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THE PLANFORM STABILITY OF EMBAYED BEACHES ON THE WEST COAST OF PENINSULAR MALAYSIA

Mohd Shahrizal Ab Razak[a]*, Nurhamizah Jamaludin[b], Nur Ariffah Zaimah Mohd Nor[a]

[a]Department of Civil Engineering, Universiti Putra Malaysia 43400 Serdang, Selangor, Malaysia
[b]IRMUDA Sdn Bhd, Johor Bahru, Malaysia

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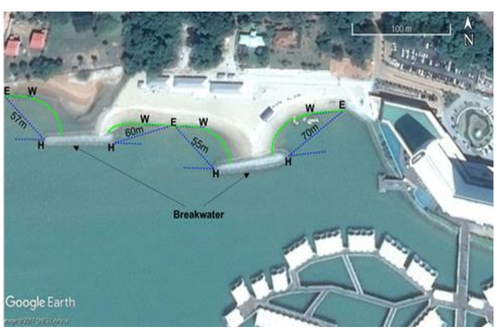
*Corresponding author
ar_shahrizal@upm.edu.my

Graphical abstract



Abstract

Embayed beaches can be found along the West coast of Peninsular Malaysia and they are subject to beach's dynamic changes. Some part of the coast along the West coasts have experienced severe erosion for several decades, in spite of the construction of various coastal defence structures. Therefore, it is crucial to predict the stability of embayed beaches along the West coast of Peninsular Malaysia. The planform stability of embayed beaches was established by applying the MEPBAY model. It was found that the total number of embayed beaches along the West coast of Peninsular Malaysia is 139 with 73 % were natural embayed beaches and 27 % were artificial embayed beaches. From the analyses, out of the 139 embayed beaches; 82 % were in static equilibrium and 18 % were in dynamic state. The causes of the instability of embayed beaches are the topography of the embayed beach, discrepancies in the design of previous coastal structures, influenced by wave climate as well as human intervenes without prior investigation of the biological and physical effects towards the beach. Furthermore, the applicability of engineering solutions applied on embayed beaches that are in either dynamic equilibrium can be predicted using MEPBAY programme.

Keywords: Bay, static beach, dynamic beach, parabolic bay shape, erosion

Abstrak

Pantai berteluk boleh dijumpai disepanjang pantai Barat Semenanjung Malaysia dan pantai ini terdedah kepada perubahan dinamik. Sebahagian daripada pantai disepanjang pantai barat mengalami hakisan teruk untuk beberapa dekad, biarpun adanya permbinaan pelbagai struktur perlindungan. Oleh itu, adalah penting untuk meramal kestabilan pantai teluk disepanjang pantai Barat Semenanjung Malaysia. Kestabilan bentuk pelan pantai berteluk ditentukan dengan mengaplikasi model MEPBAY. Ia telah didapati bahawa jumlah pantai berteluk di sepanjang pantai Barat Semenanjung Malaysia adalah 139 dengan 73 % adalah pantai berteluk natural dan 27 % adalah pantai berteluk buatan. Daripada analisis, daripada 139 pantai berteluk, 82 % adalah dalam keseimbangan statik dan 18 % dalam kesimbangan dinamik atau keadaan tidak stabil. Punca ketidakstabilan pantai berteluk adalah topografi pantai berteluk, percanggahan dalam reka bentuk struktur pantai sebelumnya, pengaruh cuaca gelombang serta campur tangan manusia tanpa penyiasatan terhadap kesan fisikal dan biologikal ke atas pantai. Selanjutnya, kebolehaplikasi penyelesaian kejuruteraan yang diaplikasi ke atas pantai berteluk samada dalam keseimbangan dinamik atau keadaan tidak stabil boleh diramal menggunakan program MEPBAY.

Kata kunci: Teluk, pantai statik, pantai dinamik, bentuk teluk parabola, hakisan

1.0 INTRODUCTION

Installing artificial coastal structures without first considering the stability of a beach may jeopardize the safety of infrastructures, both existing and new one to be installed due to the increasing potential of erosion which eventually leads to the decreasing sediment supply in the near future. Therefore stability verification for an embayed beach is strongly recommended prior to the installation of an artificial structure in the preliminary design phase [1]. According to [2], it is necessary to consider the equilibrium in beach profile in conjunction with the equilibrium in beach planform, which may be in static equilibrium, dynamic equilibrium, unstable or natural reshaping. Recently, researches on embayed beach have been increasing popular in line with open straight coasts. [3] studied on the morphological development of embayed beaches; [4] investigated morphological changes of embayed beaches in Cape Buzios, Rio de Janeiro, Brazil; [5] used a simple coastline evolution model to explore alongshore transport-driven shoreline dynamics within generalized embayed beaches to identify two primary orthogonal modes of shoreline behavior that described shoreline variation about its unchanging mean position; and many others. However, studies on embayed beach planform stability particularly by applying the parabolic bay model are scarce and limited except [1, 6], [7, 8], [9], [10], [11], [12], and [13]. The prabolic bay model was developed by [14] and is the most applied embayed model compared to other bay shape model. As indicated by [15], other models developed are logarithmic spiral model [16, 17] and hyperbolic tangent model [18].

Futher the development of parabolic bay model, [1] presented the classification of embayed beach stability i.e static, dynamic, unstable. Static equilibrium of an embayed beach is a state when the predominant waves are breaking simultaneously around the whole bay periphery, hence littoral drift is almost non-existent and external sediment is not required to maintain its long term stability. Under this condition, it may be assumed that no further sediment is being added or eroded from the bay, under the persistent swell condition; waves break simultaneously around the bay periphery; and littoral drift or alongshore currents are almost non-existent [6, 7]. In a static equilibrium state, the bay shape modelled by the parabolic bay shape model coincides with the original shape of the shoreline as shown in Figure 1, left panel.

If the predicted curve is landward of the existing beach which has remained stable over a long time, the beach is said to be in dynamic equilibrium as shown in Figure 1, middle panel. This is because the shoreline may degrade as sand supply decreases or change in the wave climate for example incident wave direction. A much similar definition is given by [7] which is when the sediment supply from updrift and/or a source within the embayment is required to maintain its stability; otherwise shoreline would retreat as supply reduces. Should supply diminish, then a beach in dynamic equilibrium could recede toward the limit defined by the static equilibrium under the same wave condition.

Referring to [1], natural beach reshaping is a state of unstable condition normally associated with wave sheltering due to addition or extension of structures on beach, where a curved shoreline planform could result with accretion in the lee accompanying by erosion downdrift. This scenario is normally arising from the construction of a new breakwater or extending an existing breakwater for a harbour [19], which is often called "groyne effect" for causing downdrift beach erosion. When the shoreline displacement is significantly verified, the beach is classified as an unstable state, as shown in Figure 1, right panel.

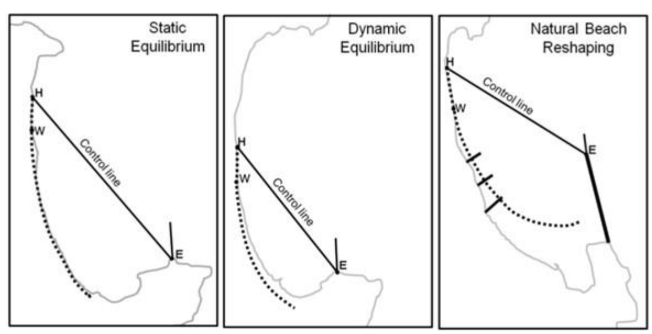


Figure 1 Planform stability of embayed beaches. The bold dotted line indicates the static equilibrium shoreline position, described by parabolic bay shape equation. H = downdrift control point; W = downdrift tangent point; E = updrift diffraction point

Having a muddy coastline, the West coast of Peninsular Malaysia, which was once vegetated by mangrove forests gives an upper hand in creating a low energy area for the waves to break before reaching the shoreline. Despite this, some part of the coast along the West coasts have experienced severe erosion for several decades, in spite of the construction of various coastal defence structures. Numerous causes can be pointed out that contribute to the above concern which include human intervention and extreme weather conditions and as a result, the coastal safety and economic values are in jeopardy. In fact, many researches mainly focus on open straight coast due to less complicated coastal environment setting and, yet the importance of embayed beaches is being deprecated. Therefore, to be able to envisage the changes in the system, it is crucial to predict the stability of embayed beaches along the West coast of Peninsular Malaysia.

Three main objectives are developed which are: (i) to determine the number of embayed beaches along the West Coast of Peninsular Malaysia; (ii) to analyse and establish the stability state of embayed beaches; and (iii) to propose and discuss the applicability of the possible engineering solutions for the beaches in dynamic or unstable state conditions.

2.0 METHODOLOGY

The main study area is along the West coast of Peninsular Malaysia. Along the coast, there were eight states which are Johor, Melaka, Negeri Sembilan, Selangor, Perak, Pulau Pinang, Kedah and Perlis as seen in Figure 5.

This study employs the long term empirical bay model known as MEPBAY (Model for Equilibrium Bay) which was developed by [20]. The model was developed based on the parabolic bay shape equation derived by [14]. The parabolic equation for a bay in a static equilibrium is presented in equation 1.

$$\frac{R}{R_\beta} = C_o + C_1\left(\frac{\beta}{\theta_n}\right) + C_2\left(\frac{\beta}{\theta_n}\right)^2 \quad (1)$$

R, R_β, β and θ are shown in Figure 2.

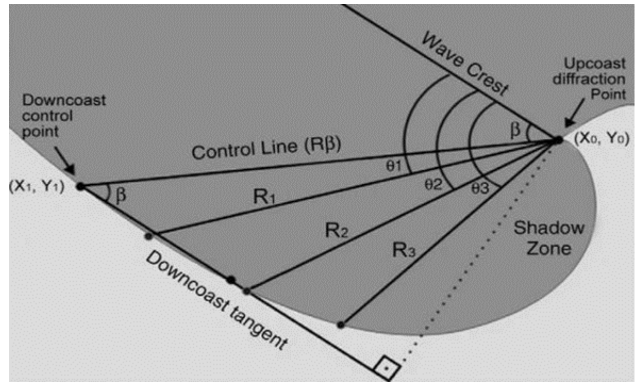


Figure 2 Definition sketch for parabolic bay shape model, showing major physical parameters (after [14])

The coefficient values of C_o, C_1, and C_2 are generated by a regression analysis. The MEPBAY model is operated by defining three important controlling points i.e upcoast wave diffraction point, downcoast control point, and downcoast tangent point as shown in Figure 2. An aerial or satellite image of embayed beaches is first required to be loaded into the programme. The satellite images of the embayed beaches were obtained from Google Earth Pro. Other applications of MEPBAY can be found in [21] and [22].

The selected embayed beaches along the West coast of Peninsular Malaysia according to its states are shown in Table 1. From the table, there are few beaches that share the same name thus the beaches are numbered according to the sequence of which come first to prevent any confusion. On top of that, since some of the beaches are unknown, therefore the names are given in accordance to the nearest landmark or cities found.

Table 1 Selected embayed beaches along the West coast of Peninsular Malaysia according to its province

No	Province	Name of selected embayed beaches
1	Johor	i. Pantai Parit Terus
2	Melaka	i. Pantai Tanjung Bidara ii. Pantai Tanjung Bidara (2) iii. Pantai Tanjung Bidara (3) iv. Pantai Pangkalan Balak v. Kuala Sungai Baru
3	Negeri Sembilan	i. Port Dickson ii. Tanjung Lembah iii. Bagan Pinang (1) iv. Bagan Pinang (2) v. Pantai Gemok
4	Selangor	i. Sekinchan
5	Perak	i. Teluk Rubiah ii. Teluk Batik iii. Teluk Senangin
6	Pulau Pinang	i. Bagan Ajam
7	Kedah	i. Pantai Lagenda ii. Pantai Chenang iii. Teluk Burau iv. Teluk Datai v. Pantai Dato Syed Omar
8	Perlis	i. Kuala Perlis

These embayed beaches as listed in Table 1 are selected so that they cover various types of stability as well as the effect of different coastal structures that may contribute to the beach erosion process. For example, some embayed beaches have river outlet while some have existing coastal structures such as breakwater, groyne or few do not have any structural features along the coast.

Furthermore, those selected beaches are popular beaches and play a part in tourist attraction, which make the study important. In addition to that this study is expected to be able to identify the sources of beach erosion thus identifying the best engineering solution that can be applied in order to mitigate the problem.

Wave direction is important as it gives information on the direction of incoming waves. In this study, wave rose plots are made to various locations to represent the nature of directional waves. Wave data was obtained from the National Oceanic Administration Agency (NOAA). The data required to produce the wave rose diagram are wave direction (θ) and wave height (Hs). Along the West coast, waves are mainly propagated from the Northwest direction. Examples of offshore wave rose plot are given in Figure 3 and Figure 4. Waves are predominantly from the northwest direction with relatively moderate to low amplitude.

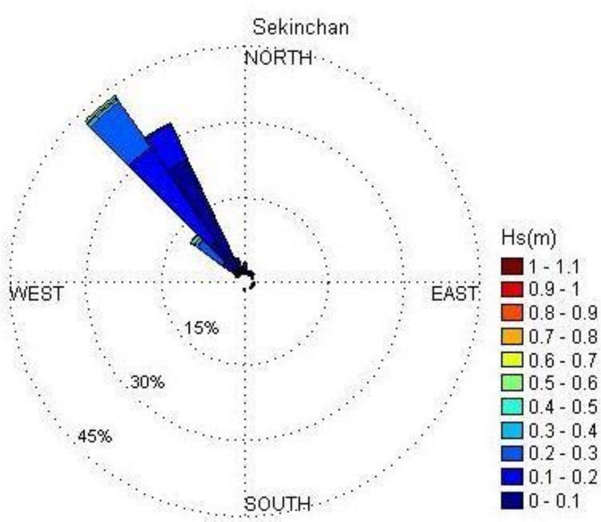


Figure 3 Wave rose diagram of Sekinchan, Selangor. Predominat wave is coming from the northwest with the majority of waves are low in a range of 0.1 m and 0.3 m

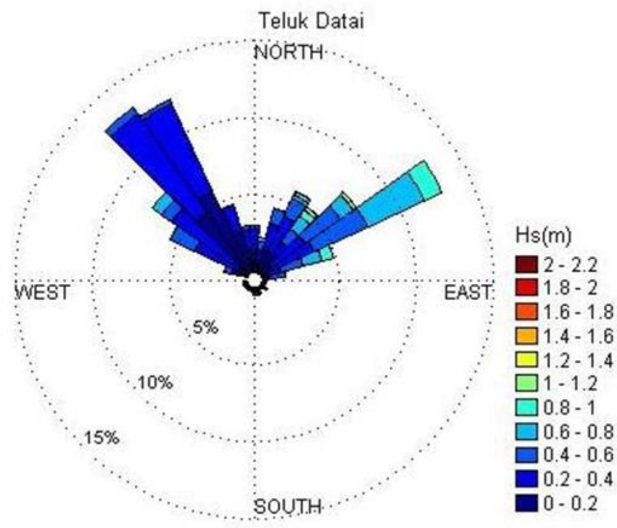


Figure 4 Wave rose diagram of Teluk Datai, Kedah showing bi-directional wave coming from the northeast and northwest direction with the majority of waves range from 0.2 m to 0.6 m height

The planform stability of embayed beaches can be categorized in three which are static equilibrium, dynamic equilibrium and unstable or natural reshaping. In this study, the declaration of the planform stability is decided based on the predicted equilibrium line generated by the MEPBAY programme. The predicted line is known as the static equilibrium planform (SEP) throughout this paper. For each photograph of embayed beaches applied to the programme, there are two possible lines that can be generated in conjunction with the existing shoreline whereby each has its own indicators. The first scenario is when the predicted SEP is landward or seaward from the existing shoreline, thus the embayed beach is said to fall under the dynamic equilibrium category or unstable. The third case is the ideal case whereby when the predicted SEP coincides with the existing shoreline, thus the embayed beach is under the static equilibrium category.

The results of the planform stability of embayed beaches located along the West Coast of Peninsular Malaysia is obtained through a detail analyses of all the 139 embayed beaches using the MEPBAY programme.

3.0 RESULTS AND DISCUSSION

The results are presented in two categories which are according to the nature of the embayed beach itself; whether it is a natural or an artificial embayed beach and the second category is according to its planform stability such as static equilibrium, dynamic equilibrium or unstable state conditions.

Overall, there are 139 embayed beaches found located along the West coast of Peninsular Malaysia. The number is generated with the aid of Google Earth starting from the Southwest of the West coast of Peninsular Malaysia up to the Northwest of the same coastline. However, the 139 embayed beaches do not include those in small islands scattered near the West coast of Peninsular Malaysia since some of the island do not pose any effect to the mainland whether if its stable or not. With this reason, embayed beaches in small islands are excluded from this study.

Out of 139 embayed beaches present along the West coast of Peninsular Malaysia, a total of 102 of them are found to be natural embayed beaches while the remaining 37 are categorized as an artificial embayed beach. Figure 5 shows the distribution of embayed beaches along the west coast of peninsular Malaysia.

Among the 73 % of the natural embayed beaches; 82 are in static equilibrium state, 20 are in dynamic equilibrium state. From the above situation, a total of 20 natural embayed beaches are facing excessive erosion thus requires proper engineering applications to recover or stabilize the existing shoreline.

On the other hand, out of the 27 % of the artificial embayed beaches 32 of them are in static equilibrium state, 13 are in dynamic equilibrium state. Although these embayed beaches have already been equipped with necessary engineering applications to help stabilized the beach, 13 of them are still facing excessive erosion.

Nevertheless, this paper presents the stability analyses based on the selected embayed beaches as introduced earlier (see Table 1). Further discussions on these beaches under three main stability states static, dynamic, and unstable are presented in the following section.

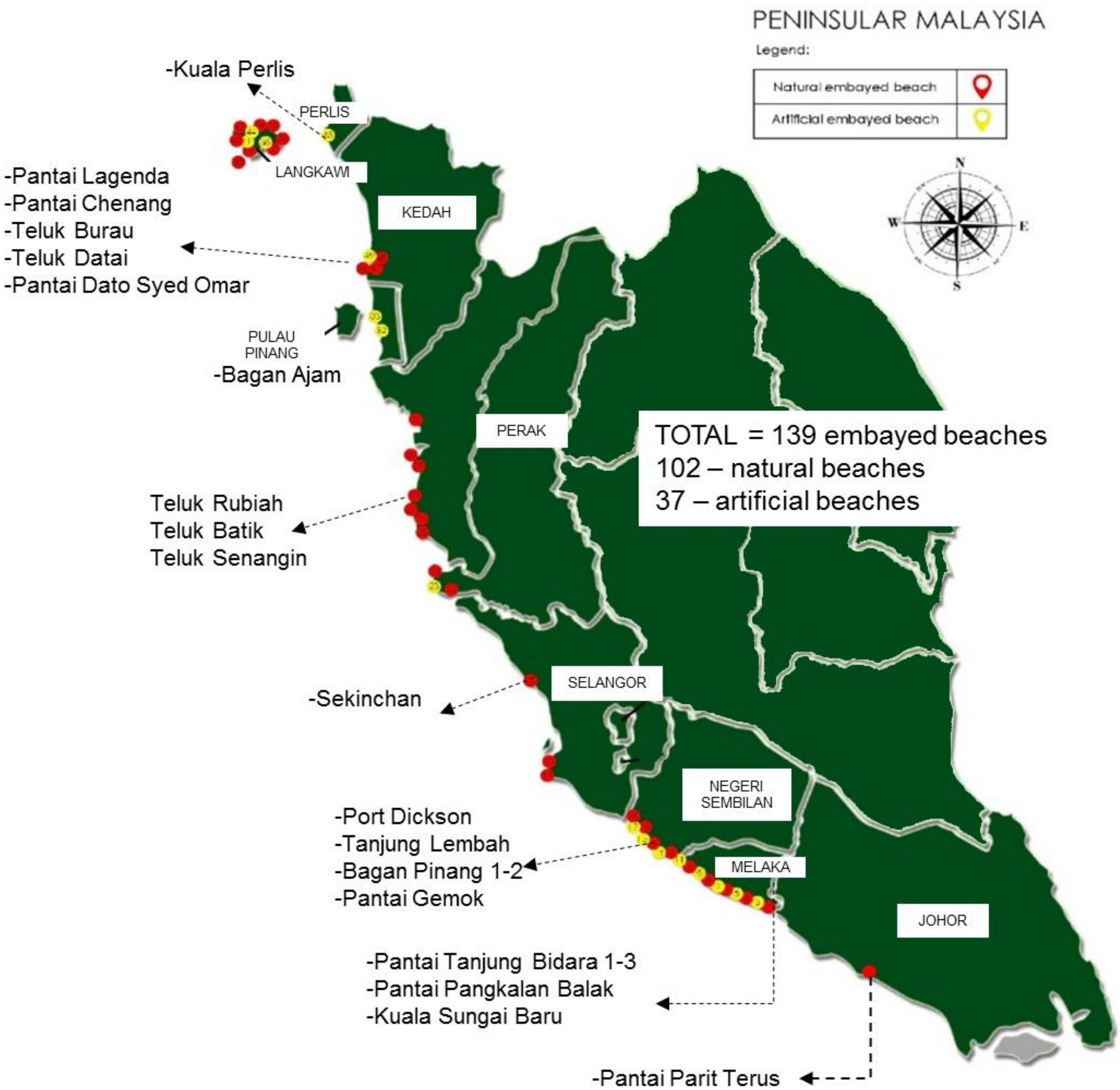


Figure 5 Map of embayed beaches along the West coast of Peninsular Malaysia. Selected beaches as tabulated in Table 1 are presented on the map

Static Equilibrium Beaches

Out of the total 22 selected beaches, 16 embayed beaches are categorized as the static equilibrium embayed beaches, five of them are of natural embayed beach with the natural headland acts as their wave diffraction point. Figure 6 shows the example of static natural embayed beach when the predicted static line coincides with the actual shoreline. It should be noted that in all figures, point E, W, and H represents downdrift control point, downdrift tangent point, and updrift control point, respectively. Those natural embayed beaches that fall under static equilibrium state are; Tanjung Bidara (3), Melaka; Teluk Rubiah, Perak; Teluk Burau, Langkawi, Kedah; Pantai Dato Syed Omar Langkawi, Kedah and Sekinchan, Selangor.

The classification of static beaches is somewhat difficult to make due to the ambiguity in locating of the updrift diffraction point. The updrift diffraction point chosen was believed to be the nearest to the embayed beach compared to the detached headland located not far from the beach. This is based on the assumption that since the length of the embayed beach can be considered as rather short, thus the point where the waves diffracted should be near to the beach.

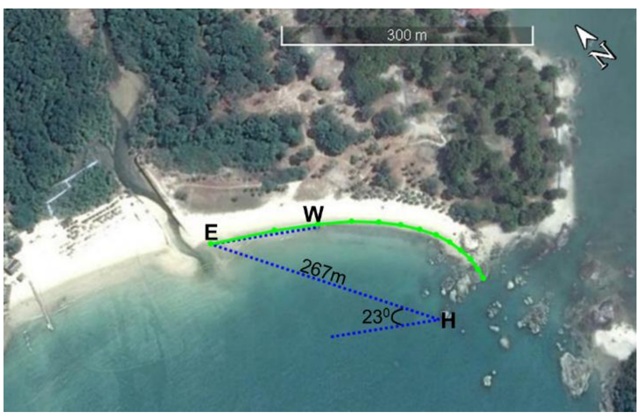


Figure 6 Teluk Burau, Langkawi and the predicted SEP using MEPBAY programme

From the total of 16 embayed beaches categorised as a static equilibrium embayed beaches, 7 of them are artificial embayed beach with groynes, which the structure acts as the artificial headland point of wave diffraction (refer Figure 7).

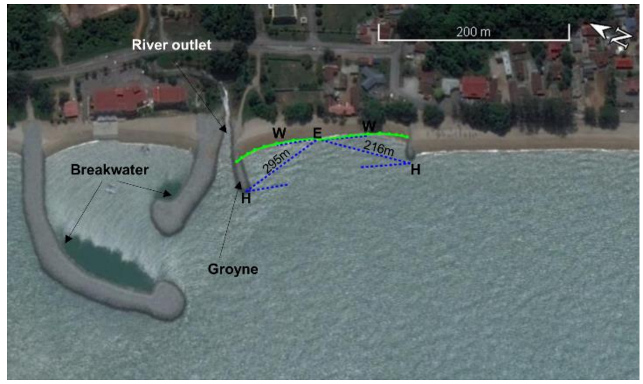


Figure 7 Pengkalan Balak, Melaka and the predicted SEP using MEPBAY programme

Those embayed beaches mentioned are; Pengkalan Balak, Melaka; Tanjung Bidara (2), Melaka; Bagan Pinang, Negeri Sembilan; Pantai Gemok, Negeri Sembilan; Bagan Ajam, Pulau Pinang; Kuala Perlis, Perlis and Kuala Sungai Baru, Melaka. Since the points of diffraction of the embayed beach are located on the groyne (as artificial headland) instead of the breakwater, thus this case is considered as an artificial embayed beach with groynes. The breakwater in this case is to create a calm water area for ships and boats to harbour. On the other hand, the purpose of the groynes is to stabilize or maintain the stability of the beach.

There is only one embayed beach in a static equilibrium state due to the proper construction of breakwater and the embayed beach is located in Port Dickson, Negeri Sembilan. Figure 8 shows the presence of tombolo mainly due to the application of the breakwater. The beach is considered in a static equilibrium state as the predicted SEP coincides with the original shoreline. The main purpose of breakwater is to reduce the intensity of wave action in inshore waters and thereby reduce coastal erosion or provide safe harbourage.

Breakwaters can also be small structures designed to protect a gently sloping beach and placed 1 to 300 feet offshore in relatively shallow water. Breakwater is only suitable to be used if the incoming wave is perpendicular to the beach as shown in the figure below. The dissipation of energy and relative calm water created in the lee of the breakwaters often encourage accretion of sediment however, this can lead to excessive salient build up, resulting in tombolo formation, which reduces longshore drift shoreward of the breakwaters. This trapping of sediment can cause adverse effects down-drift of the breakwaters, leading to beach sediment starvation and increased erosion thus and thus, further engineering protection being needed down-drift of the breakwater development.

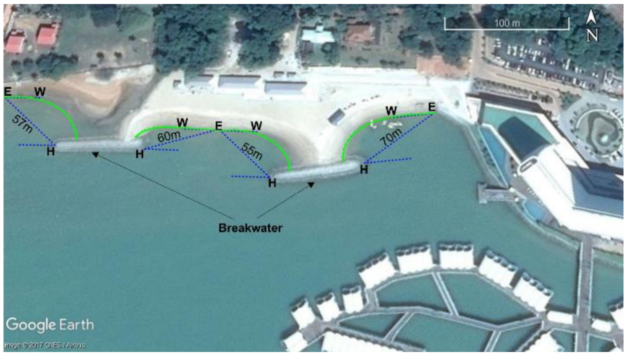


Figure 8 Port Dickson, Negeri Sembilan and the predicted SEP using MEPBAY programme

There are a variety of coastal protective measures to help in mitigating the erosion caused either naturally or due to human intervene. Figure 9 shows that a stretch of seawall has been installed around the headland as to protect it from the harsh energy wave from the North. It is believed that the installation of the seawall which helps to preserve the shape of the headland, causes the embayed beach formed behind the headland to be in a static equilibrium. The seawall does not only protect the headland from serious erosion but also the beach itself.

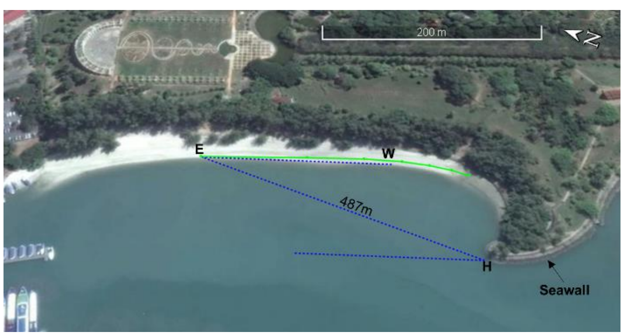


Figure 9 Pantai Lagenda, Langkawi and the predicted SEP using MEPBAY programme. The yellow bold dotted line indicates the static equilibrium planform (SEP) position

Harbours are used for ships and boats to seek shelter from stormy weather or are placed temporarily. In the study, it is found that two out of 16 of the selected embayed beaches in static equilibrium state which are Bagan Pinang (2) and Tanjung Lembah both located in the states of Negeri Sembilan. Figure 10 shows that the updrift diffraction point is located on the harbour where the wave may hit first upon reaching the shoreline. Part of the harbour acts as headland by sheltering the beach from direct incoming waves (high energy waves). The waves from the open sea may break on the harbour first before being diffracted to the beach, hence littoral drift is almost non-existent and external sediment is not required to maintain its long term stability. The embayed beach will remain the stable if there are no additional structures that can cause alteration in its diffraction point.

Figure 10 Tanjung Lembah, Negeri Sembilan and the predicted SEP using MEPBAY programme

Dynamic Equilibrium Beaches

According to [1], dynamic equilibrium is when the predicted SEP is landward of the existing shoreline which has remained stable over a long time. This is because the shoreline may degrade as sand supply decreases or change in the wave climate for example incident wave direction. Out of the selected embayed beaches, three of them are in dynamic equilibrium i.e. Tanjung Bidara, Melaka; Teluk Batik and Teluk Senangin both located in Perak. Figure 11 on the left side shows the predicted SEP situated landward from their existing shorelines thus can be categorised as dynamic equilibrium beach and is considered to be a natural embayed beach since the curvature is formed due to the diffraction point located at a natural nearby headland.

Based on [1], this phenomenon happens when sediment is still passing through it and its periphery will not be so indented compared with that in static equilibrium. Besides that, in the former, dynamic process of sediment movement within an embayment depends not only on wave conditions (height, period and direction), but also on the temporal and spatial variations in bathymetry. To put it mildly, this complex situation increases the difficulty for numerical computations as well as field measurements; therefore, without such luxury, it is hard to pin point what is the main reason of the beach to behave in that manner.

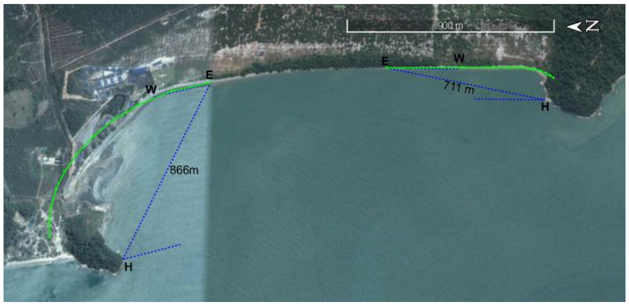


Figure 11 Teluk Senangin, Perak and the predicted SEP using MEPBAY programme

Figure 12 shows Pantai Chenang, Kedah, an artificial embayed beach with a combination of static and dynamic equilibrium.

Figure 12 Pantai Chenang, Langkawi and the predicted SEP using MEPBAY programme

The groyne and temporary breakwaters are some of the engineering application that has been applied in hope to stabilize the beach. The river outlet located beside the groyne is one of the source of which causing the sediment to accumulate on the beach and supposedly help in stabilizing the beach. However, only the groyne can stabilize the smaller part of the beach whereas both of the temporary breakwaters fail to do so. This is because, the beach is retreating from the temporary breakwater, diminishing the sediment supply from its existing shoreline.

Proposed Engineering Applications to Convert Dynamic Beaches to Static Beaches

Graphically, an embayed beach is unstable when the shoreline displacement is significantly verified [22]. According to [1], this phenomenon is caused due to the addition or extension of structures on beach such as breakwater, which could promote the formation of a curved planform with accretion in the lee accompanying by erosion downdrift. Nevertheless, it has been shown that several applications of coastal structures were led to static beaches as shown in Figure 7 and Figure 8.

Most of the coastal facilities in developing countries, including port and urban developments, have been designed and constructed without an appropriate planning or without any prior investigation both physical and climatic at work in the area. Due to this reason, many projects were doomed to fail through ignorance rather than deliberate fault. On the other hand, in some cases, lacks information not only affect the original design but also the solutions employed in hope of rectifying the undesired effects caused by it. According to [23], before proposing solutions to any types of coastal problems, analysis must be done along two branches which are; firstly, the existing coastal dynamics prior to the construction need to be understood as fully as possible, even though they may have been altered so that it can be very difficult to find hints of the original balances; and secondly, the effect of the infrastructure proposed is recommended to be assessed before any solution is adopted.

Besides that, according to [1], for an embayed beach of static equilibrium either in natural or artificial environment, "do nothing" option should be adopted to preserve its stability while any suggestion to modify the existing position of the headland tip would render the bay beach unstable or natural reshaping, which is a scenario that should be avoided at all cost. He added that, if an embayed beach is in dynamic equilibrium, then the static bay beach concept can be introduced to improve its stability by constructing an artificial updrift control point to convert its stability from dynamic to static. A conventional approach to protect an eroding shore involves the construction of hard structures, such as seawalls, revetments, groynes and detached breakwaters in narrow gaps.

An example of dynamic beach that is converted to static beach is given in Figure 13. The solution is to install a breakwater of approximately 100 metres starting at the tip of the headland (H to H' point) as shown in the Figure 13.

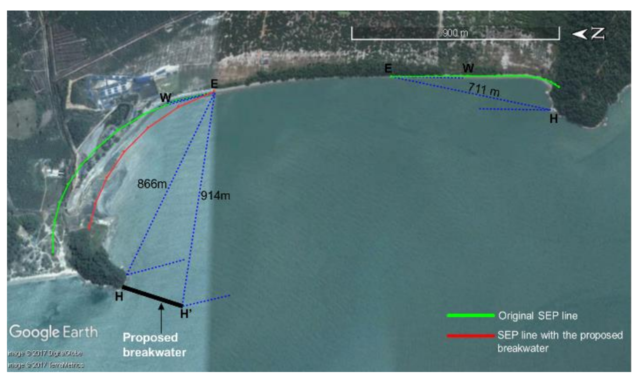


Figure 13 Teluk Senangin, Perak with previous and new predicted static equilibrium planform (SEP) position. Yellow dotted line indicates the existing predicted SEP while the red dotted line indicates the predicted SEP after the installation of new structures. The proposed breakwater is indicated by the black bold colour

Since it involves two headlands, the effect of this method must be considered on both beaches. Graphically speaking, although the shorelines of these two embayed beaches are connected but, the distance between the two headlands is too far apart. Thus, a mere 100 metres breakwater will not be affecting the static equilibrium of the embayed beach on the right as seen in the Figure 13. Therefore, it is preliminary safe to say that this method is able to stabilize the dynamic equilibrium embayed beach without affecting the equilibrium of the beach next to it.

In the case of Pantai Chenang as shown in Figure 14, the temporary breakwater is not functioning as it should be in a way that the sediment should be accumulating at the lee of the breakwater. Therefore, there are two approaches to handle such situation. The first approach is to place a beach nourishment in the lee of the breakwater so as to stabilize the beach. However, the beach will keep eroding and the sediment will decrease over time thus making the beach unstable or dynamic equilibrium again. Frequent maintenance of the beach is required whereby the beach will have to be nourished after a certain period of time, probably every two years.

The second approach is to make used of what is available on the beach by extending the breakwater of approximately 80 metres and 60 metres on both left and right breakwater respectively. By doing this, the point of diffractions is altered thus moving the predicted static equilibrium planform (SEP) line seaward than the existing deteriorate shoreline. If the breakwater is to be extended as described, the sediment will accumulate at the lee of the breakwater thus ignite sand to accumulate along the shoreline. This method may require beach nourishment, but the period of maintenance would not be as frequent as the first one. However, this approach will be more economical compared to the first approach.

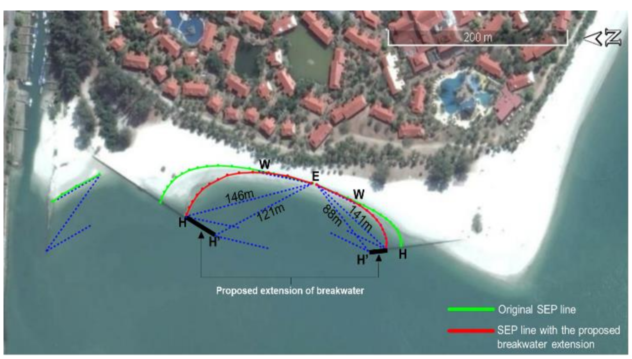


Figure 14 Pantai Chenang, Langkawi with previous and new predicted static equilibrium planform (SEP) position. Yellow dotted line indicates the existing predicted SEP while the red dotted line indicates the predicted SEP after the installation of new structures. The proposed breakwater is indicated by the the black bold colour

Nowadays, there are many engineering alternatives available either hard or soft that can help stabilized the beach. These alternatives must be considered thoroughly with further investigations of the original state of the beach, the current conditions of the beach as well as how it reacts to changes.

As stated by [24], "if cross-shore sediment transport is dominant consider nearshore breakwaters first, groins cannot create or destroy sediment, to avoid erosion of adjacent beaches always include a beach nourishment, a minimum dry beach width must be defined to evaluate success, a ratio of 2-3 between the longshore spacing and the length from the seaward tip of the groin to the design shoreline is a good start to determine the beach nourishment needed, rely on modern shoreline and cross-shore evolution numerical models, bypassing, structure permeability and balance between net and gross longshore sediment transport are the key factors in the design, consider tapered ends to minimize impacts on adjacent beaches, establish a monitoring program, be prepared to modify or remove the groins if the beach impacts are not acceptable".

In response to the above, although beach and dune nourishment are widely used techniques but they cannot solve a coastal erosion problem by themselves. [25] defined the term 'quiet revolution' to refer to the situations in which hard engineering works transfer the problem to adjacent beaches and stated that the best way to deal with these scenarios is to design a maintenance plan for beach nourishment. Overall, the success of the solution proposed here depends on good coastal management and on the participation of as many users as possible to keep the beach in a sound state.

4.0 CONCLUSION

In this study, the only method of conduct is by MEPBAY programme, which is used to establish the stability state of each embayed beach along the coastline. A Google Earth Pro is used as the main source of obtaining the satellite images of each embayed beach. From the study, it is learned that the majority of embayed beaches along the West coast of Peninsular Malaysia is comprised of natural embayed beaches instead of artificial embayed beaches. On top of that, the majority of embayed beaches regardless of its nature are in static equilibrium state while not many of the beaches are in either dynamic equilibrium or unstable state. This thus infers that the coastline along the West coast of Peninsular Malaysia is stable and does not face any major accumulation or erosion of sediments. This is mainly because of the properties of the existing sediments present on the beach along the coastline which comprises of muddy soil. The muddy soil came from mangrove plantations which can be abundantly found along the coastline of West coast of Peninsular Malaysia. However, the coastline is not entirely made up of muddy soil but some of the embayed beaches may comprise of sandy beaches too. The second ultimate reason is the significant wave height along the Straits of Malacca which is mainly propagating in the North-West direction. The wave height is not that high compared to those in the East coast of Peninsular Malaysia.

Therefore, the energy wave is not too high which may result the embayed beaches to be eroded in a short period.

The considerations of the possible engineering solutions are only for the embayed beaches that are in either dynamic equilibrium or unstable state. The engineering solutions suggested in this study is only by using MEPBAY programme as to establish the stability state of the embayed beach before and after the coastal structures are constructed. This cannot be the only measurement used to decide whether the methods are suitable to be applied thus; other factors should be taken into considerations. Thorough planning and designing the suitable coastal structures are one of the important aspects in this study.

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