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Effect Of Soil Shear Strength on Shoreline Changes at Batu Pahat Coastal Area

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Abstract: This study focuses on the effect of soil shear strength due to the shoreline changes in Batu Pahat Coastal Area. The shorelines of Pantai Punggur were chosen as the subject location for this investigation on soil shear strength and shoreline changes of eroded areas in Batu Pahat, Johor. Pantai Punggur is situated on the west coast of Johor, with a latitude of 1.62° to 1.87° N and a longitude of 102.78° to 103.19° E. Aerial photographs and field observation data were used to determine the geomorphological components of the Pantai Punggur shoreline using an unmanned aerial vehicle (UAV). The study conducted is to produce shoreline changes mapping diagram and analysis soil shear strengths across different sampling locations were measured and correlate with shoreline changes at zones A, B, C, D and E. The aerial image that has been captured by the drone was analyzed using Pix4D and Global Mapper software. Based on the data of shoreline changes zone A portrays the highest changes followed by zone B and C. As for zone D and E its shows quite a small change. Within one month interval, Pantai Punggur coastline experiences changes in about 1.57 meters. From the undrained shear strength test at 0.5 m depth at HT and MT data for December 2021, zone A with Cu reading are more than 4.5 kPa followed by zones B, C, D and lowest at zone E. Next, at depth 0.5 m and 1.0 m data for December 2021 at HT level, zone A with Cu reading is more than 4.5 kPa at the 0.5 m and 1.0 m depth and other zones are below than 3.0 kPa. The depth of soil also influences the data of this study. The correlation of changes in soil shear strength with shoreline changes is reported to have a linear correlation with R2 value is 0.9261. It can conclude that the effect of soil shear strength on shoreline changes at Batu Pahat coastal area cause by the changes in soil shear strength (Cu) gives a large effect of shoreline changes.

Keywords: Soil strength, coastal shoreline, shoreline changes, coastal erosion

1. Introduction

This study will provide shoreline topographic changes using unmanned aerial vehicles (UAVs) and collect sediment shear strength data at the point of each shoreline change using field vane shear test (VST) methods. From that, researcher able to produce shoreline changes mapping diagram by UAV photogrammetry tools and obtain soil shear strength data at each point. A shoreline is a physical line that separates land and oceans areas [1].

The causes of coastal erosion stem from human activities and nature [2]. Ocean is an important socioeconomic area where it gives pro and cons to humans and nature. Erosion of the shoreline occurs due to human and natural activities and will change the trend of the shoreline from year to year. It is estimated that about 30% of the shoreline is open to diverse degrees of erosion. Natural processes or human activities may well be the significant factors of erosion along

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the shoreline. Among the factors, contributing to coastal erosion is insufficient sand supply to coastal beaches inundation [3].

Coastal inundation caused by storm waves, earthquakes, and sea level rise (SLR) can result in significant inundation of coastal areas, having a negative effect on the natural environment and social economic conditions in the coastal area. In addition, this effect will also result in destruction in areas close to the shoreline. Figure 1 shows the situation of Pantai Punggur shoreline erosion in April 2021.

Fig. 1 - Pantai Punggur shoreline erosion in April 2021

The purpose of this research is to examine the shoreline changes from the images taken using unmanned aerial vehicle (UAV), determine shear strength of shoreline area using field vane shear test (VST) and investigate the correlation of soil shear strength on shoreline changes at study area.

2. Coastal Geomorphology

Coastal geomorphology is the study of the morphological formation and evolution of the coastal as it interacts with winds, waves, currents, and sea-level change. This study of physical processes and responses in the coastal zone is commonly used in nature, but it also includes experimentation to offer the underlying understanding required to solve the relevant equations. The shore is the strip of land that borders the body of water and is alternately covered or exposed by waves or tides [4]. The terms coastline and shoreline are often used to define the location's border at the coastal and beach areas as shown in Figure 2.

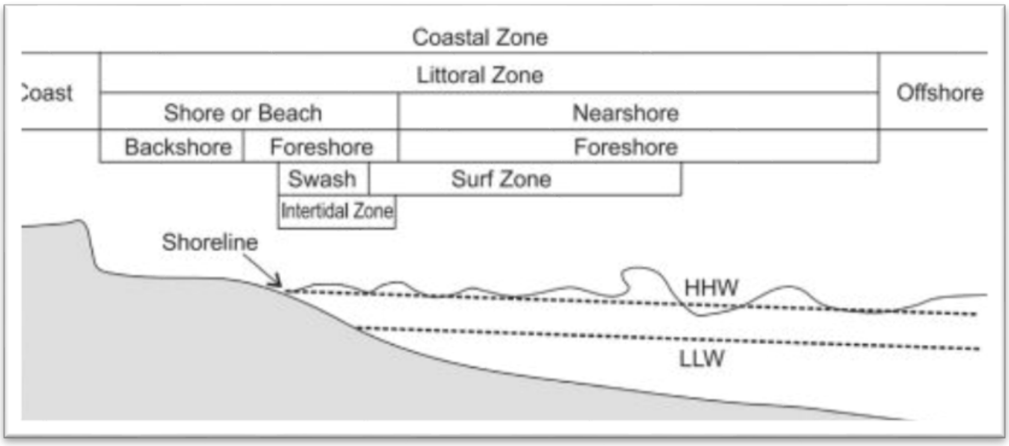

Fig. 2 - Typical beach geomorphology and coastal profile [5]

Pantai Punggur's geomorphology has been influenced by wind, waves, currents, and sea level rise (SLR). Shoreline alterations at high tide are highly visible to erode from time to time. Every year, considerable coastline changes can occur because of the monsoon season, which lasts from August to November [6].

2.1 Coastal Erosion

Coastal erosion refers to the wearing a way of land and loss of beach or sandy deposits caused by wave action, tidal currents, wave-current, and severe winds. It may be assessed on different coastal sectors across time scales ranging from a few hours or days to long-term trends spanning decades or centuries. Coastline changes are defined as changes along the high-tide shoreline. Coastal erosion may be divided into two categories: natural factors and non-natural factors (human activities). Natural factors include accretion, soil erosion, and wave action and cause significant beach changes in a short amount of time due to direct exposure to the wave [7]. This frequently involves damaging waves eroding the shoreline. The second factor of coastal erosion is also created by humans, with various activities in coastal areas such as construction, tourism, and recreation also contributing to shoreline alterations. All activities in residential and coastal areas will give economic resources to citizens in coastal areas. However, the coastal erosion that happened may have a negative influence on the local community's socioeconomic well-being. Loss of land, agricultural degradation, and infrastructure devastation all have a big impact. Batu Pahat is an area with major shoreline changes [6].

Erosion may occur in a variety of ways. Hydraulic activity can identify several types of erosion. When a wave strikes a cliff face, the air is driven into fractures under high pressure, increasing them. Over time, extensive hydraulic activity disrupted the cliffs, and rock fragments broke [8]. Corrosion or abrasion is another type of erosion. Corrosion occurs when the repetitive action of waves crashing on a cliff removes material from it over time. If there is sand and shingle in the water, it acts like sandpaper and accelerates erosion [8]. Attrition is the third type of erosion. Attrition is the process by which beach material is banged together in water, reducing its size while enhancing its roundness and smoothness [8]. Corrosion is the next method of erosion. Carbonic acid is formed when carbon dioxide in the atmosphere dissolves in water. Several rocks are sensitive to the acidic water and will disintegrate in it. The concentration of carbonates and other minerals in the water influences the rate of dissolution. Dissolution gets slower as it grows [8].

Coastal erosion may have a significant impact on the coastline [9]. The most obvious point is that the accumulation of material and longshore drift might have an effect on places further along the coast. However, the sediment is removed so that less sediment may be found on the beach to protect the coastline from of the wave.

It would undoubtedly alter the coastline region. Coastal erosion may also weaken soil and rock, making it more vulnerable to erosion. The material is rapidly worn by waves due to their natural effects, which implies that the cliff is swiftly destroyed and the waves are more effective. Since of the fetch, the effect of coastal erosion may be quite harmful because the waves may accumulate a lot of energy. It also noted that there is less sediment to defend the coastline from erosion [9].

2.2 Unmanned Aerial Vehicle (UAV)

Todays, a new technology in the development of the technology sector is being examined by surveyors to be more reliable, inexpensive and efficient. UAV or drones technology is increasingly the appropriate alternative for the surveillance of coastal erosion. It can be used where LiDAR systems are not possible. There is a risk to many degraded coastal regions at foot, a barrier that drones are uncontrolled. In harsh weather, specially constructed drones may also fly across the shoreline, take high-quality images and monitor the ever-changing shoreline with videos.

According to Masiri Kaamin et al. (2018), conducted a study by using Utilization of Unmanned Aerial Vehicle (UAV) for Shorelines Changes Mapping is simple and cost-effective. The goals are to determine shoreline changes using photographs obtained by unmanned aerial vehicles, as well as to recognize shoreline changes using Agisoft Photoscan and Global Mapper [6].

2.3 Sediment Transport Forces

Several natural factors, such as winds, waves, tides and currents drive the creation of coastal areas. These elements generate forces of intensity that can construct and modify the coastal lines through eroding, transporting and sedimentation. Furthermore, these aspects include minor occurrences, in which they induce short-term coastal alterations and occur within 5 to 10 years or few seasons [10].

3. Materials and Methods

The study begins with the identification of the problem in relation to the aims of the study of an eroded area in Batu Pahat, with Pantai Punggur chosen as the study area. The tide prediction may be obtained for each day from the website of www.tide-forecast.com. Each time a site visit is conducted, tidal water level predictions will be used. Table 1 shows the predictions of the tidal water level provide a time for the tidal sampling.

Table 1 - The low tide and high tide from November 2021 to December 2021

Date (Day)	High Tide		Low Tide	
	Time	Height (m)	Time	Height (m)
5/11/2021 (Friday)	10:04AM	3.20	4:56PM	0.09
6/11/2021 (Saturday)	10:43AM	3.32	5:38PM	0.10
7/11/2021 (Sunday)	11:23AM	3.33	6:21PM	0.21
17/12/2021 (Friday)	8:46AM	2.62	4:00PM	0.54
18/12/2021 (Saturday)	9:21AM	2.77	4:36PM	0.50
19/12/2021 (Sunday)	9:57AM	2.88	5:10PM	0.51

3.1 Data Collection

During the flight, collecting data methods have been allocated. After the recording was completed, the UAV aircraft was utilized as a reference for the whole image at a maximum of 50 m. The weather must be favorable to avoid affecting the information. Only one person was required to be the UAV pilot while the data gathering is performed. Coordinates of control points should be selected such that the data gathered may provide a better 3D picture when the procedure has been completed. The latitude, longitude and altitude coordinates in the coastal shoreline area must be used to obtain each reference point's relative location. The gathering of data is essential to generate shoreline change 3D models for the study area. In this study, the coastline map was acquired using the Pix4D Mapper and Global Mapper software.

3.2 Selecting a Sampling Station

The soil sampling station were established along the Pantai Punggur coastal. For the purposes of this test, a total of 20 point locations in Pantai Punggur coastal were marked according to zones such as Zones A, B, C, D, and E. All zone are divided for 4 tidal levels such as Maximum High Tide (MHT), High Tide (HT), Medium Tide (MT) and Low Tide (LT). The distance between the lowest subsurface and high tide, as well as the unimpeded measuring facilities of tree roots, barriers, or roadways, all impact the selection of sampling stations. The location of field soil test along the Pantai Punggur coastline is represented in figure 3.

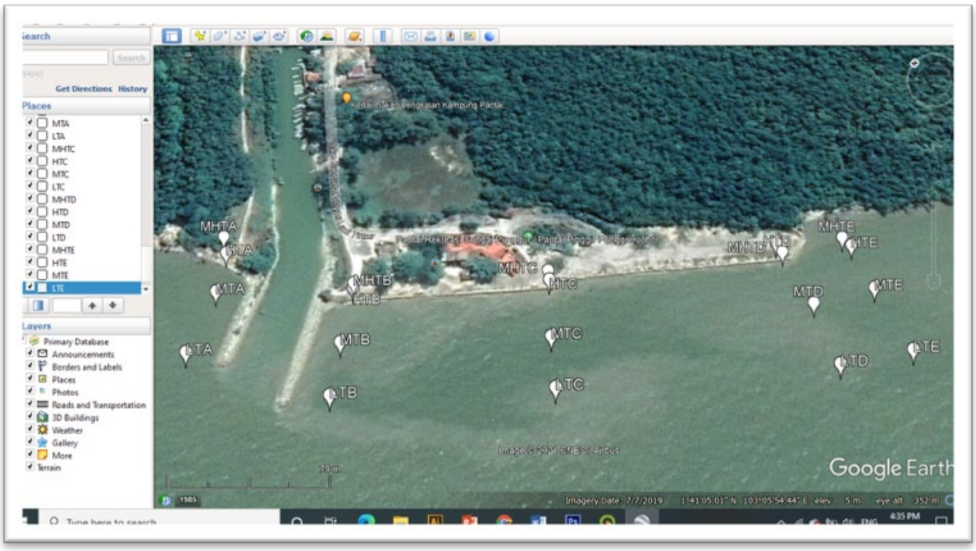

Fig. 3 - Field test stations of Pantai Punggur shoreline

3.3 Coastline Change Analysis

The coastline change analysis was performed using an overlapping approach between November and December 2021. Coastline changes analysis are important methods in this study to obtain more accurate data. This study has also been used by previous research. The average of coastline changes (CR) in one coastal area was calculated as follows [11]:

$$CR = \frac{A+B+C+D+E}{5} \quad Eq. 1$$

3.4 Field Vane Shear Test (VST)

Field methods are important studies in addition to laboratory methods. This study can also provide quick results and involve the use of tools that are appropriate to the soil conditions in the study area. For this situation, the field vane shear test (VST) is the best method to take data relevant to this study. The strength of the soil may be determined by applying a torsion force into the soil in order to obtain its torque value, which may be done in the laboratory or field using the vane shear test (VST). VST was performed in the field method for this investigation. Field vane shear testing is one of the most often used procedures for estimating soil undrained shear strength. The procedure of field vane shear test are as referred in [12]. For the purposes of this test, a total of 20 point locations in Pantai Punggur coastal were marked according to zones such as zones A, B, C, D, and E.

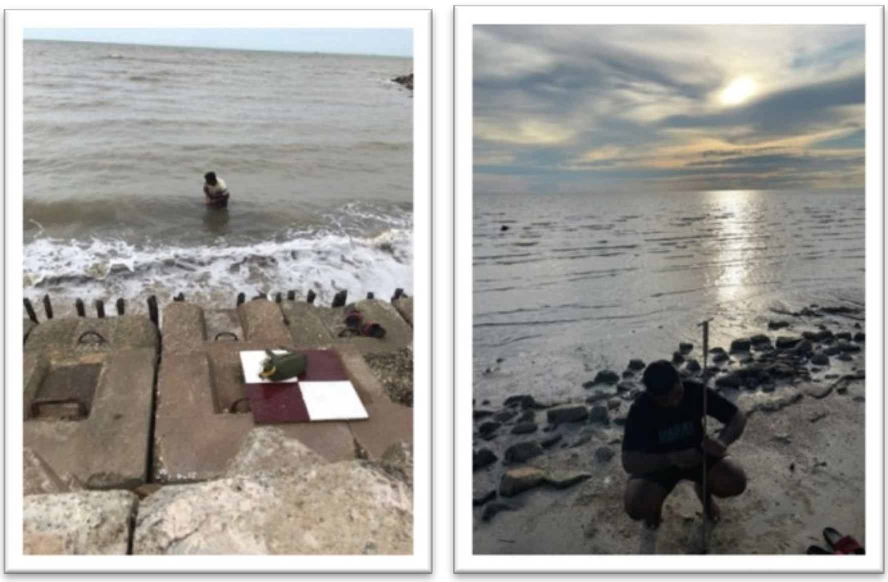

Fig. 4 - The actual situation when conducted field vane shear test (VST)

Figure 4 shows the actual situation when making this test. It is a field test used to determine the undrained shear strength of clay soils. VST was performed at each sampling station and several places on the sample were evaluated to obtain the values of the average shear strength. VST was used to estimate the vane shear strength of a soil sample ranging from soft to strong cohesive soil. Since this mud marine clay soil in this study is soft and has a low cohesive strength, the field VST is the most appropriate approach for testing the shear strength of this cohesive soil.

4. Materials and Methods

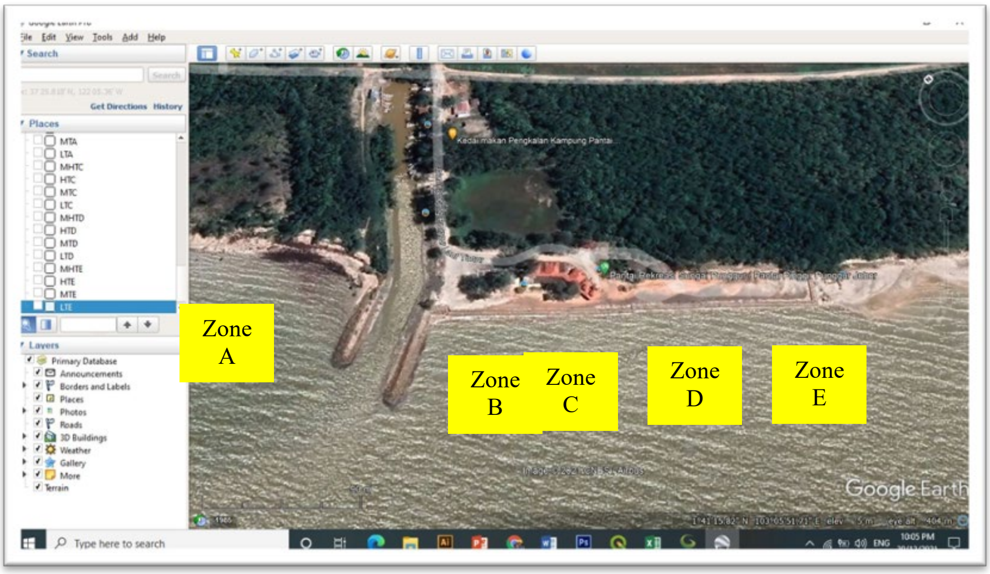

Fig. 5 - Location of zone A, B, C, D and E

Figure 5 shows the location of all zones. Zone A located at the left side of the study area has natural flora and fauna such as mangrove plants and sandy beaches. In the middle of the study site are zones B, C and D are near the revetment area (Labuan Block). This revetment was installed by the Department of Irrigation and Drainage (DID) to prevent coastal erosion in the area. Locations zone E, to the right side of the research area, experienced littoral transport from the mangrove vegetation area. The overlapped image captured by the DJI Phantom 4 Pro V2.0 is shown in figure 6.

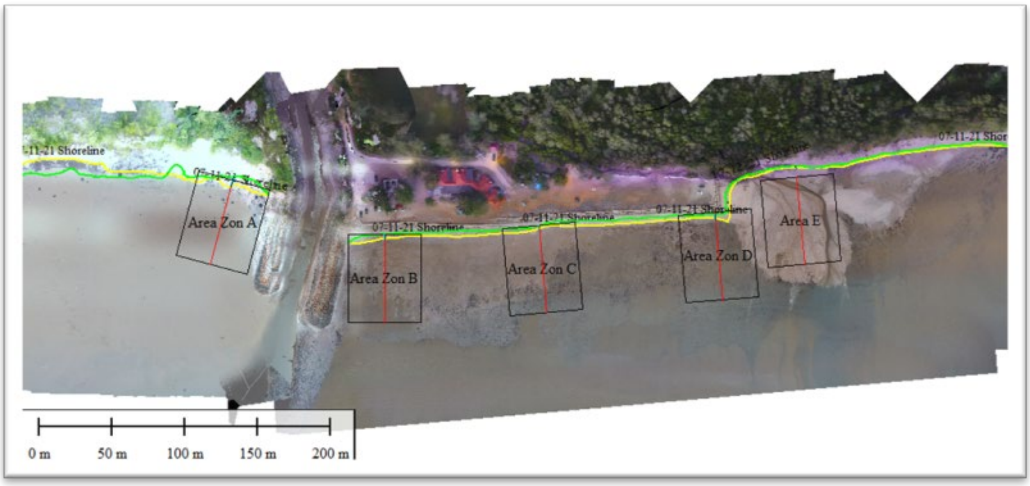

Fig. 6 - The overlapped image captured by DJI Phantom 4 Pro V2.0

The colour of the line in table 2 shows the shoreline change. Global Mapper and Pix4d software were used to process the images. Table 3 below also shows some meter-level shoreline changes recorded using Global Mapper at various locations.

Table 2 - Shoreline change

Month	The Colour Represents the Change in The Shoreline
November	(yellow line)
December	(green line)

Table 3 shows the average of shoreline changes at five zone along Pantai Punggur based on data obtained by images processed by both software taken in November and December 2021. Every zone is divided into 50 m to facilitate the calculation of the average each zone. Figure 7 shows the average of shoreline changes graph from November to December 2021.

Table 3 - The average of shoreline changes at difference zone along Pantai Punggur

Zone	Average Shoreline Changes From November to December 2021 (m)
A	2.406
B	1.978
C	1.698
D	0.956
E	0.812

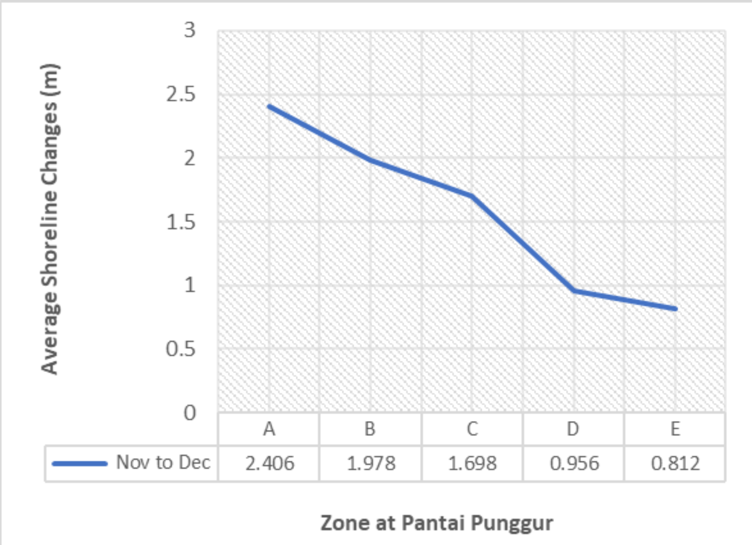

Fig. 7 - The average of shoreline changes graph from November to December 2021 graph

The average of shoreline change at zone A is more critical than in other zones because the average change approximate 2.5 m. This can indicate that zone A is an area that does not have a revetment area and only depends on the natural plants such as grass and trees. The average of shoreline change at zone B and C approximate is in the range of 1.5 m to 2.0 m because that zone are located at areas with revetment areas (Labuan Block). That shows that Labuan Block can reduce the effects of shoreline change in the area. However, the change in shoreline in zone D and E is significantly different from the zone A, B and C. The average shoreline change at zone D and E does not exceed 1.0 m. This zones undergoes minor shoreline changes because there is a process of coastal sand reclamation.

The summary of coastline change analysis was performed using an overlapping approach between November and December 2021. The average of coastaline changes at five zone along Pantai Punggur based on data obtained by images processed by Global Mapper software. The average of coastline changes (CR) in one coastal area was calculated as shown in Table 3.

Table 3 - Coastline Change in Pantai Punggur

Zone	Average Shoreline Changes From November to December 2021 (m)	Coastline Change (m)
A	2.406	
B	1.978	
C	1.698	1.570
D	0.956	
E	0.812	

Table 3 shows the average shoreline changes from November to December 2021 for every zone. The highest changes happen at zone A followed by zone B and C. The smallest shoreline changes is at zone D and E. From the overall coastal change (CR), Pantai Punggur had a 1.570 m. It is clear here that Pantai Punggur is an area that will be eroded in the future because this reading exceeds 1.5 m and above for only in a month interval. Due to its quick changes from day to day, it may produce erosion in the near future [6]. From previous study in August through

November 2017, the coastal alterations become readily evident during high tide [6]. It can be concluded that coastal changes in Pantai Punggur are unavoidable unless suitable precautions are taken.

To obtain more accurate data, this study conducted three readings field vane shear test (VST) at different depths such as readings at a depth of 0.5 m and 1.0 m on each tidal level for every zones in November 2021, but in December 2021 the data were taken in tidal level such as HT and MT. After obtaining the average value for the vane shear test, all these values shall be multiplied or divided by the value of the blade size ratio used to obtain the values of undrained shear strength (kPa) [12]. Figure 8 and figure 9 shows the result undrained shear strength (kPa) for HT and MT on November and December 2021.

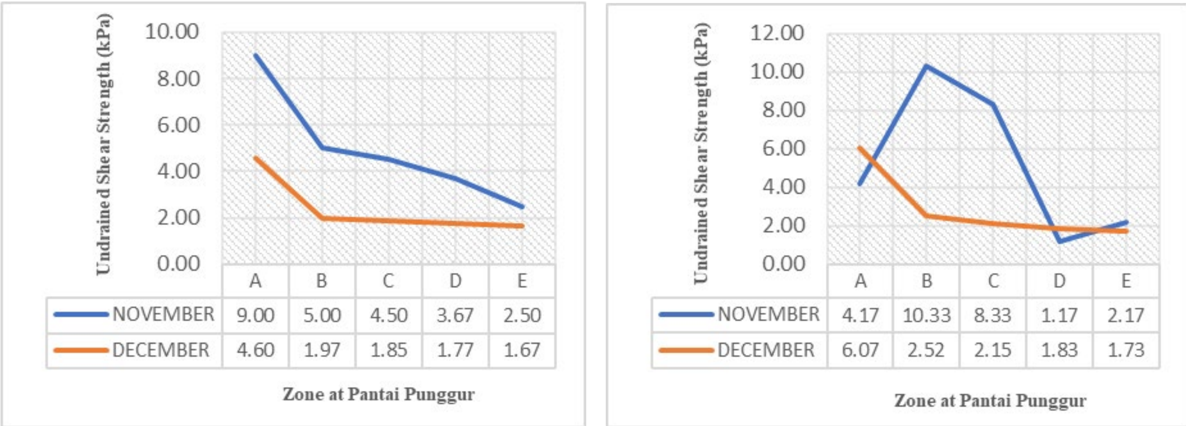

Fig. 8 - High Tide level depth 0.5 m (left) and 1.0 m (right) graph

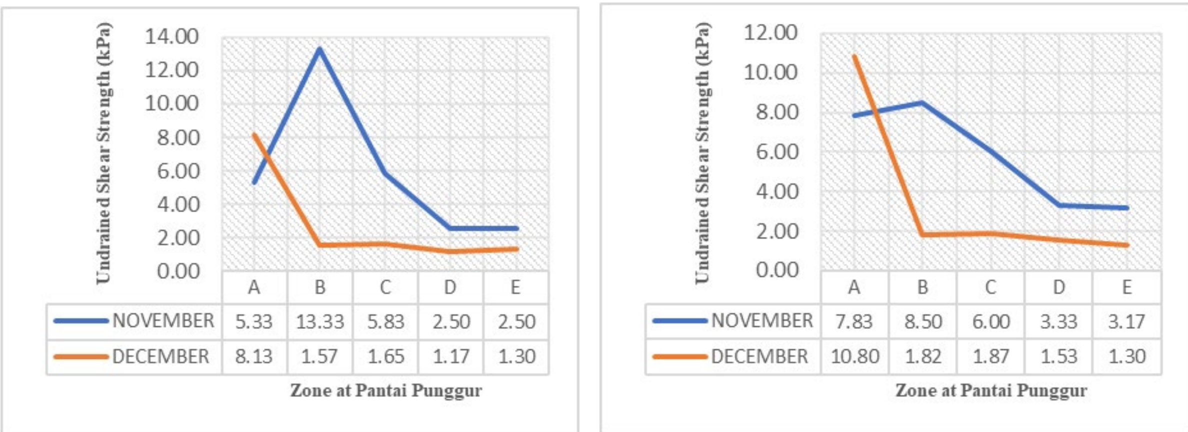

Fig. 9 - Medium Tide level depth 0.5 m (left) and 1.0 m (right) graph

Table 4 and figure 10 shows the comparison of HT and MT data for December 2021 at 0.5 m depth. This data is important because it uses reading data in December 2021 and depth 0.5 m to ensure that Cu readings can be measured more accurately at HT and MT levels. From that figure, it shows that Cu data decrease from HT to MT for all zones except zone A.

Table 4 - The HT and MT data for December 2021 at 0.5 m depth

Zone	The Undrained Shear Strength (kPa)	
	High Tide	Medium Tide
A	4.60	8.13
B	1.97	1.57
C	1.85	1.65
D	1.77	1.17
E	1.67	1.30

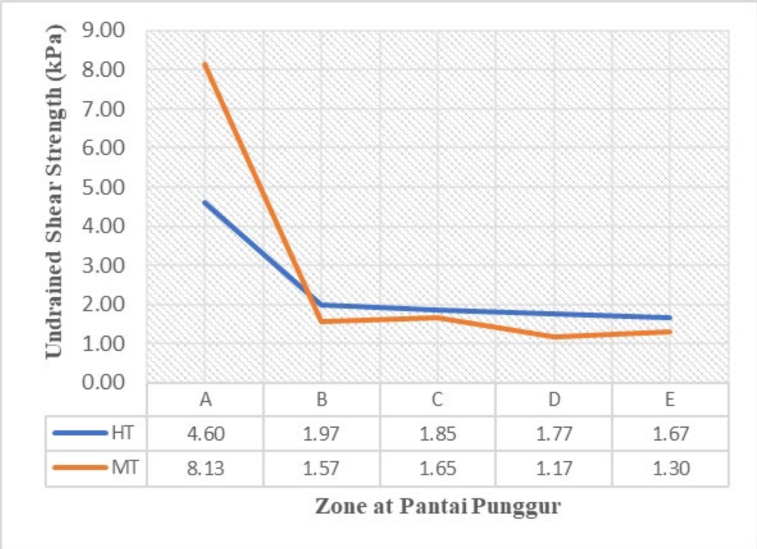

Fig. 10 - The HT and MT data for December 2021 at 0.5 m depth graph

Figure 10 also reported that the highest Cu is at zone A followed by zones B, C, D and lowest at zone E for both tide level. At zone A, the Cu reading are more than 4.5 kPa at the HT and MT level and another zones are below than 2.0 kPa reading. The readings in zone A as well show the MT is higher than the HT and the trend of this graph shows a decrease in other zones but the HT is higher than MT. These data will explain further observations in the HT zone but at different depths in table 5 and figure 11.

Table 5 - The depth 0.5 m and 1.0 m data for December 2021 at HT level

Zone	The Undrained Shear Strength (kPa)	
	0.5 m	1.0 m
A	4.60	8.13
B	1.97	1.57
C	1.85	1.65
D	1.77	1.17
E	1.67	1.30

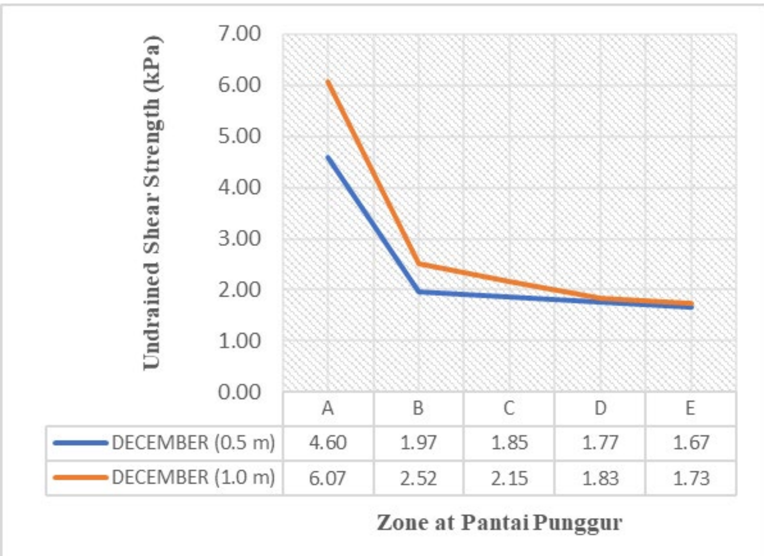

Fig. 11 - The depth 0.5 m and 1.0 m data for December 2021 at HT level graph

Figure 11 shows the graph for Cu data in December 2021 at HT level. From the graph, it shows that Cu data increase when the depth increase. The highest at zone A and the lowest at zone E for both depth level. At zone A, the Cu reading are more than 4.5 kPa at the 0.5 m and 1.0 m depth and another zones are below than 3.0 kPa reading.

The correlation of soil shear strength with shoreline changes in the study area in Pantai Punggur is related. As for this research, the actual data of Cu at HT level was selected in order to obtain the undrained shear strength as stated in Table 6. Table 7 and Figure 12 shows the correlation of soil shear strength on shoreline changes at Pantai Punggur.

Table 6 - The undrained shear strength (Cu) value

Zone	High Tide Level (Depth 0.5 m)		Changes Cu, (kPa)
	November	December	
A	9.00	4.60	4.40
B	5.00	1.97	3.03
C	4.50	1.85	2.65
D	3.67	1.77	1.90
E	2.50	1.67	0.83

Table 7 - The correlation of soil shear strength on shoreline changes

Zone	Average Shoreline Changes (m)	Changes Cu, (kPa)
A	2.406	4.40
B	1.978	3.03
C	1.698	2.65
D	0.956	1.90
E	0.812	0.83

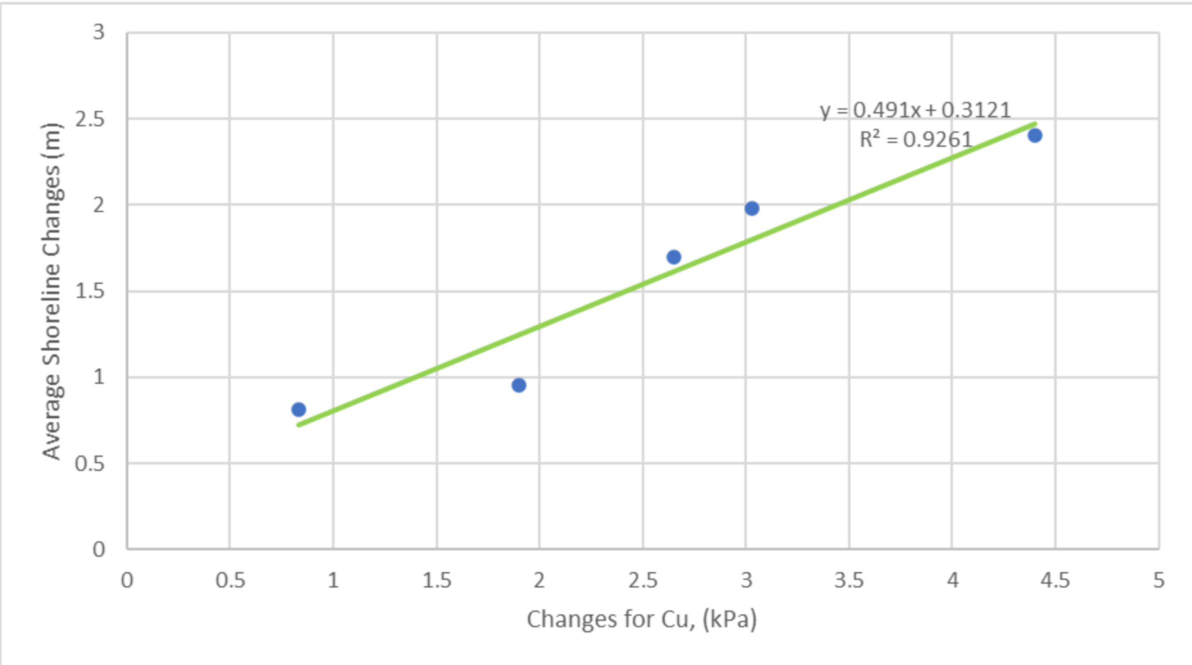

Fig. 12 - The correlation of changes in Cu versus shoreline changes graph

Figure 12 shows the correlation in changes for shoreline and Cu. From the figure above, it shows that shoreline has a liner correlation with Cu which R^2 is 0.9261. Note that the correlation is for data HT at 0.5 m depth and from that it shows that, shoreline changes increased when changes in Cu also increased.

5. Conclusions

This study is conducted to determine the effect of soil shear strength on shoreline changes at Batu Pahat coastal area where Pantai Punggur was selected as the study area. Since the study focus two parameters which is shoreline changes and shear strength of the soil. Therefore, the implementation of visual investigation has been carried out to evaluate the shoreline changes and as for the physical investigation, field vane shear test was used to determine the shear strength of the soil. Based on the data of shoreline changes obtained in the Global Mapper software in each zone, zone A portrays the highest changes followed by zone B and C. As for zone D and E its shows quite a small change. Within one month interval, which is from November to December, Pantai Punggur coastline experiences changes in about 1.57 meters. Next, the vane shear test (VST) is used to determine the shear strength of the shoreline area. From the undrained shear strength test at 0.5 m depth at HT and MT data for December 2021, zone A with Cu reading are more than 4.5 kPa followed by zones B, C, D and lowest at zone E and overall are below than 2.0 kPa. The depth of a tidal level also influences the data of this study. When the length of shoreline increase, the shear strength of data also increases. For example, at depth 0.5 m and 1.0 m data for December 2021 at HT level, zone A with Cu reading is more than 4.5 kPa at the 0.5 m and 1.0 m depth and other zones are below than 3.0 kPa. As a conclusion, the correlation of changes in soil shear strength with shoreline changes in the study area in Pantai Punggur have a linear correlation with R2 is 0.9261. For overall, when there is a huge change occur on the strength, it will directly affect the shoreline changes. Therefore from this research, it can be concluded that, shoreline changes increased when changes in Cu also increased.

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