Jurnal
Teknologi

Full Paper

BEACH-FACE MORPHODYNAMICS OF DIFFERENT MORPHOLOGICAL SETTING ALONG TELUK CHEMPEDAK TO KUALA PAHANG, MALAYSIA

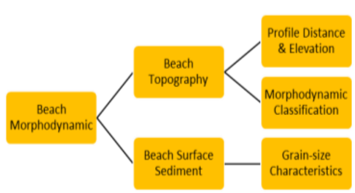
Mohd Zaini Mustapa[a*], Shahbudin Saad[a], Muhammad Salihi Abdul Hadi[b], Kamaruzzaman Yunus[a], Noraisyah Sapon[c]

[a]Department of Marine Science,
[b]Department of Computational and Theoretical Science, Kulliyyah of Science, International Islamic University Malaysia, Jalan Sultan Ahmad Shah, 25200 Kuantan, Pahang, Malaysia
[c]Institute of Oceanography and Environment, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

Article history
Received
2 July 2015
Received in revised form
5 November 2015
Accepted
25 November 2015

*Corresponding author
zoinea@gmail.com

Graphical abstract



Abstract

The present study on beach morphology and its profile dynamics was carried out to categorize the morphodynamic classification of selected beaches in Pahang, comprising the areas from Teluk Chempedak to Kuala Pahang. Beach stations were monitored monthly for a complete 1-year cycle; beginning from February 2012 to February 2013 at 12 corresponding stations established at random morphological intervals. Based on the results obtained, which include the granulometric analysis and beach surface topography, three main beach classes have been differentiated: reflective, intermediate and dissipative beaches. The reflective beaches exhibits rather high degree beach slopes and coarse-grain sand sizes compared to intermediate and dissipative classes.

Keywords: Beach morphology, beach morphodynamic classification

1.0 INTRODUCTION

Various researches were conducted from year to year with emphasized in the coastal region and related processes, in order to investigate and understand the morphological evolution in many aspects. The morphology of a beach is primarily influenced by wave climate, tidal flow, wind and sediment deposits [1, 2, 3, 4]. In this sense, the shape of the beach and nearshore region may be thought of as representing a form of averaging over time [5].

Morphodynamic evolution of cross-shore beach profiles takes place in a series of time scale vary from days to several years with respect to local weather conditions, seasonal changes and climate change impacts [6]. Though, these changes can be depended on the beach type; with some reports mentioned that the composite sand-gravel beaches are different with sandy beaches [7]. Sandy beaches have gentler and wide cross-shore slopes while the rocky beaches with relatively composite sand-gravel beaches in contrast, have a coarser steep swash zone that grades abruptly into a low-gradient sandy lower inter-tidal to sub-tidal [8].

The nature and complexity of most coastal problems vary widely with locations. Hence, a proper and desirable solution of any specific problem requires a systematic and thorough study of Pahang beaches focuses on the area from Teluk Chempedak to Kuala Pahang. For example, serious erosion problem occurred at several parts of the beaches in the study area such as Pantai Teluk Sisek to Pantai Taman Gelora and along Pantai Sepat. As the beach areas always been an attraction to the people, the appropriate insights on beach condition are necessary to maintain its sustainability in the future.

This paper complements recent work on the typologies of the beach surface based on topographic profiles from a series of surveys and sediment sample collection. The aim of this study is to investigate the temporal and spatial changes of the beach morphology and identify the sediment characteristics in order to produce the beach morphodynamic classification along the study area. The classification of beach states was classified based on an empirical model developed by [9] that categorized beach states into reflective, intermediate and dissipative beaches [10, 11].

2.0 MATERIALS AND METHOD

2.1 Study Area

The study area comprises from Teluk Chempedak (3° 48.765'N, 103° 22.330'E) to Kuala Pahang (3° 32.485'N, 103° 27.200'E) located in the state of Pahang, the largest state in Peninsular Malaysia (Figure 1). Situated in the eastern coastal region, the coastline of Pahang adjoins with South China Sea with a total length of about 209 km. The coastline is devoid by cliffs and headlands, and its long stretch of sandy and muddy beaches whose continuity is interrupted by river-mouth.

Generally, the morphology of Pahang coast encompasses the multiple shoreline background, i.e. rocky shore (Teluk Chempedak and Tanjung Tembeling), muddy shore (Tanjung Lumpur) and sandy shore (Kuala Pahang). The middle-part of the study area is mainly composed of muddy fine-sand where mean size is comparatively higher with about 5-6 phi especially in Tanjung Lumpur [12]. However, coarser grain sizes are composed at the southern part, especially in Kuala Pahang where the area is located near to the estuary. A total of 12 stations were set-up on beaches at various points with random intervals comprising of different morphological settings. The stations selected are: Teluk Chempedak (TC), Taman Gelora (TG), Tanjung Lumpur (TL), Peramu (PER), Suntiana (SUN), Kempadang (KEM), Chempaka (CEM), Sepat-A (SPT-A), Sepat-B (SPT-B), Cherok Paloh (CP), Serandu (SER) and Kuala Pahang (KP). The selection of these stations is made with respect to diversity in morphological background, such as near headland, open-coast and near the estuary (Figure 1).

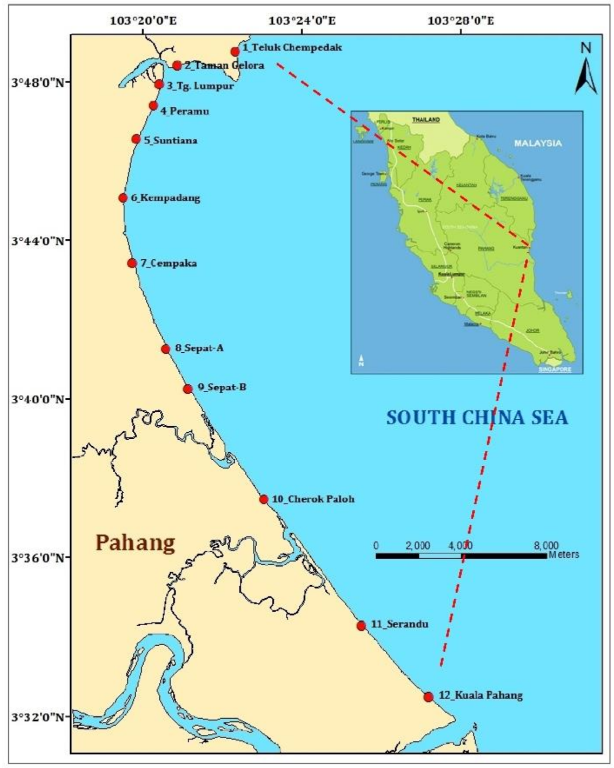


Figure 1 Map showing the study area which consists of 12 stations at irregular intervals. The distance between upper-North station (Teluk Chempedak) and lower-South station (Kuala Pahang) is about 35 km

2.2 Beach Topographic Survey

The beach topographic survey was carried out on a monthly basis from February 2012 to February 2013, concerning a complete 1-year cycle. Surveys have been conducted using a total station (Leica Builder 409) for distance and elevation measurements.

Topographic data were collected from the foredune down to the low water line during the low-tide condition. The total length of longshore coverage was approximately 100m with a 10m interval between each transect line. The spacing between each point of each transect line was set at regular intervals or when there is a break in elevation, as lower gaps between the points will allow detail preview of beach surface. Point coverage and spacing varied for each survey and site depending on the field conditions such as weather and wave conditions, and the availability of personnel and equipment [13].

Data points contain x, y and z axis of the total station was imported and processed using Surfer 11.0 software, for three-dimensional (3D) surface interpolation. For interpolation, the kriging algorithm was applied to generate a Digital Elevation Model (DEM) that converts survey point data into continuous field grids [14].

2.3 Grain Size Analysis

To provide grain-size insight on the studied beaches, sediment sampling was conducted parallel during the topographic survey along the cross-shore profiles. Samples were collected from different sub-tidal levels, particularly high-tide (HT), mid-tide (MT), low-tide (LT) and swash zone (SZ).

Sediment samples were oven dried at 70 °C for 24 hours [15] and grain-size analysis was carried out using two different approaches; dry-sieve for coarser fraction that have more than 63 μm size, and laser diffraction equipment for finer composite. For the dry sieving process, approximately 100 g of each sample was sieved in Retsch sieve shaker machine through 13 different sieves with mesh size of 4, 2.8, 2, 1.4, 1, 0.71, 0.5, 0.355, 0.25, 0.18, 0.125, 0.09 and 0.063 [16, 17]. Samples retained in each mesh were weighed using electronic balance.

Analysis of finer samples using laser diffraction systems (Malvern Mastersizer 2000) allowed to analyze the fraction with less than 63 μm and the lowest detection limit is 0.02 μm. About 5 g of sediments that were suspended in 100 ml of distilled water treated with Calgon solution were put inside a beaker with mechanical stirring propeller and connected to the ultrasonic system. Analysis of suspended particle size through a liquid flow controller that pumped the particles into the cell column and scanned by the laser beam (De Falco *et al*., 2003). Principal statistical parameters (mean size, sorting, skewness and kurtosis) were calculated using the Logarithmic Method of Moments [18, 19, 20] with the statistical formula as follows:

$$\text{Mean: } \bar{\chi}_\phi = \frac{\sum f\, m_\phi}{100} \tag{1}$$

$$\text{Sorting: } \sigma_\phi = \sqrt{\frac{\sum f\,(m_\phi - \bar{\chi}_\phi)^2}{100}} \tag{2}$$

$$\text{Skewness: } Sk_\phi = \frac{\sum f\,(m_\phi - \bar{\chi}_\phi)^3}{100{\sigma_\phi}^3} \tag{3}$$

$$\text{Kurtosis: } K_\phi = \frac{\sum f\,(m_\phi - \bar{\chi}_\phi)^4}{100{\sigma_\phi}^4} \tag{4}$$

Where *f* is the weight percentage (frequency) in percent; and m_ϕ is the midpoint of each class interval in phi unit.

2.4 Morphodynamic Classification

An integrated classification was applied to classify the morphodynamic state of the beaches studied [9]. It describes the variability conditions by evaluating the relationships between wave forcing, sediment and beach slope characteristics [21, 22]. The two parameters identified for beach state prediction and classifying morphodynamic condition are the dimensionless fall velocity (Ω) and surf-scaling parameter (ε) that can be calculated by given formula:

$$\Omega = \frac{H_b}{W_s T} \tag{5}$$

$$\varepsilon = \frac{a_b \omega^2}{g \tan^2 \beta} \tag{6}$$

Where H_b is significant breaking wave ($a_b = 2H_b$); W_s is average sediment fall velocity; *T* is wave period; *g* is acceleration due to gravity; β is beach slope; and ω is radian frequency (2π/T). Dimensionless fall velocity predicts the beach morphodynamic state, from reflective (Ω < 1), intermediate (1 < Ω < 6) to dissipative states (Ω > 6) [23]. Meanwhile, surf-scaling parameter conditions could be differentiated into reflective (ε < 2.5), intermediate (2.5 < ε < 20) and dissipative (ε >20) [23, 21].

3.0 RESULTS AND DISCUSSION

3.1 Wave Climate

Data of wave components i.e. wave height and wave period are important in discussing the energy level that affect the changes of beach morphology. In this study, the wave height and wave period data obtained from the Meteorological Department of Malaysia and measured during field survey were integrated as physical parameter input. The analysis presents a distinction of seasonal variation with higher waves recorded in November, December and January, whereas lower values were common during April – June (Figure 2a). Wave period (Figure 2b) demonstrated higher values during the southwest monsoon. Comparatively, lower wave period was observed during the northeast monsoon indicating rapid wave activity during this period.

3.2 Sediments

The superficial sediment of the shoreface indicates the mean size predominantly classified as very coarse sand, coarse sand, medium sand and fine sand type [25]. Most of these sediments show angular in shapes ranged between -0.60 φ – 2.85 φ (Figure 3). This suggests that the longshore variations occurred in a small scales as only fine and medium sand dominated. Regionally, more finer-grained sediment found at the middle provinces, and coarser-grained sediment obtained at upper-north and lower-south of the study area. This implies a comparative pattern, where the northern part located near the headland (TC) and southern part is appreciable by the influence of river sand supply (Kuala Pahang). Sorting coefficient specifies that most of the sediment varied between poorly sorted to moderately-well sorted ranged from 0.26φ to 1.89φ.

Sediment skewness shows less variability with most of the central regions comprised of negatively skewed distributions. This could probably due to the presence of coarse sediments in greater percentage or due to mixing of unequal proportions of the sediments that subjected to variations in wave energy. The majority of the sediment collected from the study area are composed of very negatively skewed type.

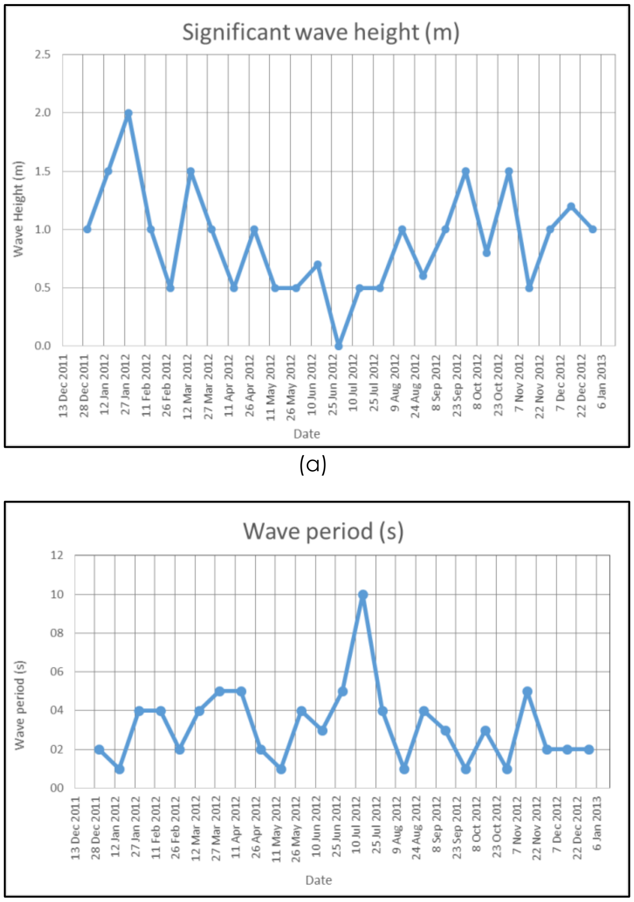


Figure 2 Wave climate distribution during the studied period: (a) significant wave height; (b) peak wave period

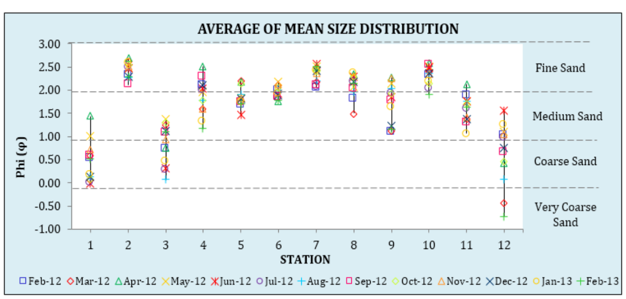


Figure 3 Average mean size distribution

3.3 Beach State

Six beach states were identified (Figure 4) based on criteria such as profile shape, shoreface slope, sediment characteristics and local specificities of the shoreface.

3.2.1 Reflective Beaches

Reflective beaches are characterised by a steep slope, an abrupt profile with the absence of nearshore bars. This type of beach states is only observed at the TC and TL beaches. The sediment is coarse-grain with mean size and median diameter (D_{50}) ranged -0.69φ – 2.07φ and 0.282mm – 1.464mm. The swash slope is steep and attains of range between 3.763° to 5.112°.

3.2.2 Intermediate Beaches

Intermediate beaches are observed at most central region of the study area. For certain station, the intermediate beaches exhibit a well-developed bar morphology for instance in SUN, CEM and KEM beach stations, as illustrated in 3D surface interpolated beach profiles (Figure 4). There are some beaches classified as intermediate-reflective and intermediate-dissipative, though they fall into intermediate class.

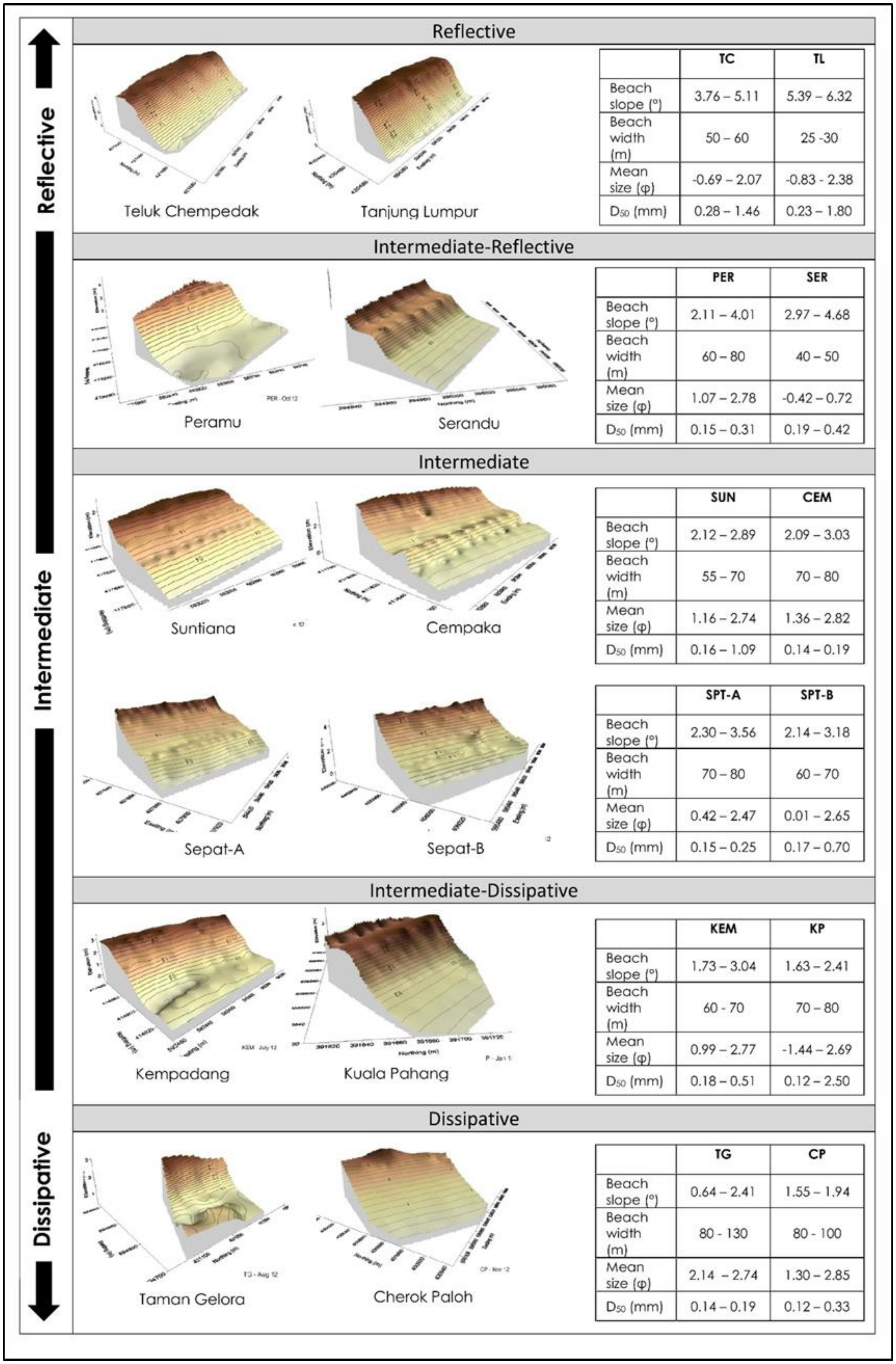
3.2.3 Dissipative Beaches

Dissipative beaches are found at TG and CP beaches. The beach profile differs from the previous one by relatively lower shoreface slope degree, ranged from 0.64° to 1.94° evolving into a convex configuration towards surf zone.

3.2.4 Morphotype Classification Analysis

At the northern region of Pahang, the classification of beaches of TC, TG and TL varied from reflective and intermediate, where the beach site of TG tend to be near-dissipative type. The reflective beaches were mostly obtained at the northern part of Pahang coast due to steeper swash slopes as exposed by wave attack vulnerability. The TC beach for example, became a tourist attraction for years, provides diverse assortment of activities and facilities. It can be considered the beach presently under-utilized. This may give plausible explanations to the reflective morphodynamic formation.

The strong collapsing breakers to the beach-face during northeast monsoon were steadily increased the risk factor of beach hazard [26]. This explained that these hazards occurred due to reflective beach morphotypes that are sheltered from waves by structures such as rocks or jetties development. Even though wave height is relatively low in these protected locations, the deep inshore water along steep-reflective beach-faces poses a high risk of swimming activities.



	TC	TL
Beach slope (°)	3.76 – 5.11	5.39 – 6.32
Beach width (m)	50 – 60	25 -30
Mean size (φ)	-0.69 – 2.07	-0.83 - 2.38
D_{50} (mm)	0.28 – 1.46	0.23 – 1.80

	PER	SER
Beach slope (°)	2.11 – 4.01	2.97 – 4.68
Beach width (m)	60 – 80	40 – 50
Mean size (φ)	1.07 – 2.78	-0.42 – 0.72
D_{50} (mm)	0.15 – 0.31	0.19 – 0.42

	SUN	CEM
Beach slope (°)	2.12 – 2.89	2.09 – 3.03
Beach width (m)	55 – 70	70 – 80
Mean size (φ)	1.16 – 2.74	1.36 – 2.82
D_{50} (mm)	0.16 – 1.09	0.14 – 0.19

	SPT-A	SPT-B
Beach slope (°)	2.30 – 3.56	2.14 – 3.18
Beach width (m)	70 – 80	60 – 70
Mean size (φ)	0.42 – 2.47	0.01 – 2.65
D_{50} (mm)	0.15 – 0.25	0.17 – 0.70

	KEM	KP
Beach slope (°)	1.73 – 3.04	1.63 – 2.41
Beach width (m)	60 - 70	70 – 80
Mean size (φ)	0.99 – 2.77	-1.44 – 2.69
D_{50} (mm)	0.18 – 0.51	0.12 – 2.50

	TG	CP
Beach slope (°)	0.64 – 2.41	1.55 – 1.94
Beach width (m)	80 - 130	80 - 100
Mean size (φ)	2.14 – 2.74	1.30 – 2.85
D_{50} (mm)	0.14 – 0.19	0.12 – 0.33

Figure 4 3D classification of beaches observed based on beach morphodynamics states; reflective, intermediate and dissipative

On the middle and southern regions of the study area, beaches from PER to KP exhibits as intermediate and dissipative state during the six respective months. The intermediate and dissipative beaches are usually longer than the reflective beaches, with gentler slope gradient. This may due to the site specific and differential energy forces (lower) that act towards this area at particular time.

4.0 CONCLUSION

It could be generally define that the beaches along the Pahang coastal region are classified as intermediate and dissipative state, with some of them are reflective beaches. Most of the beach sediment confined of fine and medium sand with relatively lower beach slopes exhibits at the central region of Pahang shoreline.

Acknowledgement

The authors sincerely thank the International Islamic University Malaysia especially Department of Marine Science, Kulliyyah of Science (KOS) and Institute of Oceanography and Maritime Studies (INOCEM) for their financial support and staff assistance. We would like to thank our colleague and friends who involved during fieldwork and data collection activities.

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