Akademika No. 23, Julai 1983

A NOTE ON THE CURVATURE AND ORIENTATION OF BEACHES ALONG THE COASTS OF NEGERI SEMBILAN AND MELAKA, PENINSULAR MALAYSIA

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Sinopsis

Kertas ini bertujuan menghuraikan kelengkungan dan orientasi pantai di Negeri Sembilan dan Melaka dari segi model geometri, dan juga meninjau sama ada pantai tersebut terdapat dalam keadaan seimbang atau sebaliknya. Sebahagian dari pantai tersebut mempunyai kelengkungan berbentuk arka bulatan dan kebanyakannya mempunyai orientasi yang menghadapi arah kedatangan ombak yang dominan walaupun tempat pengwujudan ombaknya pendek. Lencungan dari orientasi Barat-daya ke Selatan mungkin disebabkan oleh akibat topografi dan biasan ombak. Kebanyakan dari pantai tersebut memenuhi sebahagian dari keperluan bagi pantai seimbang, tetapi cuma sebuah pantai sahaja yang paling hampir menepati kesemua keperluan tersebut.

Synopsis

This paper aims at describing the curvature and orientation of beaches in Negeri Sembilan and Melaka in terms of geometric models and also looks into whether the beaches are in an equilibrium state or vice-versa. Some of the beaches have their curvatures in a circular arc form and most of them are oriented to the direction of the dominant waves, although the fetch is short. Deviations from the predominant Southwest to South orientation may be due to the topographic and wave refraction effects. Most of the beaches fulfill parts of the requirements for equilibrium conditions, but only one beach approximates all the requirements.

Introduction

Coastal environments are collectively characterized by change, and one of the most dynamic of these environments is the beach. The changes to which beaches are subjected may be seasonal or longer in duration, over a single tidal cycle or even from one crashing wave to the next. The dynamic nature of the beach environment had, for the past two centuries, spurred numerous scientists to study the beach morphology in relation to the various processes involved. Coastal landforms have been viewed, traditionally, in terms of profiles and cross-sections in illustrating their evolution or sequential development through time. For the past few decades, however, coastal geomorphologists have been considering the shape of beaches in plan by comparing it with certain geometric models. This simplification has been of great help to coastal geomorphologists in making comparisons between beaches as well as understanding beach dynamics and characteristics.

Geometric models have been used to describe the equilibrium plan shape or the curvature of beaches. Beaches have been regarded as in equilibrium if they are aligned perpendicularly to the direction of arrival of the most important constructing waves, or prevailing wave direction. Thus reference to some recent works in beach morphology shows attention being given to the relationship between the curvature and orientation of beaches. The actual shape and orientation of the beach itself is dependent on a number of variables, including the direction of wave energy approach, beach material, and the overall shape and composition of the coast.

Previous work

Various attempts have been made to fit specific geometrical forms to the beach outline in plan. McLean (1967: 17 — 19) used 86 beaches along the east coast, South Island, New Zealand to describe their form in terms of their radius of curvature relative to a circular arc. It was concluded that most of the beaches reach an arc of equilibrium where Waikouaiti beach having the closest fit, with an angular width of 95°. The curvature often increases towards the end of the beaches particularly when affected by wave refraction. In areas where there is a considerable amount of longshore movement, the establishment of the arc of equilibrium is hampered owing to the one-way movement of material. Of the 86 beaches there are only two cases where the curvature is convex seawards which is due to the deltaic nature of these areas.

Yasso (1964a & b) made a detailed study of the form of a spit-bar shoreline at Horseshoe Cove, Sandy Hook, in New Jersey. The wave-built sandy feature has a curvature convex to the sea as a result of wave refraction. The plan shape of the spit-bars seems to represent an equilibrium form which is maintained even under extreme conditions of tidal range and attack by large waves, such as those generated by hurricanes. The form that fits this beach is the logarithmic spiral, defined by $r = e^{\theta \cot \alpha}$. In this equation r is the length of a radius vector from the log-spiral centre at angle θ , and α is constant for the given logspiral, and varies from about 60° to about

90°. The logspiral curve was fitted to four beaches where there is little correspondence between the spiral angle α and the shape of the shoreline. This lack of correspondence may be due to different wave conditions at each location. However, the close fit that has been established, particularly on Sandy Hook, suggests that such a relationship may be useful in predicting changes in the plan of beaches in the lee of headlands.

Other geometric models have been applied to describe the curvature of beaches such as a circle or ellipse (Zenkovitch, 1959), and a nearly hyperbolic form (Dicken, 1961).

As far as the beach orientation is concerned a number of theoretical views on the processes that are important in determining the orientation of a beach have been put forward. Lewis (1931; 1938) discussed the tendency for beaches to turn in a direction normal to the approach of the dominant waves. He considered that any feature of marine deposition will tend to align itself normal to the direction of approach of the dominant waves, which he assumed to be the largest storm waves. If, however, the storm waves approach at an oblique angle they will cause longshore movement to the opposite direction. The beach, will therefore, tend to swing round to a position normal to their direction of approach. To illustrate this process, Lewis (1938: 107 — 127) cited as an example the orientation of the forelands in north Cardigan Bay, Wales, which he pointed out as facing the direction of maximum fetch, from which the largest waves come across the Irish Sea from the Atlantic Ocean.

Schou (1945) considered that the orientation of a beach depends on both the direction of maximum fetch and the resultant wind direction, R. This resultant wind direction value is calculated by drawing a vector diagram of all winds of Beaufort force 4 and over. The beach is orientated normal to the direction of R if the fetch maximum direction coincides with the direction of R, or when the fetch is equal in all directions.

The views put forward by both Lewis and Schou apply essentially to shingle structures that are built up by storm waves generated by local winds. Therefore, the wind direction plays an important role in determining the orientation of the beach.

The dominance of long swells on the orientation of sand beaches has been proposed by Davies (1959; 1960). He has shown how the wave crests approach the shore closely parallel to the orientation of the beach on many exposed beaches of Southern Australia and Tasmania. He pointed out that the amount of refraction the long swells undergo as they pass through the offshore relief plays an important part in determining the orientation of the beach. This is possible because the waves anticipate the beach before they reach it as they became adjusted to the underwater contours. He also argues that storm waves are destructive on sandy beaches and, therefore, it is more likely that the beach orientation will be determined by the swell.

According to McLean (1967: 19), the majority of the beaches of South Island, New Zealand face between southeast and east-southeast, which is the direction from which the dominant swells come. Beaches which are most exposed and those on the straightest parts of the coast approximate most closely to this orientation, while those on the most indented parts show the greatest divergence in orientation.

The curvature and orientation can be used to consider the equilibrium character of beaches. However, the beach must be supported at both ends to be in equilibrium and it must have a circular curvature. Both the curvature and orientation of beaches can be regarded as response to a series of process elements as put forward by Krumbein (1963).

Aim and Study Area

This short paper aims at describing the curvature of beaches along a short stretch of the West Coast of Peninsular Malaysia in terms of a geometrical model, and their orientation to the wave incidence and the effect of a short fetch. It is also aimed at looking to what extent some of the alluvial beaches found along the coast satisfy the requirement of equilibrium conditions put forward by both Lewis (1938) and Hoyle and King (1958).

The curvature of a beach is its plan shape which, theoretically, should be either concave or convex seawards representing a circular arc form. On the other hand, beach orientation is the general alignment of the beach to the wave approach. According to Davies (1960: 42), the beach fits the waves, but it is not necessarily straight, even if the waves approach from a consistent direction in deep water. The amount of refraction experienced by the waves as they pass through the shallow water plays an important part in determining the orientation of the beach. One of the most important variables on which the beach orientation depends in this situation is thus the underwater topography which plays a dominant part in determining the amount and character of the wave refraction.

The beach curvature and orientation therefore, can be regarded as responses to complex series of process elements which may vary both in time and space. Nevertheless, due to the length of time required by these processes to effect changes, the resulting beach curvature and orientation is often found to be less variable than expected, because many beaches appear to approach an equilibrium plan shape. However, for a beach to be regarded as being in equilibrium it has to satisfy certain conditions (Hoyle & King, 1958), whereby the curvature of the beach should be concave seawards and must have a circular form. The angle subtended by the radii from the ends of the beach should be 0.25 radians (14.3°). It must be orientated consistent with the prevailing wave conditions, and it must have an equilibrium gradient.

The beaches under investigation are along a 65 mile (104.6 km) stretch of coast in Negeri Sembilan and Melaka (Figure 1), from the mouth of Sungai Sepang (Lat. 2° 35'N, Long. 101° 43'E) to the mouth of Sungai Kesang (Lat. 2° 06'N, Long. 102° 29'E). Most of the beaches in Negeri Sembilan and some in Melaka are sandy, usually separated by rocky headlands, while the rest are of alluvium with mangrove swamps at the rear, especially towards the mouth of Sungai Kesang.

Research Methods

The methods used to determine the curvature and orientation of the beaches are essentially that of McLean's (1967: 17).[1] The beaches were determined for their end points and subsequent measurements were made to determine the curvature and orientation of the beaches. All the 28 beaches shown on West Malaysia L7010 series of 1: 63360 sheets are mapped regardless of their size and the beach material composition. All the beaches with their orientation and the radius of curvature are listed in Table 1.

The maximum and minimum fetch are also determined for the end points of the study area as presented in Figure 1. Annual wind speed and direction (Figure 2) was obtained from the Meteorological

[1]Theoretical radius of curvature for each beach was obtained by measuring the chord length, C, after locating the end points of the beach on maps. At the mid-point of the chord a perpendicular, P, was drawn to the shore and measured. A convenient index of curvature is obtained through the ratio of C to P. By using C and P, a conversion is made for the radius of curvature, R, by the formula:

$$R = \frac{C^2 + 4P^2}{8P}$$

The orientation of the line P in degrees from North is measured for the beach orientation. The resulting figures were classed into 22.5° interval anticlockwise between North and Southeast.

Station at Melaka and analysed to show the dominant wind direction in the study area.

Table 1
Radius of Curvature and Orientation of Beaches in Negeri Sembilan and Melaka

Beaches	Orientation (°)	C	P	R	Index of Curvature
1. Kampung Sepang Besar — Bukit Keramat	188	5.00	1.15	3.29	4.35
2. Bukit Keramat — Tanjung Gemok	248	1.65	0.30	1.28	5.50
3. Tanjung Gemok — Kampung Gelam	283	1.65	0.35	1.14	4.71
4. Port Dickson — Si Rusa	213	3.65	0.90	2.30	4.06
5. Si Rusa — Tanjung Lembah	238	1.30	0.20	1.16	6.50
6. Tanjung Lembah — Teluk Kemang	266	0.95	0.05	2.25	19.00
7. Teluk Kemang — Tanjung Tanah Merah	253	1.20	0.25	0.84	4.80
8. Tanjung Tanah Merah — Tanjung Tuan	279	2.35	0.40	1.93	5.88
9. Tanjung Tuan — Tanjung Pelanduk	164	2.80	0.50	2.21	5.60
10. Tanjung Pelanduk — Tanjung Sungai Menyala	162	0.55	0.05	0.75	11.00
11. Tanjung Sungai Menyala — Tanjung Terus	166	0.50	0.20	0.26	2.50
12. Tanjung Terus — Tanjung Pantai Mengkudu	176	0.45	0.15	0.23	3.00
13. Tanjung Pantai Mengkudu — Tanjung Selamat	205	2.05	0.55	1.23	3.73
14. Tanjung Selamat — Tanjung Serai	235	3.40	1.05	1.90	3.24
15. Tanjung Serai — Tanjung Dahan	197	1.60	0.10	3.25	16.00
16. Tanjung Dahan — Tanjung Konet	202	3.50	0.50	3.31	7.00
17. Tanjung Konet — Batu Keramat	235	4.00	0.60	3.63	6.67
18. Batu Keramat — Batu Gajah	211	0.45	0.05	0.50	9.00
19. Batu Gajah — Tanjung Puteri	223	0.85	0.15	0.62	5.67
20. Tanjung Puteri — Tanjung Panchor	233	1.00	1.30	10.00	
21. Tanjung Panchor — Tanjung Beruas	227	5.20	0.65	5.52	8.00
22. Tanjung Lereh — Limbongan	195	4.00	0.60	3.63	6.67
23. Limbongan — Melaka	215	1.85	0.40	1.27	4.63
24. Melaka — Sungai Duyong	202	3.20	0.20	6.50	16.00
25. Sungai Duyong — Tanjung Ketapang	206	2.25	0.25	2.65	9.00
26. Tanjung Ketapang — Sawah Laut	204	4.40	0.30	8.22	14.67
27. Sawah Laut — Permatang Pasir	191	4.00	0.50	4.25	8.00
28. Permatang Pasir — Kuala Kesang	199	4.10	0.15	14.08	27.33

Beach Curvature and Orientation

The curvature of most of the selected beaches traced from maps is shown diagrammatically in Figure 3.[2] The diagram includes five of the six beaches where R = less than 1.0 mile (1.61 km); five of the eight beaches where R = 1.1 to 2.0 miles (1.77 to 3.22 km); nine of the ten beaches where R = 2.1 to 5.0 miles (3.38 to 8.05 km); and all the three beaches where R = 5.1 to 9.0 miles (8.21 to 14.49 km).

[2]The curves of six beaches could not be shown at the chosen scale on the diagram, and this includes the only beach with a radius of curvature over nine miles (14.49 km).

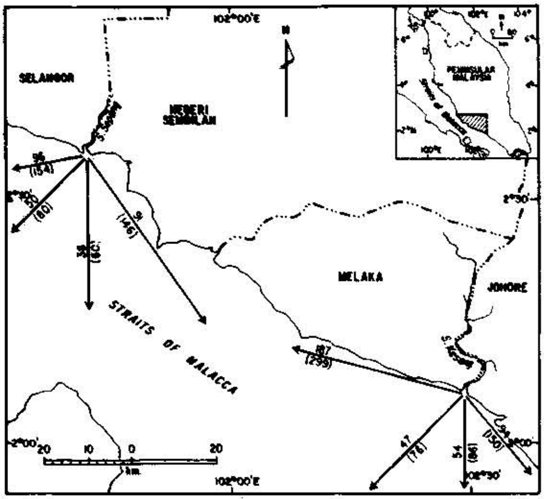

Figure 1
The Study Area. Arrows Indicate Length of Fetch in Miles and Their Equivalent in Kilometres in Parenthesis

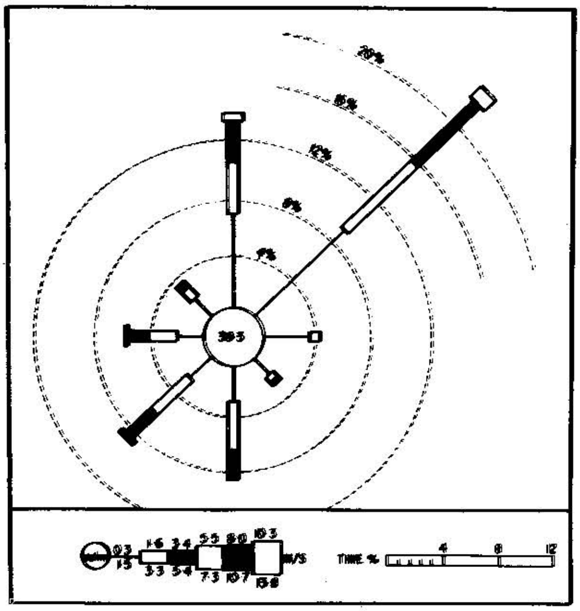

Figure 2
Annual Wind Speed and Direction at Melaka
(Source: Malaysian Meteorological Service)

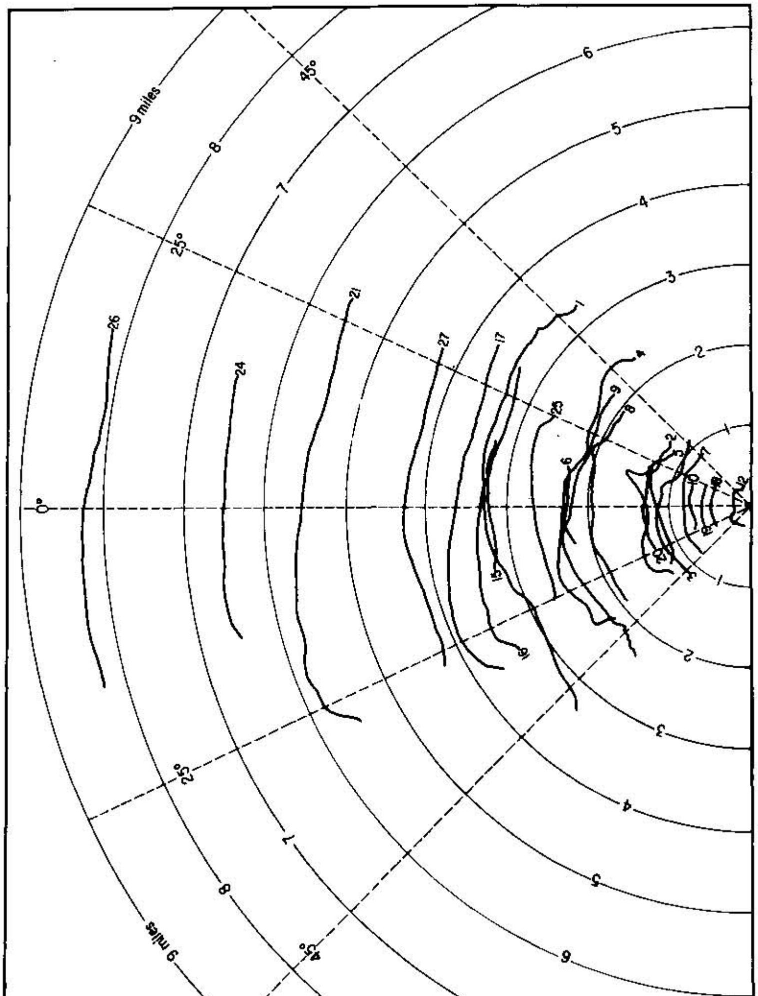

Figure 3
Curvature of Selected Beaches Along the Coasts of Negeri Sembilan and Melaka

Examining Figure 3, more than half of the beaches in the study area approach the 'arc of equilibrium' suggested by Hoyle and King (1958). These beaches have a general circular arc form, although they are of different sizes. The beach curve which fits closes to the circular arc is beach no. 7 (Table 1), that is the beach between Teluk Kemang and Tanjung Tanah Merah in Negeri Sembilan. This particular beach also has a large angular width of 90°. However, some of the beaches deviate from the theoretical circular arc form either at the ends or in the centre. Some of them are almost straight at one end and curve only towards the other end. Most of such beaches lie to the northwest of headlands. The radius of curvature of these beaches increase away from the headlands and thus making them approach an exponential curve. This kind of beaches are defined by Yasso (1965: 709 — 711) as 'headland-bay beaches'.

Some other beaches deviate from the theoretical circular arc form because the central parts are flat. According to McLean (1967: 19), along these beaches there is a common predominant direction of longshore drift of material which prevents the development of an 'arc of equilibrium' since there will be little exchange of materials between the beach ends. None of the 28 beaches within the study area has the whole of its curvature convex seawards.

Figure 4 shows the orientation of the 28 beaches in Negeri Sembilan and Melaka. Since the general orientation of the beaches

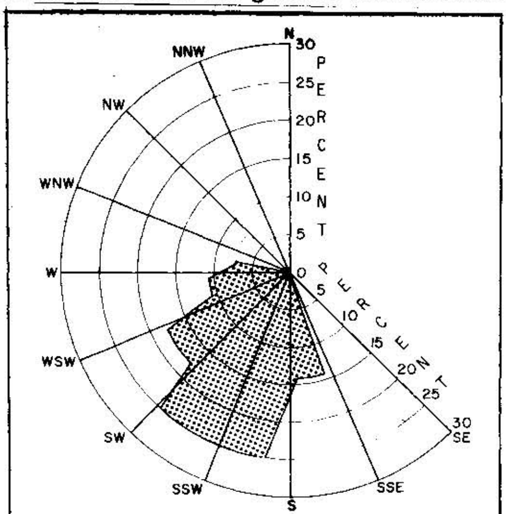

Figure 4
Orientation of 28 Beaches along the Coasts of Negeri Sembilan and Melaka

in the study area is towards the southwest, data have been grouped in 22.5° divisions anticlockwise between North and Southeast. From the diagram, it is observed that the dominant direction of beach orientation is Southwest to almost South.

The location and orientation of individual beaches is shown in Figure 5. Beach orientation is shown as deviations from the modal classes which is the dominant direction of beach orientation distinguished on Figure 4. In Figure 5, the length of the horizontal line indicates the degree of deviation according to the principal points of the compass, while ticks on the horizontal lines indicate whether deviations are to the north or south of the modal classes. Beaches that fall within the modal classes are indicated in the diagram by small circles.

From Figure 5 it can be seen that while beaches in the modal classes do occur on the straightest, most exposed, parts of the coasts in conformity with the dominant onshore wind direction (Figure 2) and

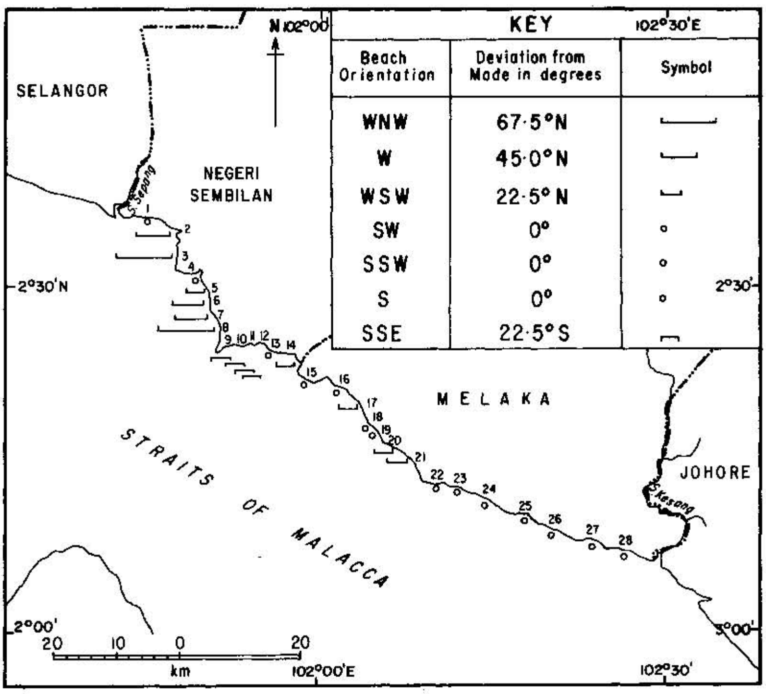

Figure 5
Location and Orientation of Individual Beaches Studied along the Coasts of Negeri Sembilan and Melaka

dominant wave direction of Southwest to South-Southwest (Mahani, 1978: 65 — 66; Ho 1979: 36), the maximum fetch for the stretch of coast under investigation is either more westerly or more southerly (Figure 1) of the dominant onshore wind and wave directions. In fact, at times, the beaches, especially in Negeri Sembilan, do experience waves coming from West-Northwest (Mahani, 1978: 64), which could well be the remnant of much refracted swell from the Indian Ocean or the Bay of Bengal. Beaches which deviate from the dominant orientation are located at places where there is a significant change in direction of the coastline. These beaches, though not oriented perpendicular to the dominant wave direction, are actually still experiencing the effect of the wave that has been refracted and thus still oriented perpendicular to it. Therefore, it is clear that the orientation of many beaches in the study area is consistent with the prevailing deep water wave direction and whatever deviations from the predominant Southwest to South orientation can, perhaps, be explained by topographic and wave refraction effects mentioned earlier.

According to McLean (1967: 20), the curvature and orientation of beaches can be considered as important characteristics of beach equilibrium. The presence of beaches having cricular arc curvature and their orientation normal to the approach of the dominant waves in the study area suggests that these beaches meet the equilibrium requirement of Lewis's model (1938). In addition some of these beaches possess two more criteria used by Hoyle and King (1958: 292) to distinguish stable beaches, namely the beach must be supported at both ends and the slope of the beach profile must be in equilibrium. In this case, although some beaches are not supported by headlands at both ends, some are indeed being supported by artificial or man-made structures while others are supported by mangrove colonies. Most of the sand beaches[3] are in a state of dynamic equilibrium, whereby there is a continued adjustment in foreshore slope to changes in energy and material factors.

Looking through the Index of Curvature (Table 1), none of the beaches in the study area satisfies the requirement of the prescribed angle, 0.25 radians (Hoyle and King, 1958), which is equivalent to C/P index of 15. This index of curvature is perhaps approached by

[3]Example of such beaches are Tanjung Lembah-Teluk Kemang beach with a mean grain size of 2.49ϕ(Mahani, 1978: 57); Teluk Kemang-Tanjung Tanah Merah beach with a mean grain size of 2.1ϕ(Ho, 1979: 48); and Batu Gajah-Tanjung Puteri beach with a mean grain size of 1.1ϕ(Rosnah, 1980: 67).

Tanjung Ketapang-Sawah Laut, Melaka-Sungai Duyung, and Tanjung Serai-Tanjung Dahan beaches. However, of these three beaches only Melaka-Sungai Duyung beach approximates a circular arc form.

Conclusion

A number of geometrical forms have been recognized in the outline of beaches. In this study, some of the beaches in Negeri Sembilan and Melaka are found to have a curvature that approximates the arc of a circle, while others are rather straight although they are supported by headlands or artificial structures at both ends. It is important to note that most of these beaches are oriented to the direction of the dominant waves despite the fact that they are only facing a short fetch. Deviations from the predominant Southwest to South orientation, may be explained by topographic and wave refraction effects. The results show that many of the beaches in Negeri Sembilan and Melaka satisfy at least some of the essentials for equilibrium beaches, although only one beach approximates all the requirements for equilibrium conditions.

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