of coast transport mechanism.

This study involves investigating the condition of surficial sediment and Littoral environment in three beach environments along the West Coast of Malaysia by collecting soil and sediment samples and analysing them for their physical properties. The study also involves the acquisition of LEO data and particle size distribution test data, which be used to better understand the conditions Batu Pahat coastal area. The findings of this study have important implications for Malaysia's coastal management and conservation. Other than that, it will help in the creation of sustainable management and conservation policies and plans.

2. Methodology

The study focused on surficial sediment and littoral environment data along the shoreface of Batu Pahat, Johor coast. Data collection for this study is divided into two (2) which, data collection for Littoral Environment Observation (LEO) and data collection for soil sampling. Selection of coastal area at Pantai Parit Hailam, Pantai Punggur and Pantai Perpat particularly at each habitat on Malaysia's west coast. A total of three stations of soil sampling were set at the coastal area of Pantai Perpat and Pantai Punggur meanwhile, two sample stations were at Pantai Parit Hailam. The stations are based on eight different conditions of soil at three coastal regions, since the different spots do have different characteristics and properties of the sediment.

One of the most essential steps in soil testing is soil sampling. For soil sampling, soil samples were collected at the selected points of the coastal area. The process of collecting the samples began by identifying the locations of the sample stations, which could only be carried out at low tide. The disturbed samples are useful for a range of purposes, such as soil identification, description and tests that do not require the soil to be in its original state [10]. Figure 1, Figure 2 and Figure 3 indicate the location of soil sample stations along the Pantai Parit Hailam, Pantai Punggur and Pantai Perpat. Next, the LEO data at each sample point was observed consisting of wind speed, water depth, wave period, wave direction and wave angle. The LEO data was carried out during high tide while the soil sampling was carried out at low tide at the same points.

Fig. 1. Sampling point at Pantai Parit Hailam

Fig. 2. Sampling point at Pantai Punggur

Fig 3. Sampling point at Pantai Perpat

2.1 Littoral Environment Observation

The purpose of the extensive Littoral Environment Observation (LEO) initiative is to frequently observe and monitor the littoral environment, which is the region where land and water converge. A field data gathering program called Littoral Environment Observation (LEO) was established to provide data on coastal phenomena using a simple method, inexpensive equipment and expendable supplies [11]. LEO is crucial in understanding climate change and sea-level rise by providing essential data for monitoring and managing coastal dynamics. LEO data for this study focused on wind speed, water depth at the breaker point, wave period and wave angle. The wind speed is measured using an anemometer (Figure 4), in which a counter displays the number of rotations of the anemometer over a time interval using a data logger and indicates the average speed over that interval. Water depth refers to the distance between the surface of a body of water and the bottom or bed of that body of water. Water depth is measured using levelling staff at the breaker point as shown in Figure 5.

The wave period is the amount of time it takes a wave to go through one complete cycle and it is measured in seconds [12]. The stopwatch is used to measure the space of time between two successive wave crests in order to calculate the wave period. The wave angle was determined using a protractor and compass. The protractor will be used to calculate the wave angle, while the compass used to identify the south and north axes [13]. On the beach, draw a line to depict the shoreline and another to show the direction of the waves as they approach the shoreline.

Fig. 4. Measuring wind speed

Fig. 5. Measuring water depth

2.2 Sediment Particles Distribution Test

The soil sampling for each coastal area was collected which consisted of eight total samples overall along the Pantai Parit Hailam, Pantai Punggur and Pantai Perpat shoreline. Ensuring the soil samples are properly secured is crucial to soil sampling. The soil samples are intended to remain undisturbed throughout the collection from each coastal experimental site and be analysed in the laboratory. The sampling method is based on the British Standard BS5930. The technique that is used to extract the sample is by hand auger boring method and scoop was carried out at low tide at every sample point. A sample of soil was taken 0.2 meters below the surface for eight samples during low tide. Then, the freshly retrieved soil samples are initially secured in plastic bags and subsequently encased in layers of cling film to avert moisture loss during transit and storage. The soil sample was meticulously extracted to protect the soil samples.

The purpose of the laboratory testing was to examine the extracted samples. This study involves sediment particle distribution and physical testing on samples. Sampling and the analysis of the sediment samples were carried out to identify the grain-size classification and physical features of the sediment. The purpose of the grain size analysis test is to estimate the proportion of each size of grain that makes up a soil sample [14]. The results of the test can be used to produce the grain size distribution curve and can define the type of soil at the sample point. The geotechnical relevant data are progressively applied to support studies of coastal erosion and the creation of coastal morphology models [15].

Fig. 6. Soil sampling

A particle size distribution test is used to identify the distribution of particle sizes in a soil sample. The further analysis of particle size distribution and curve following the British Standard BS 1377: Part 2: 1990. The test be performed by sieving the soil through a series of sieves with different mesh sizes. A graph be created to show the percentage of soil that is retained on each sieve. The particle size distribution curve can be used to assess the soil's permeability, compressibility, shear strength and texture. A grade size distribution curve is analysed by using different particle sizes: D60, D30 and D10. The curve is the graph plotted between the percentage finer in the y-axis to the particle size on the x-axis in a logarithmic scale. This is plotted based on the observations from sieve analysis conducted on the soil sample. The uniformity coefficient (Cu) and the coefficient of gradation (Cc) are the measures of soil gradation. These coefficients help to classify the soil as well-graded or poorly graded.

3. Result

3.1 Littoral Environment Observation

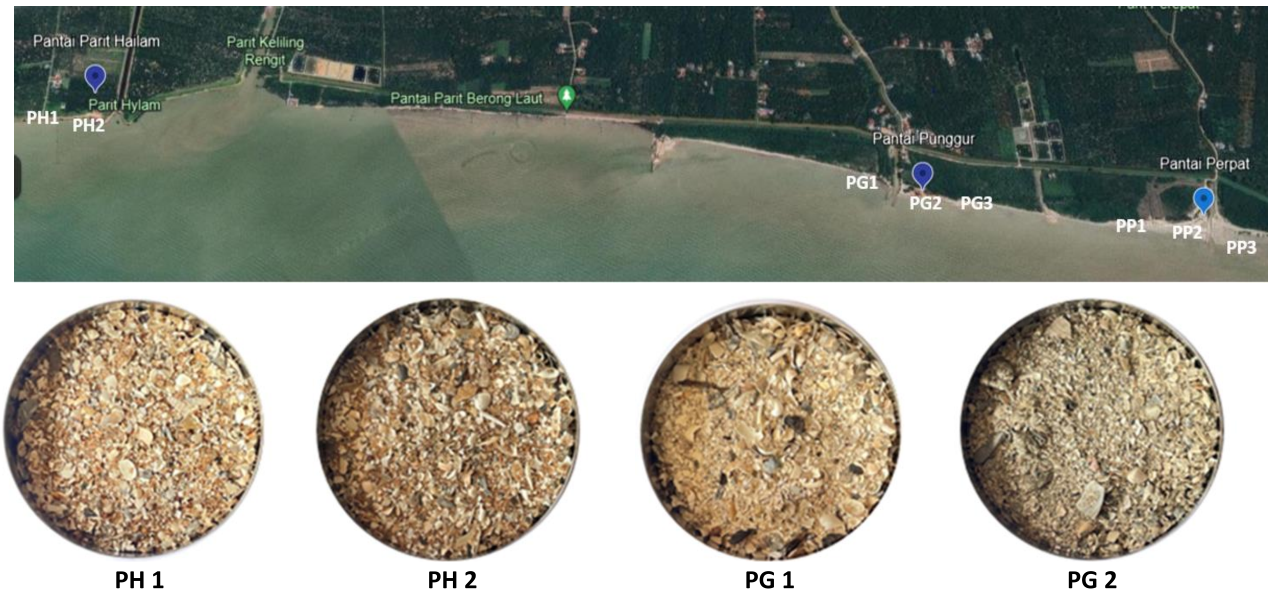
Table 1 shows Littoral Environment Observation (LEO) data for Pantai Parit Hailam, Pantai Punggur and Pantai Perpat. LEO data consists of tide level, wind speed, water depth, wave period and wave angle. The tidal water level for this data obtained is between 1.11 m to 1.88 m. The wind direction is from west and south. In this study, the minimum and maximum average wind speed ranged between 0.89 to 2.5 m/s and the highest wind speed was at PG 2, 2.5 m/s. The maximum water depth is 0.85 m which is at PG 1 and the minimum at PG 3. Water depth is related to wave height, which is one of the most important factors influencing the design of coastal constructions. Meanwhile, the wave period for PG 2 is the highest which is 8.3 sec and the lowest is PP 1 is 3.7 sec. The wave angle for this study ranges between 5° to 30°. So, the highest at point PH 1 and the lowest at PG 3 and PP 1.

Table 1
Littoral environment observation (LEO) data for Pantai Parit Hailam, Pantai Punggur and Pantai Perpat

Sampling Point	GPS Location	Tide Level (m)	Wind Direction	Wind Speed (m/s)	Water Depth (m)	Wave Period (sec)	Wave Angle (°)
PH 1	1°42'23.1"N 103°04'07.8"E	1.71	W	2.2	0.65	5.1	30
PH 2	1°42'22.3"N 103°04'09.6"E	1.88	W	1.7	0.7	4.3	20
PG 1	1°41'12.2"N 103°05'49.7"E	1.88	S	2.1	0.85	4.7	10
PG 2	1°41'05.0"N 103°05'54.5"E	1.64	W	2.5	0.50	8.3	10
PG 3	1°41'01.5"N 103°05'59.3"E	1.38	W	2.0	0.25	8.0	5
PP 1	1°40'43.2"N 103°06'23.0"E	1.11	S	1.39	0.5	3.7	5
PP 2	1°40'38.5"N 103°06'27.5"E	1.55	S	0.89	0.4	8.3	10
PP 3	1°40'36.1"N 103°06'33.6"E	1.63	W	1.83	0.6	8.3	20

3.2 Sediment Particles Distribution

Figure 7 shows the physical sediment features of three coastal areas, Pantai Parit Hailam (PH), Pantai Punggur (PG) and Pantai Perpat (PP). From the figure, the sample from Pantai Parit Hailam (PH) can be classified as medium sand for both points. Therefore, the sample from Pantai Perpat can see have very fine sand than Pantai Punggur and Pantai Parit Hailam. Sampling point PP 3 shows that there appears to be some grey coloration, which might be the result of soil mixing between clay and sand.



PG 3 PP 1 PP 2 PP 3

Fig. 7. Physical sediment features

Marine clay was identified as the main sediment found along the beach on Johor's west coast and this sediment is often associated with the coastal mangrove forest [16]. However, the characteristics of the sediment composition might also vary depending on the coastal location. Particle size distribution analysis is a mechanical study used to determine the particle size of a soil sample. Particle size distribution of soil sample can be carried out by using the sieve analysis. Table 2 shows the data of the particle size distribution for three coastal area, which was consist D60, D30, D10, median grain size (D50), uniformity coefficient (Cu) and coefficient of curvature (Cc). The effective size (D10) data obtained between 0.17 to 0.23 mm. The D30 value (diameter corresponding to 30% finer material) was range between 0.2 to 2.2 mm. The maximum D60 value where, diameter corresponding to 60% finer material was 3.2 mm at PG 3 and minimum was 0.50 mm at PH 2. Sand is the largest soil particle size (2.0 mm - 0.05 mm), silt is intermediate in size (0.05 mm - 0.002 mm) and clay is the smallest (less than 0.002 mm) [17].

Table 2
Summary of grain size at 60%, 30% and 10%

Location	Sample	Grain Size (mm)			D_{50} (Soil Size) in mm	Type of Soil	Uniformity Coefficient (Cu)	Coefficient of Curvature (Cc)
		D_{60}	D_{30}	D_{10}				
Pantai Parit Hailam	PH 1	3.10	0.70	0.17	2.00	Loamy	18.24	1.33
	PH 2	1.00	0.16	0.06	0.42	Silt Loam	16.67	2.67
Pantai Punggur	PG 1	2.20	0.20	0.07	0.80	Sandy Loam	31.43	1.30
	PG 2	1.80	0.20	0.08	0.90	Sandy Loam	22.50	1.39
	PG 3	4.20	0.60	0.08	3.00	Loamy	52.50	1.79
Pantai Perpat	PP 1	1.50	0.30	0.06	0.75	Sandy Loam	25.00	3.33
	PP 2	1.60	0.35	0.06	0.80	Sandy Loam	26.67	3.65
	PP 3	1.70	0.19	0.06	0.80	Sandy Loam	28.33	1.86

Based on Table 2, the soil type for the three coastal areas consists of loamy, sandy loam and silt loam. All the results of the type of soil for every coastal area study were determined by using the USDA texture triangle. The uniformity coefficient (Cu) data range between 16.67 to 52.50. Meanwhile, the maximum data for the coefficient of curvature (Cc) was 3.65 at PP 2 and the minimum value was 1.30 at PG 1. For the soil to be well-graded, the value of Cc must range between 1 and 3 [14]. Sediment which has a very good uniformity, has Cu = 15 or greater. For gravel and sand, Cu must exceed 4 and 6, respectively [18]. The samples are classified as poorly-graded sand, although six of the eight samples in this study are well-graded sand. The particle distribution data for the samples is presented through the graph throughout the analysis, the composition percentage of the sediments can be determined as shown in Figure 8, Figure 9 and Figure 10 for three coastal studies.

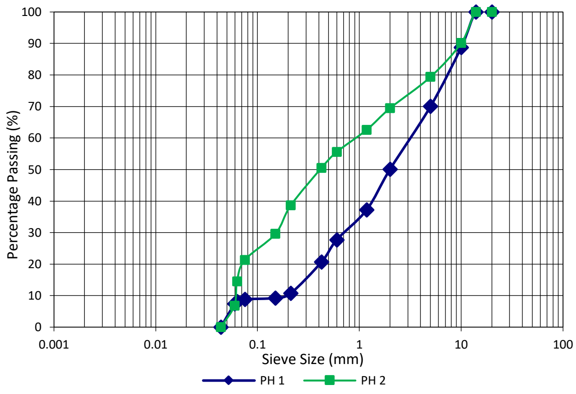


Fig. 8. Particle size distribution Pantai Parit Hailam

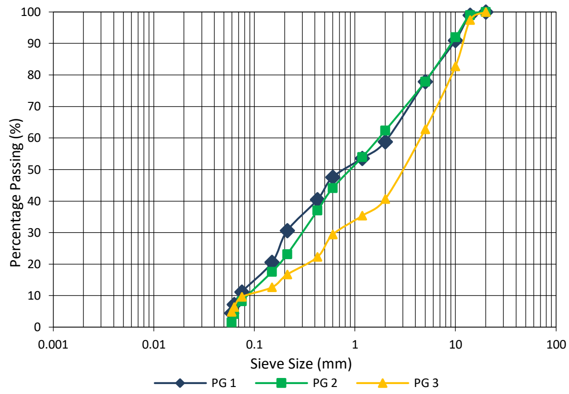


Fig. 9. Particle size distribution at Pantai Punggur

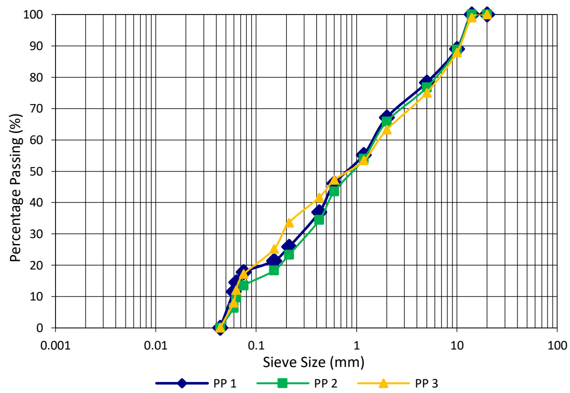


Fig. 10. Particle size distribution at Pantai Punggur

Figure 11 shows the results of D50 and it can be noted that the median sediment particle size at three coastal areas. The particle size distribution provides information about the proportions of different particle sizes present in the soil sample [19]. The range of median particle size is between 0.42 mm to 3.0 mm. The maximum D50 was 3.0 mm at PG 3 and the minimum was 0.42 mm at PH 2. Thus, the sediment in three coastal areas was in the sand and gravel category. The beaches containing a diverse range of sediments, such as silts, sands, gravels, cobbles and boulders, often display a combined profile with a distinct change in slope between the higher foreshore, where coarse material is prevalent and the low-tide terrace, where finer sediment is more abundant [20].

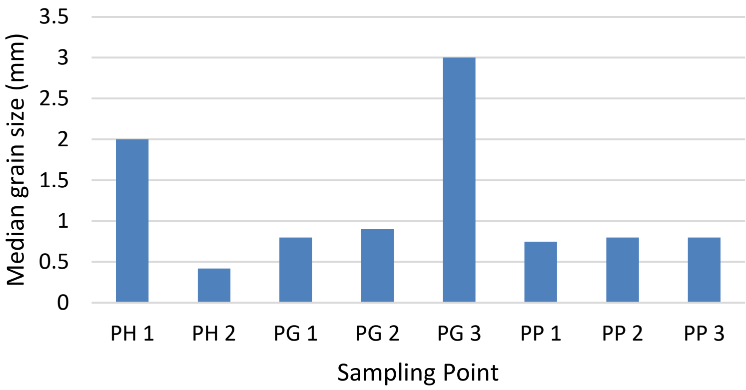


Fig. 11. Median sediment particle size

Figure 12 shows the data obtained from LEO data which is wind speed. The maximum wind speed at PG 2 was 2.5 m/s and the minimum was 0.89 at PP 2. The wind speed for both years (2012 and 2013) along the southern Strait of Malacca is observed to be between 10 km/hr and 20 km/hr [21]. Thus, the change for the present study is wind speed increase might be influenced by monsoon. Figure 10 shows the data obtained for wave angle. It was found that the range of the wave angle at three coastal areas was between 5° to 30°. Wave angle can affect the sediment transport and beach morphology. Initiation of Aeolian transportation is controlled by wind velocity, the characteristics of sediments, beach morphology, moisture content and the degree of roughness elements present [22].

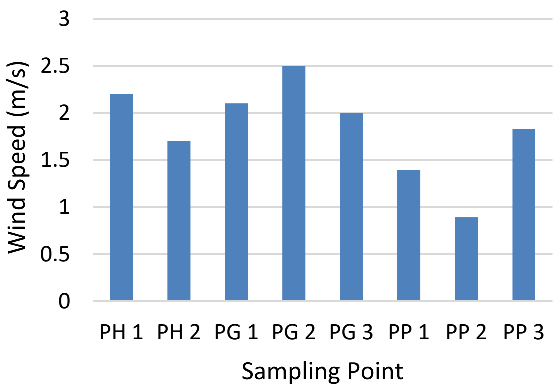


Fig. 12. Wind speed

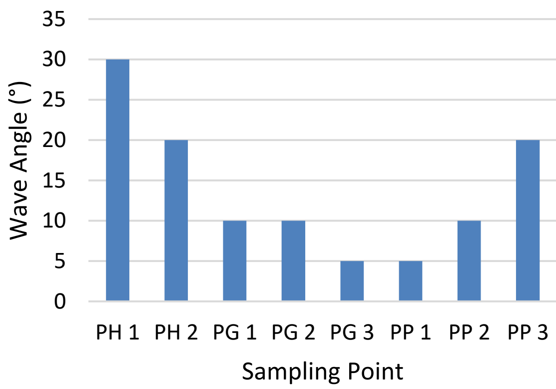


Fig. 13. Wave Angle

There is a significant correlation between the environmental data and sediment properties in Batu Pahat coastal area. Figure 14 shows the graph of median sediment particle size with water depth. The relationship between water depth and median sediment particle size in coastal areas is characterized by a significant negative correlation. As water depth increases, the median grain size tends to decrease, which has implications for sediment transport and ecological dynamics. A study in Selin Co, Tibet, found a strong negative correlation (r = -0.767) between median grain size and water depth, indicating that deeper waters are associated with finer sediments [23].

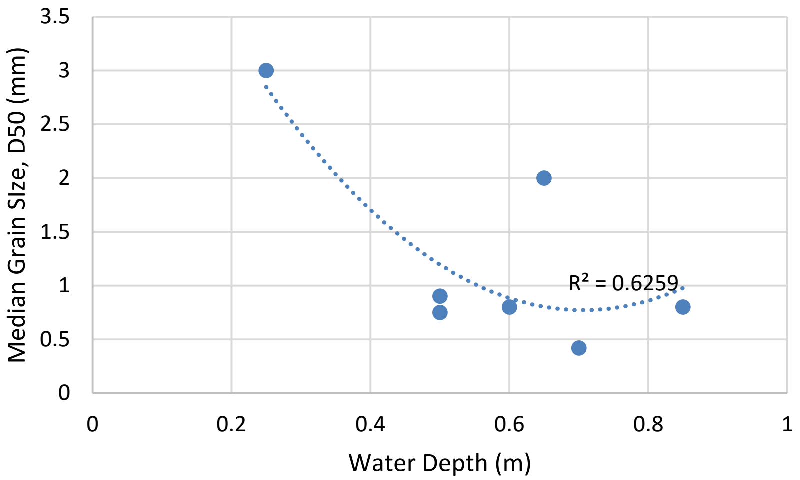


Fig. 14. Median sediment particle size with Water Depth

4. Conclusions

In conclusion, an in-depth review of Littoral Environment Observation and sediment properties, i.e. the grain size distribution and physical features for three coastal areas Pantai Parit Hailam, Pantai Punggur and Pantai Perpat are reported. One of the objectives of this study is achieved which is to observe and determine the Littoral Environment Observation (LEO) data. The LEO data consists of tide level, wind speed, water depth, wave period and wave angle has been obtained. The study found that Pantai Punggur has the highest wind speed, water depth and wave period. This study makes it feasible to understand the coastal condition. Other than that, the study achieved Objective 2 by producing a particle size distribution test and examining the median grain size (D50). The range of median particle size is between 0.42 mm to 3.0 mm. The maximum D50 was at Pantai Punggur and the minimum was at Pantai Parit Hailam. The sediment samples include Pantai Parit Hailam, which ranges from loamy sand to silt loam; Pantai Punggur, which predominantly features sandy loam with some gravelly loam; and Pantai Perpat, which consistently displays sandy loam.

The findings showed that the highest median grain size and wind speed is at Pantai Punggur, which has the lowest wave angle there. The relationship developed in this study improves the knowledge of the relationship between sediment analysis and environmental data. From these properties, further analyses such as settling velocity and prediction of erosion and accretion can be determined. The sediment properties are important information in managing the shoreline. 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. Future work should consider the sediment characteristics reported in the paper for further studies related to Batu Pahat coastal area.

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References

[1] Mohd, Fazly Amri, Khairul Nizam Abdul Maulud, Rawshan Ara Begum, Othman A. Karim, Md Firoz Khan, Siti Norsakinah Selamat, A. A. A. Rahman *et al.,* "Variation of beach profile along Pahang Coast in Malaysia." *Int. J. Eng. Technol* 7, no. 3.14 (2018): 196-201. https://doi.org/10.14419/ijet.v7i3.14.16884

[2] Mohamed Rashidi, Ahmad Hadi, Mohamad Hidayat Jamal, Mohamad Zaki Hassan, Siti Salihah Mohd Sendek, Syazana Lyana Mohd Sopie and Mohd Radzi Abd Hamid. "Coastal structures as beach erosion control and sea level rise adaptation in malaysia: A review." *Water* 13, no. 13 (2021): 1741. https://doi.org/10.3390/w13131741

[3] Mokhtar, Mardiha, Fitrah Hayazi, Amy Shahrin Amir Hamzah, Mohamad Shahril Shafiq Isnin, Masiri Kaamin, Mohamad Azim Mohammad Azmi and Nor Baizura Hamid. "Condition Survey of Eroded Area in Pantai Punggur, Malaysia Shoreline Using UAV Photogrammetry." *Solid State Technology* 63, no. 3 (2020): 826-833.

[4] Cochran, Richard E., Olivia S. Ryder, Vicki H. Grassian and Kimberly A. Prather. "Sea spray aerosol: The chemical link between the oceans, atmosphere and climate." *Accounts of chemical research* 50, no. 3 (2017): 599-604. https://doi.org/10.1021/acs.accounts.6b00603

[5] Bird, Eric CF. *Coastal geomorphology: an introduction*. John Wiley & Sons, 2008.

[6] Umar, Hasdinar, Sabaruddin Rahman, A. Yasir Baeda and Syerly Klara. "Identification of coastal problem and prediction of coastal erosion sedimentation in South Sulawesi." *Procedia Engineering* 116 (2015): 125-133. https://doi.org/10.1016/j.proeng.2015.08.273

[7] Putro, Anthony Harlly Sasono and Jung Lyul Lee. "Analysis of longshore drift patterns on the littoral system of nusa dua beach in bali, indonesia." *Journal of Marine Science and Engineering* 8, no. 10 (2020): 749. https://doi.org/10.3390/jmse8100749

[8] Zakaria, N. A., Rosnan, Y., & Zakaria, M. P. “Sediment transport rate in the west coast of Peninsular Malaysia.” *IOP Conference Series: Materials Science and Engineering*, 226(1), (2017): 012041. https://doi.org/10.1088/1757-899X/226/1/012187

[9] Mokhtar, Mardiha, Mohd Effendi Daud, Masiri Kaamin, Muhamad Syamil Sabri, Fitrah Hayazi, Muhammad Hanif Hisham, Mohammad Ikhmal Siddiq, Mohamad Azim Mohammad Azmi, Nor Baizura Hamid and Hafsa Mohammad Noor. "Beach Profile and Shoreline Sediment Properties at Eroded Area in Batu Pahat." *Construction Technologies and Architecture* 4 (2023): 127-137. https://doi.org/10.4028/p-ny3700

[10] Carter, Michael and Stephen P. Bentley. *Soil properties and their correlations*. John Wiley & Sons, 2016. https://doi.org/10.1002/9781119130888

[11] Hentry, C., N. Chandrasekar and S. Saravanan. "Beach dynamics of Colachel open coast, Kanyakumari district (SW India)." *Z Geomorphol* 57, no. 1 (2013): 75-95. https://doi.org/10.1127/0372-8854/2012/0077

[12] Lv, Jialei, Wenjing Zhang, Jian Shi, Jie Wu, Hanshi Wang, Xuhui Cao, Qianhui Wang and Zeqi Zhao. "The Wave Period Parameterization of Ocean Waves and Its Application to Ocean Wave Simulations." *Remote Sensing* 15, no. 22 (2023): 5279. https://doi.org/10.3390/rs15225279

[13] Le Roux, J. P. "A simple method to determine breaker height and depth for different deepwater wave height/length ratios and sea floor slopes." *Coastal engineering* 54, no. 3 (2007): 271-277. https://doi.org/10.1016/j.coastaleng.2006.10.001

[14] Hossain, M. D., M. D. Islam, Faria Fahim Badhon and Tanvir Imtiaz. "Properties and Behavior of Soil-Online Lab Manual." (2022).

[15] Stark, Nina, Brendan Green, Nick Brilli, Emily Eidam, Kevin W. Franke and Kaleb Markert. "Geotechnical measurements for the investigation and assessment of arctic coastal erosion—a review and outlook." *Journal of Marine Science and Engineering* 10, no. 7 (2022): 914. https://doi.org/10.3390/jmse10070914

[16] Zarina, M. A., Lai, W. T., Syed, M. M. S. T. and Ayu, F. A. H. “Sediment Properties of Pantai Punggur.” *Proceedings of Sixteenth TheIIER International Conference, Kuala Lumpur, Malaysia. Johor*. (2015): 114-119.

[17] Ma, Jianquan, Xiaojie Zhao, Shibo Li and Zhao Duan. "Effects of high shearing rates on the shear behavior of saturated loess using ring shear tests." *Geofluids* 2021, no. 1 (2021): 6527788. https://doi.org/10.1155/2021/6527788

[18] Kalore, Shubham A. and GL Sivakumar Babu. "Significance of Cu and Cc in Evaluating Internal Stability with Application to Design of Subbase Gradation in Pavements." *Transportation Geotechnics* 40 (2023): 100972. https://doi.org/10.1016/j.trgeo.2023.100972

[19] Mokhtar, Mardiha, Muhammad Azri Fikri B. Ariffin, Mohd Effendi Daud, Masiri Kaamin, Mohamad Azim Mohammad Azmi and Nor Baizura Hamid. "Sediment Properties of Eroded Coastal Area at Batu Pahat, Johor, Malaysia." *Environment and Ecology Research* 10, no. 2 (2022): 248-259. https://doi.org/10.13189/eer.2022.100214

[20] Osborne, Philip D. and David P. Simpson. "Cross-shore variation of grain size on beaches." *Encyclopedia of Coastal Science. Encyclopedia of Earth Science s Series. Springer Nature Switzerland, Cham* (2018): 666-672. https://doi.org/10.1007/978-3-319-93806-6_105

[21] Rahman, Z. A., W. Z. W. Yaacob, S. A. Rahim, T. Lihan, W. M. R. Idris and W. N. F. Sani. "Geotechnical characterisation of marine clay as potential liner material." *Sains Malaysiana* 42, no. 8 (2013): 1081-1089.

[22] Sloss, C. R., Patrick Hesp and Michael Shepherd. "Coastal dunes: Aeolian transport." *Nature education knowledge* 3, no. 10 (2012): 21.

[23] Wang, Can, Hailei Wang, Gao Song and Mianping Zheng. "Grain size of surface sediments in Selin Co (central Tibet) linked to water depth and offshore distance." *Journal of Paleolimnology* 61 (2019): 217-229. https://doi.org/10.1007/s10933-018-0054-8