Seasonal Variations in Wave Energy and the Changing Beach Characteristics: A Case Study of Beaches of Karachi

Syed Shahid Ali* and Sheeba Afsar

Department of Geography, University of Karachi, Pakistan

Abstract: The study of beach characteristics is generally described in terms of the relationship of wind velocity, wave energy, beach profile and grain size variation of the beach sediments. Most of the coastal research is concerned with investigating the behavior of water and sediments along the shoreline; these being the processes responsible for the formation of coastal land forms. The amount of erosion and depositional activities along a shoreline depends on the quantity of energy in the waves which are also responsible for bringing changes in the beach profile and hence beaches are classified on the bases of the impacts of these processes which are presented here in this paper.

Keywords: Wavelength and wave energy, grain size analysis.

INTRODUCTION

Coastal evolution is generally considered in terms of the geomorphic system within which various factors influence processes acting upon the coast. There is an input of energy (e.g., wind, tide, living organisms) and materials like water, rocks, sediments, which interact to generate landforms and there is a feedback in the sense that the developing morphology has influenced geomorphic processes and has thus become a factor influencing subsequent coastal evolution.

“A beach is an accumulation on the shore of generally loose, unconsolidated sediment, ranging in size from very fine sand up to pebbles, cobbles and occasionally boulders, often with shelly material. Beaches fringe about 40 per cent of the world’s coastline, and generally consist of unconsolidated deposits of sand and gravel on the shore” [1].

“The mean grain size, sorting, and skewness of a sedimentary deposit are dependent on the sediment grain size distribution of its source and the sedimentary processes of i) winnowing (erosion), ii) selective deposition of the grain size distribution in transport, and iii) total deposition of the sediment in transport. If a source sediment undergoes erosion, and the resultant sediment in transport is deposited completely, the deposit must be finer, better sorted, and more negatively skewed than the source” [2].

“A physical model relates the differences between the size-frequency distributions of sands from the zone of swash and backwash on beaches and from rivers to the environmental conditions under which they are deposited. The sweeping oscillatory motion of the breaker zone on a beach tends to separate fine-grained suspended particles from coarser-grained particles moved by saltation. Fine particles are removed seaward into deeper water and coarser particles remain as a lag deposit; their size-frequency distribution is truncated at the fine-grained end” [3].

Study Area

Pakistan is bounded by the coastal strip in the south, which is 616 miles [4] or about 991 Km long. In Karachi a stretch of 30 miles (about 48 Km) of beaches, extends west-east from Cap Monz to Clifton, is the major focus of the beach users. Half of this section is cliff and remaining half stands as sandy barrier bars of spit and other sand stretches. Further east there is a series of creeks and hence could not develop as recreational spots. In this study three beaches of Karachi were selected mainly Pacha beach(Bulleji Beach), a cliff coast in the west near Cap Monz, and to the east of it are Sandspit and Clifton which are the sandy strips (Figure **1**).

MATERIAL AND METHODS

Generally the discussion of process, sediment movement and morphology measurement is divided into two sections dealing with the surf zone and the offshore zone respectively. Following Inman and Bagnold (1963), the surf zone comprises a large area of the beach where waves dissipate energy and this is the zone,where both depostional and erosional precesses are shaping the coastal landforms [5]. This is the zone where the study is confined.

The Surf Zone

The most important process in the surf zone is related to the oscillatory movement of shoaling and

*Address correspondence to this author at the Department of Geography, University of Karachi, Pakistan; E-mail: shahidgeog@yahoo.com

ISSN: 1814-8085 / E-ISSN: 1927-5129/13

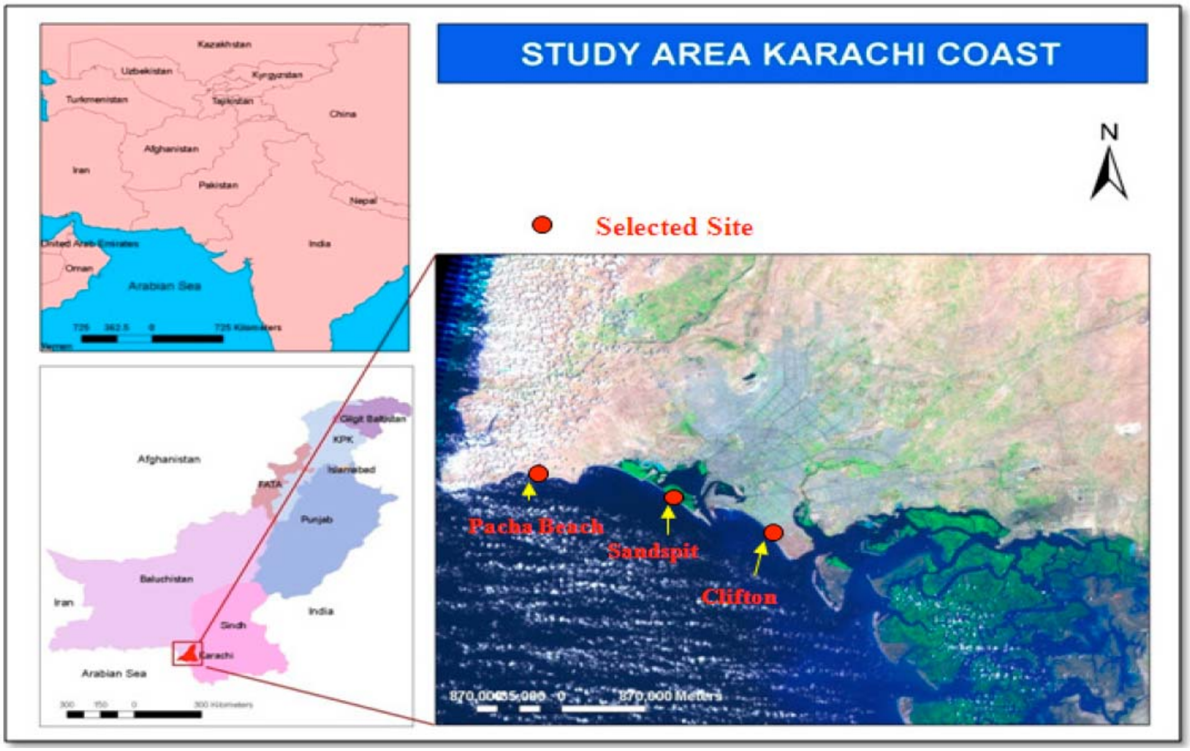


Figure 1: Selected Site/Beaches of Karachi.

breaking waves. This is the zone of wave action extending from the water line (which varies with tide, surge set-up, etc.) out to the most seaward point where waves break termed as breaker zone (Figure **2a**). Recently several techniques have been developed to measure the velocities and stresses associated with breaking waves to determine more directly the energy inputs at the water / sediments interface. In this research three critical wave's parameters were observed within the surf zone, namely wave height, wave period and the direction of waves in order to evaluate wave length and the amount of energy dissipated by the waves. All of these measurements were recorded for the shallow water waves where the depth of water was less than half the wave length.

The beach material was collected for the grain size analysis, from the swash zone where the waves were terminating and where the beach profiles were recorded by using simple instruments i.e., Indian clinometer.

Measurements of Waves in the Surf Zone

The simplest method of measuring wave height and period is by visual observation as Ingle (1966) measured the wave height by comparison of the lowest and highest level in a water surge on a graduated pole kept in the breaker zone [7]. Wave period was determined in the shallow water simply by noting the number of waves that is 50 waves passing a fixed point in the swash zone and calculate the average wave period however to analyze the full wave spectrum for a longer period of time various instrument could be used which can record the data continuously, such as wave staffs, wave wires, pressure transducers and ultrasonic devices. Even satellites can help us in recording such information. Wave length is a little difficult to assess but fortunately it has a relationship with the time period of waves and therefore wave length can be determine by any one of the following equations:

For deep water waves (water depth > ½ wave length):

$$L= 1.56xT^2$$

Where

L= wave length in meters.

T= wave period in seconds.

For shallow water waves (water depth < ½ wave length):

$$L=3.\ 13xTx\sqrt{d}$$

Where

d=Depth of water in meters.

Now at this stage the wave energy can be determined by the following equations

E=740xh sq. x L

Where

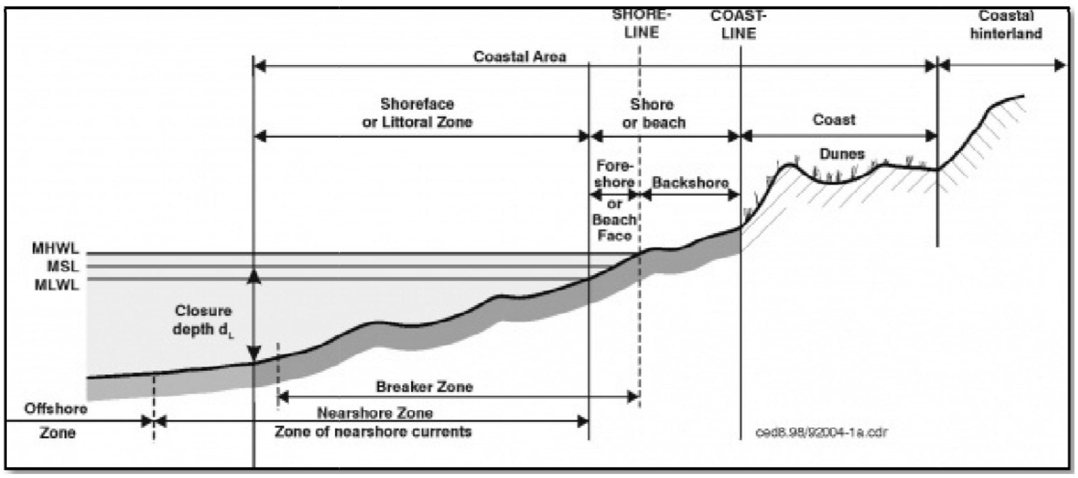
E = Wave energy in joules per meter (J/m) width

H=Wave height in meters.

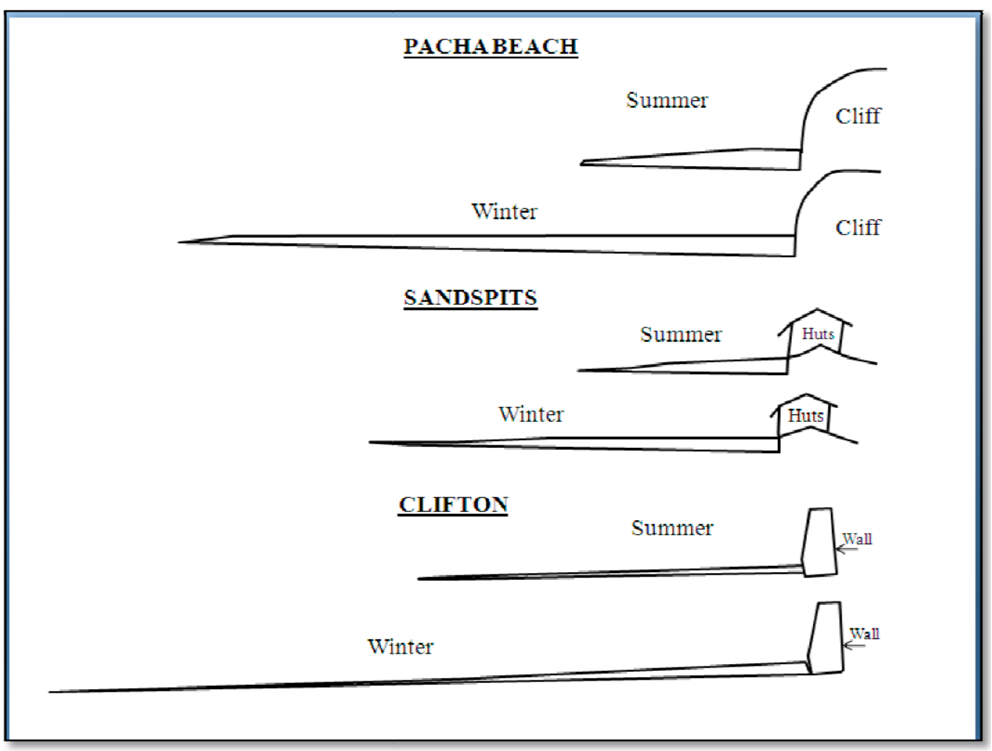
L=Wave length in meters [8]

This Information was collected in the first week of the month of September, i.e., the late summers in Karachi and in December for the winter data 2010. On Karachi coastal region summer Monsoons are mainly responsible for transferring energy to the waves and therefore comparatively large splashing waves were observed in the summer with the formation of plunging breakers. These winds mainly blow from south – west to north- east with a speed of 25 knots approximately.

On the contrary almost a reversal of the winds takes place and northerly winds started to blow over this



a



b

Figure 2: a. Surf Zone Source: Shore Protection Manual, 1984 [6].
b. Profiles of the three beaches of summer and winter

region but with a greatly reduced speed of less than 10 knots, which results in the formation of quite gentle waves, reduced in height in winter and hence lowering the wave energy. The plunging breakers almost disappear rather spilling breakers appears in the wave form. Similarly the pattern of long shore drift also changed from SW to NE in summer to SE to NW in winter.

The values for the wave energy in summer with a wave height of only 1.2 meters was around 20,000 J/m although it may be expected higher in other summer months i.e. June, July and August, when the wave height is also slightly above 2 meters on Karachi coastal waters. In winters, this value reduces to become around 1000 J/m. Among the three beaches it was found that the greater amount of energy appears to be dissipated at Pacha beach and it gradually reduces toward Clifton Beach in the east both in summer and in winter the reason is the apparent difference in the slope of beach face, as it was found steeper at Pacha beach gradually reduces towards Clifton beach as shown in Figure **2b**.

Changing Characteristics of Beach Material

In summer most of the Karachi beaches have a cover of pebbles on the beach sand. At Pacha beach, cobbles and even boulders were also found. The size of the pebbles and sand particles also reduces towards Clifton, which is a pebble free beach. The reason for this distribution is not only the difference between the wave energy and the beach slope but also the location of these beaches. As in case of Pacha beach much of the material is derived from the nearby cliffs and also partially supported by the material ones brought by river Hub which makes its mouth in Arabian Sea, a little west to the Pacha beach. Now this river is dammed to supply the water to Karachi and hence flowing in a very small strip. To the east of Pacha beach the coast line runs in a smooth curve then suddenly changes at Manora, a sharp turn towards Kiamari (Karachi Harbour) and again turns toward east and follow the same smooth curved pattern at Clifton. This change may be a probable cause of pebbles not reaching to Clifton beach. Near Clifton beach river Malir is draining out mainly in the creeks, a little east of it but this river is in real sense carrying polluted material discharged mainly from the Korangi and Landhi Industrial Area. In summer this beach receives the pollutant material from the west i.e. Karachi harbors and the waste of Lyari River, and that is why this beach is reported to be the most polluted beach of Karachi. But it is still most attractive beach for the Karachiites mainly because of very high accessibility.

Grain Size Analysis

Beaches are an accumulation of sediments deposited by waves and current in the shore zone. In terms of Wentworth of scale of particle diameter, shown in the Table **1** given below. They are typically composed of sand or pebbles granular beaches are uncommon but silt beaches may occur on very sheltered coastlines. The proportion of each grain size can be determined by mechanical analysis, when a known weight i.e. 25 gms. In this study, of dried sediments was passed through a succession of sieves of diminishing mesh diameter, and divided into size grades which are weighed separately.

Beach grain size categories: The Wentworth scale of particle diameters, shown in the Table **1** given below. The ø scale is based on the negative logarithm (to base 2) of the particle diameter in millimeters (ø = log 2d), so that coarser particles have negative values.

Table 1: Wentworth Scale Category [1]

Wentworth scale category	Particle diameter (mm)	ø scale
Boulders	>256	below−8ø
Cobbles	64–256	−6ø to−8ø
Pebbles	4–64	−2ø to−6ø
Granules	2–4	−1ø to−2ø
Very coarse sand	1–2	0ø to−1ø
Coarse sand	1/2–1	1ø to 0ø
Medium sand	1/4–1/2	2ø to 1ø
Fine sand	1/8–1/4	3ø to 2ø
Very fine sand	1/16–1/8	4ø to 3ø
Silt	1/256–1/16	8ø to 4ø
Clay	<1/256	above 8ø

RESULTS AND DISCSSION

Sorting

As a rule, sample of beach sediments is well sorted, in the sense that bulk of the sample falls within a particular size grade but in this study, as the graphs show, the sorting found is of variable character on the 3 beaches under consideration. Comparing the values of sorting in the samples is shown with the help of cumulative frequency graph in Figure **3**. Pacha beach

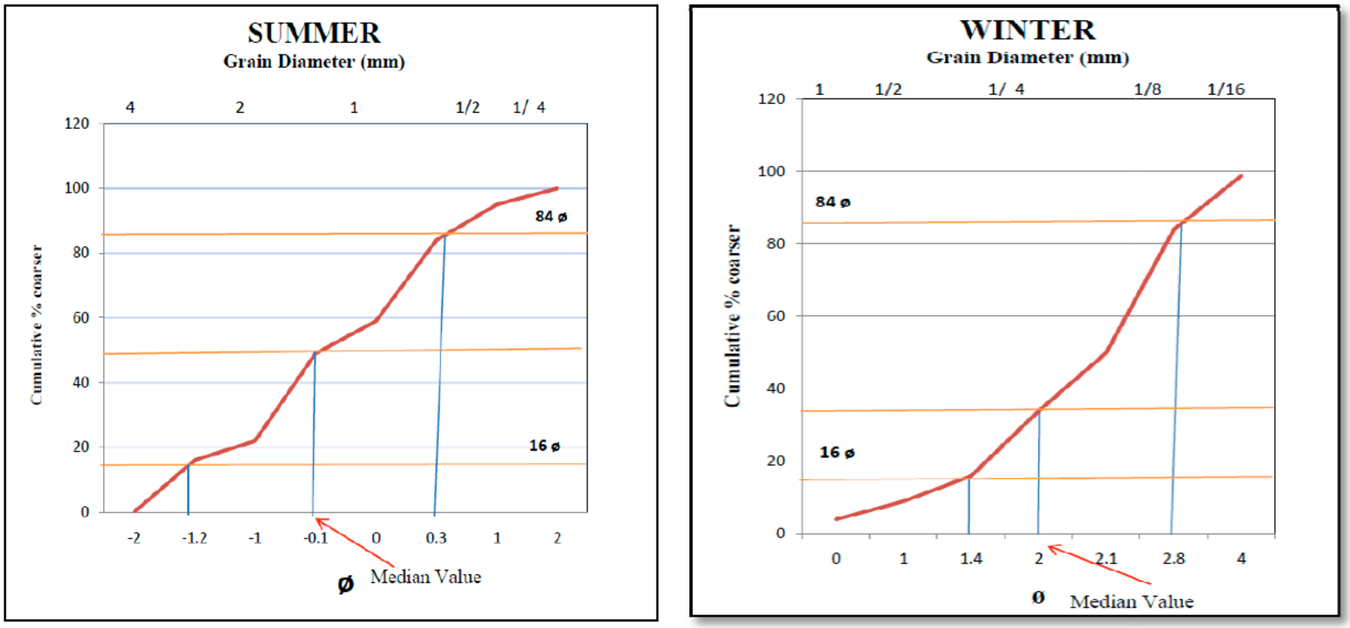


Figure 3: Pacha Beach.

is found to be moderately well sorted while sand spit appears to be well sorted Figure **4** and Clifton inclined towards a very well sorted distribution Figure **5**. As a matter of fact sorting of sediments on the beach by wave action may take several forms therefore this study is limited up to the superficial sorting which often produces a zone of shingle and coarse and fine send parallel to the shoreline.

Skewness

Statistical parameters based on mechanical analysis indicate that the grain size distribution of beach sediments is commonly asymmetrical, and negatively skewed, the mean grain size being coarser than the median that is also the case of Pacha beach and sand spit both in summer and in winter, as shown in the Figures **3** and **4** between phi (Ø) scale for grain

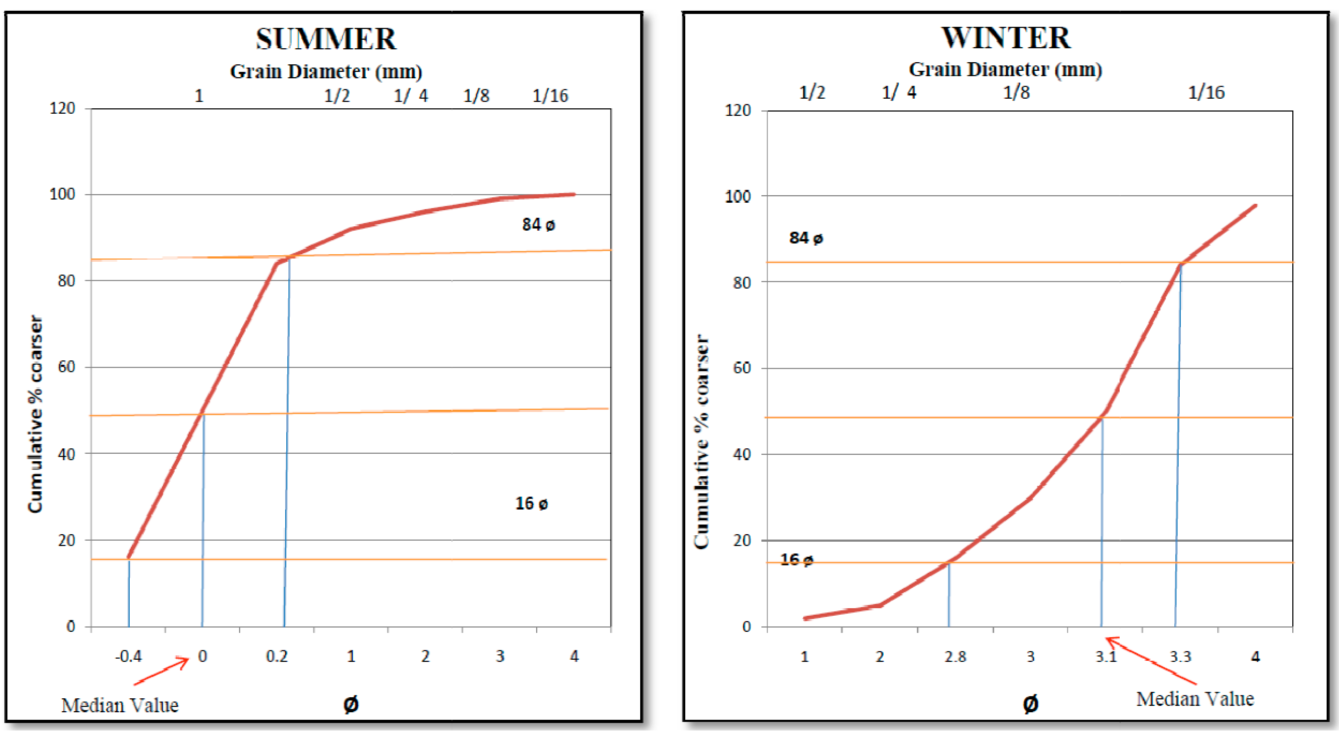


Figure 4: Sandspits.

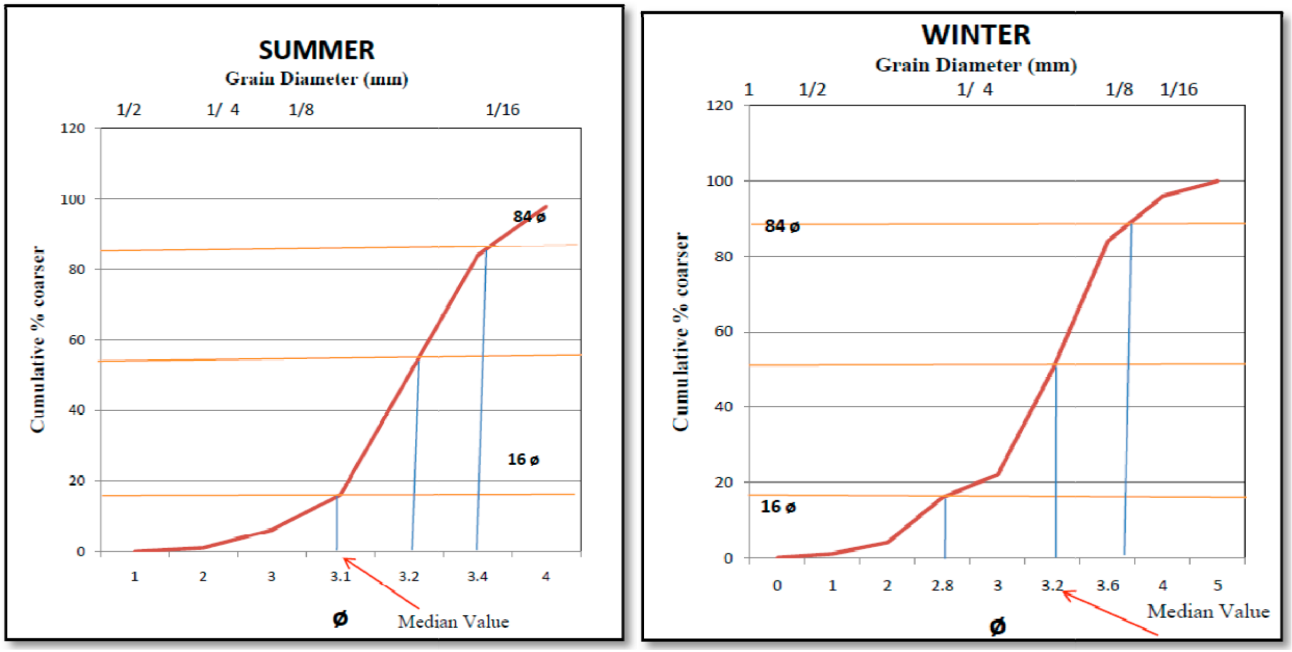


Figure 5: Clifton Beach.

diameter and cumulative % coarser for the grain. Evidently the winnowing effect of wave action reduces the relative proportion of fine particles. Such parameters may assist in the identification of former beach deposits permitting a distinction from positively sickness which is a reflection of the deposition of very fine sand at Clifton beach and a very gentle slope.

Particle Size and Slope Variation

Beach sediments composed of larger particles tend to develop steeper gradients as the slope of Pacha beach and sand spit were found to be around 7 degrees and 4 degrees respectively which is chiefly because of their permeability. Wave swash sweeps sediments forward onto a beach and backwash tend to carry it back, but the greater permeability of gravel and coarser sand beaches diminishes the effects of backwash, leaving swash piled sediments at relatively steep gradients.

Fine sand beaches are more affected by backwash and have gentler slopes, often of firmly packed sand across which it may be possible to drive a car. This is true in the case of Clifton where the slope is around 1 degree.

CONCLUSION

The coasts are shaped by tectonic forces and structural features, the nature of the rock forming the coast and depositional and erosive activity. Adding to these factors is sea-level history. Today's sandy coastlines are products of a rise in sea level that began almost 15,000 year before present and slowed about 5,000 years ago. Although the rapid rise of sea level ended some 5,000 years ago, there has been a slow rise of several centimeters during the last fifty years. General sea level rise can be compared to local tectonic adjustment to determine the relative emergence, submergence or stability of a shoreline. In an area of limited tidal range, a rise of several centimeters would lead to changes in the beach equilibrium.

Classification schemes are used to reduce a highly variable world into smaller groups that are easier to consider individually. Among them Sheppard's classification follows integration of simple ideas that stresses the relative importance of primary and secondary agents. In this study the beaches of Karachi are studied in context of beach sediments and the related tidal behavior. The distribution of the beaches shows moderately well sorted in the western parts i.e., Pacha beach to very well sorted Clifton beach, in the east. Furthermore the seasonal variation suggests that fine particles are added in winters on all the beaches showing the impact of low wave energy. According to the measurement of wave height which is around 2 meters in Summer and lower in winter the beaches roughly fall at the confluence of micro and meso- tidal characteristics.

REFERENCES

[1] Bird Eric CF. Coastal Geomorphology: An Introduction, Second Edition, John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England 2008.

[2] Patrick M. An Interpretation of Trends in Grain Size Measures. J Sedimentary Petrol 1981; 51(2): 611-24.

[3] Friedman, Gerald M. Dynamic Processes and Statistical Parameters Compared for Size Frequency Distribution of Beach and River Sands. J Sedimentary Petrol 1967; 37(2): 327-54.

[4] Snead RE. Physical Geography Reconnaissance: West Pakistan Coastal Zone. Published by Department of Geography, University of New Mexico, Albuquerque, New Mexico 1969.

[5] Inman DL, Bagnold RA. Littoral processes. In: Hill MN, Ed. The Sea, Wiley-Interscience, New York, N.Y., 1963; Vol. 3: pp. 529-533.

[6] Shore Protection Manual, Coastal engineering Research Center, Department of the Army, Waterways Experiment Station 1984. books.google.com/books/about/Shore_Protection_Manual.html

[7] Ingle. The Movement of beach sand: an analysis using flourescent grains. Elesvier Co. (Amsterdam and New York) 1966.

[8] Lenon, Barnaby J, Cleves PG. Techniques and Fieldwork in Geography. Published by Bell& Hyman, London UK 1987.

Received on 20-04-2013 Accepted on 25-04-2013 Published on 08-05-2013

http://dx.doi.org/10.6000/1927-5129.2013.09.47