Retraction Notice

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History

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X no

Correction:

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X no

Comment:

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Classification of Beach Based on Beach-Surf-Zone Morphodynamics—A Case Study

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Abstract

The beach classifications based on theoretical and numerical modelling study are more in literature. The paper discusses a case study regarding the morphological response of sandy beach to the monsoonal waves and its classifications based on the energy conditions. The sediment dynamics associated with morphological changes are functions of incident wave climate, sediment characteristics and other environmental factors. The study establishes quantitative relationships between incident wave energy flux, fall speed parameters, grain size and wave steepness, and classifies beach in accordance with energy conditions using different empirical functions. A criterion for sediment transport direction with different wave climate is also proposed and validated in the field conditions.

Keywords

Surfscaling Factor, Surf Similarity Index, Directional Criterion, Fall Velocity

1. Introduction

The hydrodynamics and associated sediment transport in the nearshore zone at microscopic level is complex and become more complex in a high-energy beach. The morphologically active part of the beach, often called foreshore, is shaped by the continuous impingement of hydrodynamic forces. Depending on the wave conditions, profile shape and sediment properties, the cross-shore sand transport rate will be generally either offshore or onshore over the entire profile. Offshore transport results in erosion at the landward end of the beach profile and formation of a bar near the break point, whereas onshore transport leads to accretion of sand on the foreshore and berm build-up, and the gradual disappearance of the bar near the breakpoint. These two types of profile responses forming two distinctly different beach shapes are commonly observed in both laboratory and field studies, and are known as bar and berm profiles. As the formation of bar and berm profiles are related to the direction of cross shore sediment transport, the criterion used for delineating bar and berm profile could be used to determine cross-shore transport direction. The berm profile corresponds to the on-shore transport of sediments and a bar profile corresponds to the off-shore transport. The bar/berm profile configurations are also referred to as erosional/accretional, winter/summer or storm/normal or dissipative/reflective profiles. Incident wave undergoes transformation as they approach to the shore and wave energy dissipation depends on beach gradient in relation to wave steepness. The sand transport will be generally either offshore or onshore over the entire profile, leading to erosion or accretion. The concept continuum of beaches based on energy level can be defined in terms of empirical indices such as surfscaling factor, surf similarity index and dimensionless fall speed parameter. The objective of this paper is to classify beach and study the morphological response to monsoon waves, by making use of different empirical functions that are available in literature. Kerala coast subjected to high erosion during south-west monsoon and the nature of sediment transport is the cross-shore sediment transport than longshore transport [1]-[7]. A case study has conducted at Calicut beach, Kerala, India during the south-west monsoon.

2. Methodology

The Calicut coastline (Figure 1) is generally straight and oriented in NNW direction.

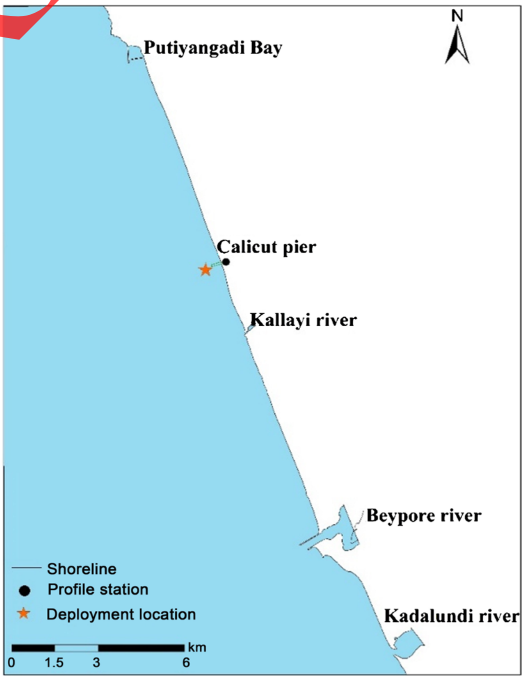

Figure 1. Location map of Calicut study area.

The beach is comparatively wide, with a foreshore of moderate slope. Towards south of the coast two rivers Kadalundi and Beypore debouch into the sea. This coast like other parts of west coast of India is under the spell of southwest monsoon during June-September. The Calicut region features a tropical monsoon system with three different seasons like monsoon, post-monsoon and pre-monsoon. During the south-west monsoon, the rainfall is more and sea conditions become rougher which leads to high erosion in the coastal areas. The winter season observes in December and January and summer season during April and May.

Secondary data on nearshore waves, beach morphology, sediment characteristics, etc. available at NCESS (National Centre for Earth Science Studies, Government of India) for the period 1981-1982 are used for the study. The nearshore waves were measured at a depth of 5 m (75.768180E 11.258567N) during 1980-1985 as part of a wave project conducted by CESS (**Figure 1**). A pressure type wave and tide telemeter system was used for recording the waves. The data used are taken from the Data Report published by NCESS [8]. The wave parameters like, H_s, T_z and wave direction recorded during July-August 1981 were taken for analysis and modelling study. Beach profile measurements using dumpy level and staff, together with surficial sediment sampling were carried out twice—first, on the early stage of deployment and second on the later stage of retrieval of the equipment. The size characteristics of sediments were derived from analysis.

3. Result and Discussion

The measure data from the field analyzed and different criteria were tested in the file conditions for the classifications of beach and are discussed in the following sections.

3.1. Data Used

The statistical parameters of waves relevant for the period July-Aug 1981 are given in **Table 1**. The frequency distribution of significant wave heights (H_s) indicates that about 16.7% of the H_s are below 1.2 m, 38% in the range 1.2 - 1.8 m, 41% in the range 1.8 - 2.4 m and 11% above 2.4 m. The standard deviation 0.32 indicates wide spreading of wave height. The wave period (Tz) varies from 8 to 20 s, with T_z less than 8.7 s for 16.7% of time, T_z in the range 8.7 - 10.5 s for 50% of time and T_z above 10.5 s for 33.3% of time. During this period, the wave direction varies from 235˚N to 300˚N. The mean wave direction is 260˚N, which taken for modelling study. In the early stages of monsoon significant erosional

Table 1. Nearshore wave statistics off Calicut pier during monsoon 1981.

Parameters	Period	Min.	Max.	Mean	Standard Div.
Wave Height (H_s), m	Monsoon (01.07.1981 to 01.08.1981)	0.13	1.53	0.93	0.32
Wave Period, (T_z) sec		8.0	20.5	9.93	1.83

is typical of monsoon waves. The beach profiles for the monsoon of 1981 were tendency is observed with the formation of bar in the nearshore (Figure 2). Towards the latter part of monsoon the beach build-up is initiated with the shoreward migration of bars.

3.2. Sediment Characteristics

The sediment size characteristics for berm crest and beach face at Calicut pier stations are used for the study. The mean grain size varies from 0.17 mm at foreshore to 0.28 mm at berm. The size characteristics also characteristics the high-energy conditions of the beach during the southwest monsoon.

3.3. Criteria Used

A number of bar/berm criteria have been developed for predicting the general response of a beach profile (a bar or berm profile) to incident waves [9] [10] [11] [12]. The deep-water wave steepness "H_0/L_0" (the ratio between the wave height and the wavelength in deep water, a dimensionless parameter) appears in all criteria. The suspension of bed material depends on the energy flux of waves. The energy flux of incident waves acts as a forcing factor for beach morphology changes, which determine the fluid mixing as well as velocity field under waves [13]. The energy flux can be represented in terms of deep water wave height and wave steepness (Figure 3). Other parameters appearing in these criteria are the sediment characteristics, such as average grain size or fall velocity and the beach slope. Some of the important criteria were proposed by Dean R G, 1973, Hattori M and R Kawamata 1981, Sunarnura T and K Horikawa, 1973, Larson M and N C Kraus, 1989, Kraus N C and M Larson, 1991. In all criterions the wave period

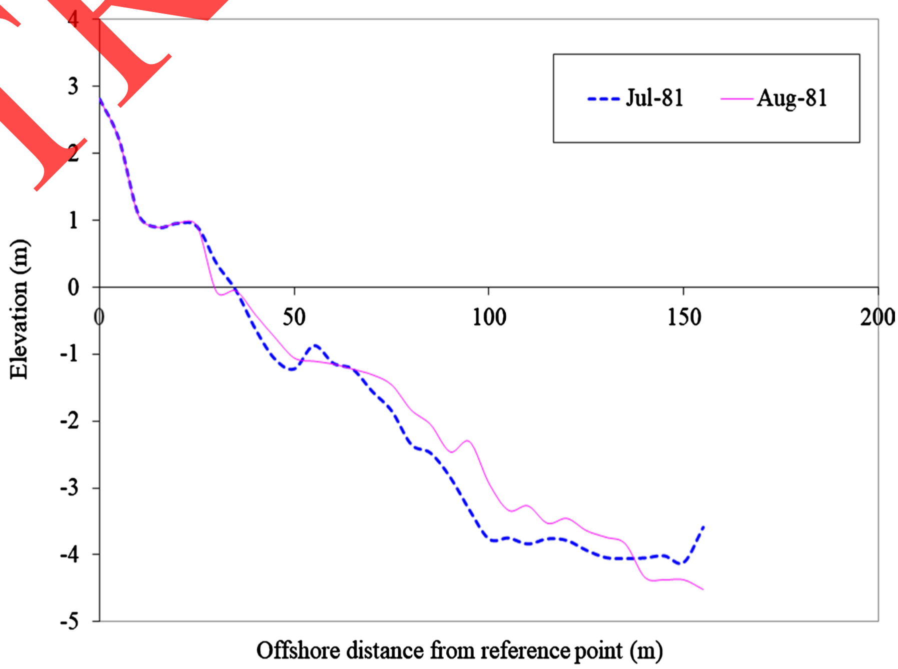

Figure 2. Beach profiles measured at Calicut pier during monsoon period of 1981.

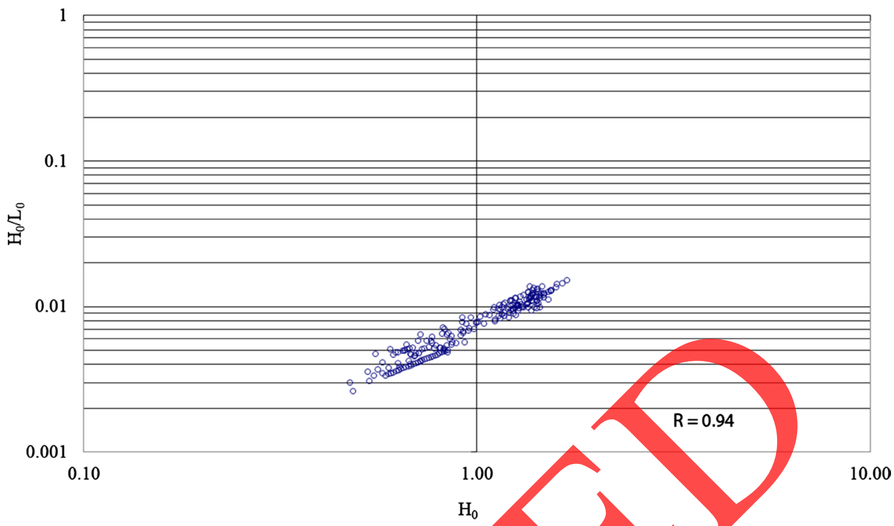

Figure 3. Relationship between wave height and wave steepness at Calicut.

included and performs equally. The criterion proposed by the Larson and Kraus performs well due to the inclusion of wave height. In the Dean criteria significant wave height is used as well predicting parameter. In their study Hattori and Kawamata included width of the surf zone included as a parameter which controls the sediment direction, while Sunamura and Horikawa included beach slopes as one of the important parameters. Kraus, Larson and Kraus where used dimensionless fall speed parameter for predicting the direction of the sediment transport [14]. The criterion used by Kraus, under predicts the erosion events [15].

An evaluation of the bar/berm criterion proposed by Larson M and N C Kraus, 1989, which is the most widely used one, is undertaken here using the comprehensive field data for different locations. The criterion is used to delineate the accretion and erosion nature of beach in response of wave. The criteria include deep-water wave steepness "H_0/L_0" (the ratio between the wave height and the wave length in deep water), the sediment characteristics, such as average grain size or sediment fall velocity and beach slope. The parameters appearing in these criteria have distinct physical meaning. The deep-water wave steepness (H_0/L_0) is a measure of the wave asymmetry, which influences the direction of the flow field in the water column. The dimensionless fall speed "H_0/wT" is a measure of the time that a sediment grain remains suspended in the water column.

As stated in Equation (1), the criteria used by them for fixing the direction of transport is,

$$\text{Ho/Lo}\begin{cases} < M\left(H_0/wT\right)3, & \text{bar profile or offshore transport} \\ > M\left(H_0/wT\right)3, & \text{berm profile or on-shore transport} \end{cases} \quad (1)$$

where, M = 0.0007 is a constant, H_0 is the significant wave height in deep water in the case of field observations, w is the sediment fall velocity (m/sec) and T is the zero crossing wave period (sec). The wave steepness parameter (H_0/L_0)

points the wave asymmetry and direction of fluid motion [12].

3.4. Bar-Berm Criterion

The deep-water wave parameters were calculated from the measured wave data for the period 01.07.1981 to 01.08.1981. The dimensionless fall speed (H_0/wT) and wave steepness were calculated for each data set. Figure 4 shows a plot of the wave steepness against dimensionless fall speed for Calicut. It can be seen that for most part of the time, wave steepness is less than fall speed parameter. In other words, the profile is characteristic of a bar profile characterised by offshore transport of the sediments. The bar/berm criterion for Calicut shows the condition is favourable for bar formation, which is corroborated with field conditions. It is well reflected in the field signature like bar formations, high erosion, etc. Hence this criterion can be applied to this coast and similar coasts, where same environmental conditions prevail.

3.5. Directional Criterion

Another criterion to establish the erosion/accretion nature of the beach in response to wave is proposed based on the present study. It is called direction constant, which is defined as the ratio between wave steepness and fall speed parameter. If the value of direction constant is <1 the seaward movement of sediment takes place, which leads to erosion and if the value of direction constant is >1 onshore movement of sediments takes place, leading to accretion. Figure 5 presents the distribution of direction constant showing the number of events against each value at both the locations. It can be seen that the values of direction constant fall below "1" in most of the cases at both the locations and very few cases fall above "1", indicating the eroding nature of the beach, which is obvious from the field observation. Hence the proposed directional criterion could be successfully used to find the profile response to waves.

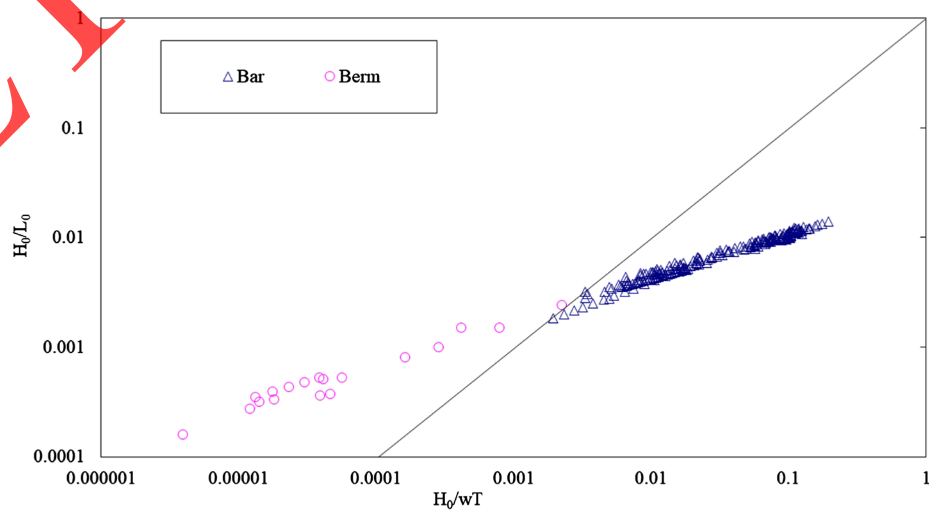

Figure 4. Categorisation into bar and berm profiles based on wave steepness and dimensionless fall speed at Calicut.

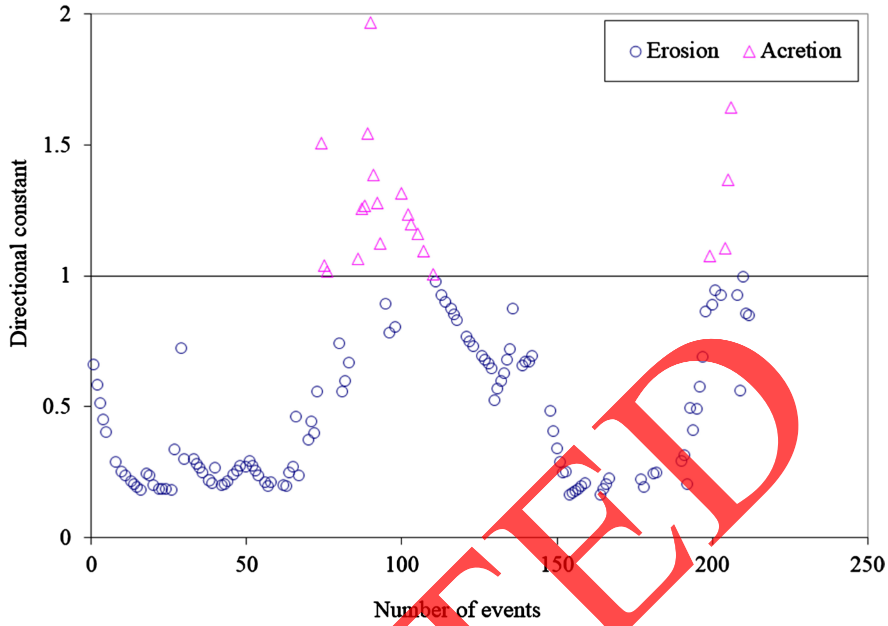

Figure 5. Directional criterion for erosion/accretion pattern at Calicut during the study period.

3.6. Classification of Beach

The wave dominant environment beach can be classified in terms of wave heights, sand size, and wave periods. Such beaches are active in sediment transport in cross shore as well as alongshore caused by the significant wave action [16]. The different state of beach morphodynamics is defined by taking account of the durations and intensity of incident waves [17]. Beach-surf-zone morphodynamics concept has to develop to study the energy conditions of the coast. Among three types of coast, the Calicut coast has been identified as intermediate type beach, which is most of the time wave breaking type is plunging. The analysis of important empirical parameters like surfscaling factor (ε), Surf similarity index (ζ) and dimensional fall velocity (Ω) underlines that Calicut coast, Kerala is an intermediate type beach. The surfscaling factor (ε) is a function of wave amplitude, wave period and beach slope [17]; if it is in between 20 to 2.5, the beach is termed as intermediate type. The range of values of surfscaling parameter in this study area is within the above prescribed range and is given in **Figure 6**. The other two parameters are given in **Table 2**. The values of Surf similarity Index (ζ) [18] and Dimensionless fall velocity (Ω) [19] are also within the range for intermediate type beach.

4. Conclusion

The study on beach morphological changes during the first phase of south-west monsoon at a micro tidal beach using measured hydrodynamic and beach profile data, has provided insight into beach morphodynamics in response to high intensity monsoon waves. Quantitative relationships were established between incident wave energy flux, dimensionless fall speed, median grain size and deep

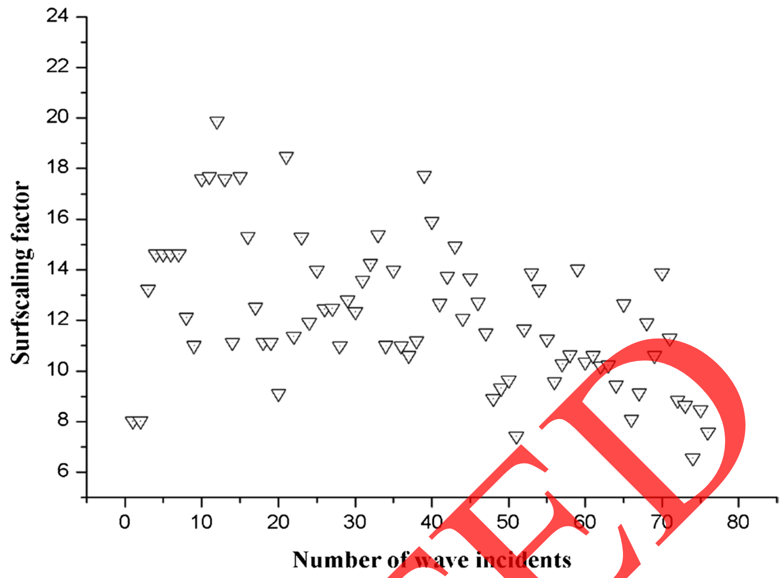

Figure 6. Distribution of surf scaling factor during study period.

Table 2. The parameters used to discriminate beach type.

Parameter	Range
Surf similarity Index (ζ)	0.45 - 0.9
Dimensionless fall velocity (Ω)	3.32 - 4.2

water wave steepness. The bar/berm criterion has been effectively tested in field and it can be used as predictive tool. The newly proposed directional criterion can be used to find out the beach response to particular wave climate. Even though Calicut beach is known as a high energy beach, the present study based on the empirical functions like Surf Scaling Factor, Surf Similarity Index and Dimensionless Fall Velocity, categorises it as an intermediate energy beach.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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