

Sediment characteristics at intertidal regions across Yarada beach, East coast of India

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Received 10 October 2013; revised 28 October 2013

Sediment samples were collected once a month at five different inter-tidal zones across Yarada beach during May-2009 to May-2010. These sediments are characterized by bimodal and unimodal behaviour and most of them are sorted as 'moderately' as well as 'moderately well' sorted. Beach sediments are identified as follows: 71% are positively skewed and 29% are negatively skewed with 35% are very leptokurtic and 23% are platykurtic character. Mean values suggest that samples across the beach vary from medium to fine with 58% medium sands and 32% finer. Average median size (D_{50}) of samples varies between 0.253 mm and 0.353 mm and effective grain size (D_{10}) varies between 0.154 mm and 0.225 mm. Moderately sorted sediments are dominating more along this coast.

[Keywords: *Grain size, Central tendency, Skewness, Sorting, Kurtosis*]

Introduction

Beaches are composed of sediments with various sizes, and shapes that tend to be very fine to very coarse. The size and character of the sediments in the beach depends on the forces acting on it and type of the source material. Due to weathering of rocks, small rock fragments reach the beach as sand through rivers and streams. Usually, clay and silts do not exist in the beaches because they are in suspension by the action of waves, currents, etc¹. Changes in sediment statistics like mean, sorting and skewness are used to speculate the direction of sediment transport using a simple model². Sediment samples deposited by the action of waves and currents may be coarser, better sorted and positively skewed or finer, better sorted and negatively skewed with a decreasing energy regime^{2,3} suggested that sediment statistics of the deposited sediment depend on its sediment distribution of its source and sedimentary processes so that the source sediment is under erosion and the resultant sediment deposited must be finer, better sorted and more negatively skewed than the source. Sedimentary environments like beaches, dunes, streams, etc can be recognized easily by use of grain size parameters⁴.

Environmental interpretation can be possible if sediment structures, position in sequence, fauna, mineralogy, and textural information are available⁵. Multiple observations of beach characteristics help to

establish a relation between beach face slope and sand grain size^{6,7} identified the distinct differences among grain size parameters and conclude that even though the beaches have different wave exposure conditions, mean of their grain size statistics have good similarity. Skewness and Kurtosis is important for distinguishing bimodal characteristics of the sediments. The changes of Skewness, Kurtosis, and Sorting with sediment transport are simple functions of the ratio between the two modes of the sediment⁸. Grain character analysis from Karnataka coast during March 2008 to April 2009 gives medium sand with unimodal and bimodal characteristics and negative (coarse) skewed sediment samples were 1.7 times of positive (fine) skewed samples indicates strong winnowing and erosion along the study area⁹.

Based on the sediment size, how well the sediment is separated resembles the sorting character of the samples. If the component sediments are of same size then it is called as well sorted. And it is poorly sorted, if it is a combination of Gravel, sand and silt. While skewness describes the deviation of sediment distribution from the symmetry which may be positive or negatively skewed, depends on the sediment size. Fine sand associated is with positive skewness and coarse sand with negative skewness¹⁰. But kurtosis is not environment sensitive like skewness which does not contribute the information about depositional or

erosional behaviour of the respective sediment location¹¹. It gives the degree of peakedness of a given distribution from its normal curve (mesokurtic). If peak is sharper means leptokurtic and flatter gives platykurtic¹².

Wentworth¹³ classified sediments based on its size and shape as coarse sand (1-0.5 mm), medium sand (0.5-0.25 mm), fine sand (0.25-0.12), very fine sand (0.12-0.063), silt (0.063-0.004), and clay particle (0.004-0.002 mm). It is also pointed out that after mechanical analysis only, one should name sediment type. Transgressive sediments also play an important role for producing bimodal sediments and this bimodality gives the stableness of the sediment¹⁴. Skewness of sediment can be positive or negative. Positive skewness is due to unidirectional flow of transportation agent and negative is caused by removal of fine grains due to wind or wave action⁴.

In this study, sediment samples were collected for one year (a) to identify the grain size distribution variation (b) to study the statistical parameters and (c) to study seasonal variations of sediment percentiles. The sediments are collected from the intertidal regions and are assumed that these sediments in general represent the nearshore region.

Materials and Methods

Yarada beach (Lat: 17° 39'4 N, Long: 83°16'3 E) situated on the northern region of Andhra Pradesh coast line, is a NE-SW oriented coastline with a narrow coastal plain lying between Dolphin's Nose in the North and Gangavaram Port in the south (Fig.1). Yarada is an important beach with deposition and erosional changes through various seasons in this region¹⁵.

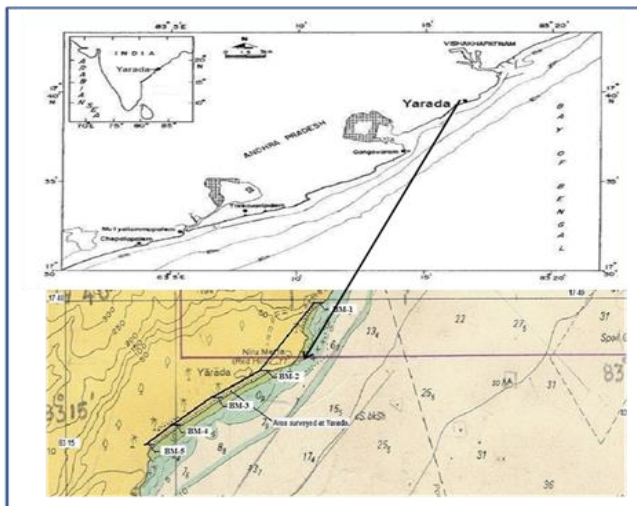


Fig. 1—Study area

Wave characteristics of Visakhapatnam, give an idea that during SW monsoon significant wave height (1.18 m) is higher than that of NE monsoon (0.72 m) and transition period (0.78 m). But the period is more during transition period (12 s) than SW (5.7 s) and NE (5.1 s) monsoon¹⁶. At Yarada beach currents transport the sediments towards offshore because of the influence of Pigeon Hill¹⁷ which is the reason for erosion at Yarada beach and further affected the sediment distributions.

Sediment samples are collected from five different locations across the Yarada beach during an annual cycle from May 2009 to May 2010. In the laboratory, these sediment samples were washed with fresh water to remove the calcareous materials and salt content. The washed samples were oven dried for further sieve analysis. Sieve-Shaker with six sieves with mesh sizes 2 mm, 1 mm, 0.5 mm, 0.250 mm, 0.125 mm, and 0.063 mm is used.

GRADISTAT (version 8) program of¹⁸ was used to obtain the cumulative percentage curve, statistical parameters like mean, mode and median, sorting, skewness and kurtosis using Folk and Ward method⁸. One of the advantages of this method is conversion of parameter values to descriptive terms for the sediment. Sorting and skewness can be described in terms of a mixture of modes⁸ and could interpret the sediment distribution and observed a systematic change in parameters for each mode¹⁹.

Grain size information for a sediment distribution can be explained in terms of ϕ using eq. 1 which was proposed by²⁰.

$$\Phi = -\log_2 d = -\left[\frac{\log_{10} d}{\log_{10} 2} \right] \quad \dots (1)$$

Statistical parameter 'Mean' of the sediment distribution can be explained by four methods viz; Arithmetic method, Geometric method, Logarithmic method and Logarithmic (original) Folk ward⁸ method. Among these methods, Folk ward method was used to calculate mean of the sediment distribution.

$$Mean(Mz) = \frac{\Phi_{16} + \Phi_{50} + \Phi_{84}}{3} \quad \dots (2)$$

where ϕ is particle size in ϕ units and d is diameter of the particle in mm.

Result and Discussions

Cumulative percentage distribution of collected samples from five different places (BM-1 to BM-5) across the Yarada beach is indicated in Fig. 2. Prominent features observed at BM-1, as monthly variation of grain size is far greater than that of other samples. A rapid increase of grain size percentile is observed during September at BM-1, due to large volume (9.5 m³) of sediment erosion¹⁵. But comparing the samples for the entire year at BM-1, there is only a slight decrease in grain size. At BM-2, slight increase in grain size is observed from May 2009 to May 2010. At BM-3 and BM-5 grain size is increased during the survey period but at BM-4 abrupt increase of grain size was observed during January and February 2010. Grain size at BM-4 is decreasing during May 2009 to May 2010. Comparing average sediment size between SW monsoon (June-September), NE monsoon (October-January) and Transition period (February-may) reveals that D₅₀ and D₁₀ at Yarada beach are decreased (Table 1) except at BM-4 where a prominent increase in D₅₀ observed.

Statistical Parameters of Sediment samples Central tendency (Mean, Median and Mode)

Across the Yarada beach at BM-1, the mean value of the sediments varies between 0.067φ to 3.06φ with an average value of 1.98φ; whereas mean at BM-2 is between 1.45φ and 2.6φ with an average value of

1.92. But in the case of sediments at BM-3 and BM-4, mean value varies from 1.11φ to 2.76φ and 1.02 φ to 2.50φ with an average value of 1.85φ and 1.6φ respectively. Obtained mean values suggest that sediments across the beach vary from medium to fine with 58% medium sands and 33% finer (Table 2).

Median grain size (D₅₀) variations (Fig. 4) at Yarada beach showed abrupt changes in grain size at different locations of the beach. Among that from BM-1 during September, the maximum grain size is 1.108 mm with an average D₅₀ of 0.31 mm. Average D₅₀ is maximum at BM-4, about 0.35 mm. Smallest median size of 0.08 mm is observed at BM-5 during February 2010. Median grain size variations showed that from May 2009 to May 2010 at BM-1 and BM-4, D₅₀ increased but at BM-2, BM-3 and BM-5 D₅₀ values decreased. Average effective grain size (D₁₀) is maximum at BM-4 (of about 0.22mm) but considering one year data showed that D₁₀ decreased except for BM-4.

Modality of the sediment distribution is the number of peaks in it, viz., unimodal has 1peak, bimodal has 2 peaks, trimodal has 3 peaks and poly modal with more than 3 peaks. Along the study region the sediment characteristics are as follows: Unimodal(6%), Bimodal (54%), Trimodal (31%) and Polymodal (9%). Among 54% bimodal sediments, 40% are moderately well sorted. At BM-1 not only bimodal (46%) and trimodal (38%) sediments are prominent but 7.6% of Polymodal are present.

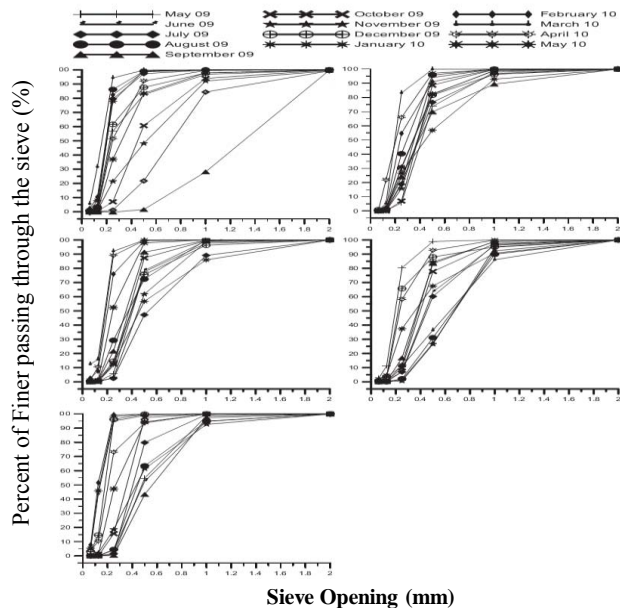


Fig. 2—Cumulative percentage distribution of collected sediment samples across Yarada beach

Table 1—Grain size variation during Monsoon and post monsoon months

Location	Effective Grain size(mm) D ₁₀			Median Grain size(mm) D ₅₀		
	SW monsoon	NE monsoon	Transition period	SW monsoon	NE monsoon	Transition period
BM1	0.28	0.16	0.11	0.50	0.29	0.19
BM2	0.15	0.17	0.12	0.29	0.30	0.19
BM3	0.18	0.19	0.10	0.35	0.32	0.16
BM4	0.32	0.20	0.19	0.38	0.33	0.40
BM5	0.26	0.11	0.09	0.38	0.22	0.16

Table 2—Percentage of sample type at different locations

Location	Percentage of sand type (%)			
	Very fine	Fine	Medium	Coarse
BM-1	7.69	53.84	23.07	15.38
BM-2	0	30.76	69.23	0
BM-3	0	30.76	69.23	0
BM-4	0	15.38	76.23	0
BM-5	23.07	15.38	53.84	0

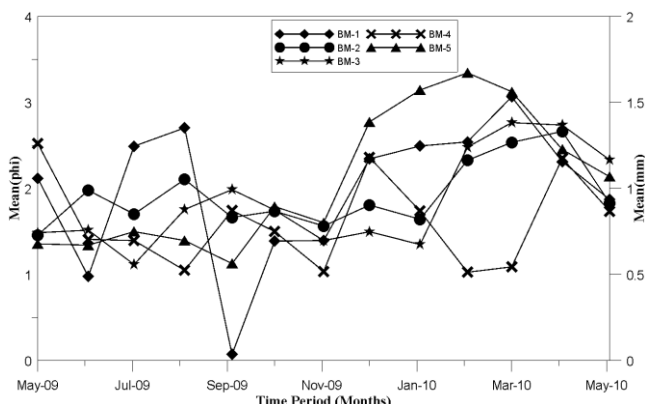


Fig. 3 —Mean grain size distribution at Yarada beach

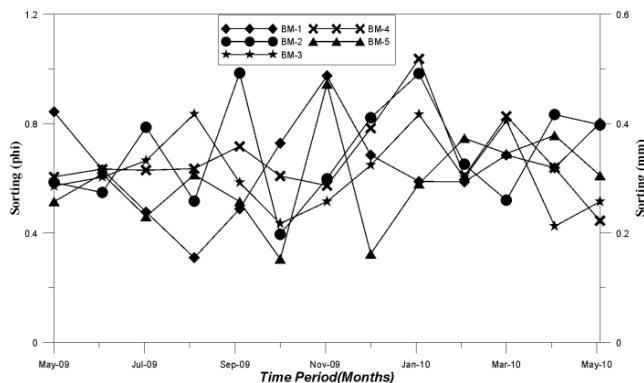


Fig. 5—Sorting of the sediments

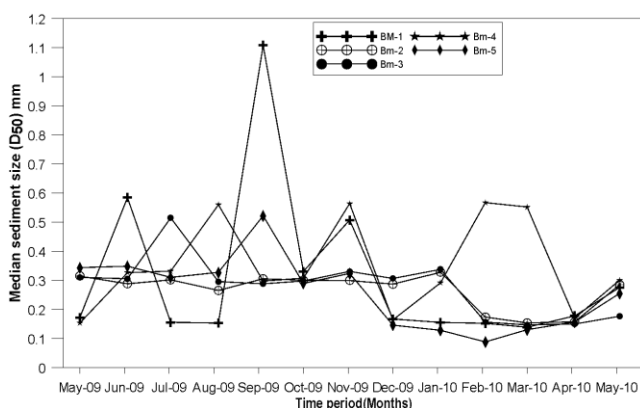


Fig. 4—Median size variations at Yarada beach

At BM-2, 38.46% of the total sediments are trimodal, 30.76% are bimodal, 15% are Polymodal and 7.6% of unimodal sediments are identified. Sediments at BM-3 show that trimodal (46.15%) behaviour is more here than bimodal (38.46%) even though Polymodal (7.69%) and unimodal (15%) behaviour are observed. At BM-4 and BM-5 unimodal characteristic are dominant 61.55% and 84.61% respectively with 30.76% of trimodal sediments at BM-4 and without trimodal characteristics at BM-5.

Sorting (ϕ)

Grain size and Sorting of beach sand is related to width of coastal plain in such a way that better sorted and fine sand is associated with wider coastal plain²¹. Sorting results showed that beach sediments at Yarada are very well (4.6%) to poorly sorted (1.5%) (Fig. 5). Among the collected samples about 53.84% are moderately well sorted and 29.23% are moderately sorted. But only 1.5% is poorly sorted and 10.7% and 4.6% of samples are well sorted and very well sorted.

Hence Yarada beach is dominated by moderately sorted sediments which further imply that beach width is narrow. At BM-1 46% of the samples collected are moderately well sorted but at BM-2 samples are sorted as moderately (46%) as well as moderately well sorted (46%). At BM-3 and BM-4 moderately well sorted samples (61%) are dominating. At BM-5 53% are moderately well sorted. So except from BM-1 all cross sections of the Yarada beach dominated by moderately well sorted and medium sand. But at BM-1 moderately well sorted sediments with fine sand is dominant. Intertidal region is always affected by the action of waves and currents, which controls the transportation of sediments along/across the shore, which further implies the sorting character of the sediment.

Skewness and Kurtosis

Sediments at Yarada beach varied from very coarsely skewed to very finely skewed (Fig. 6). About 29% of the samples are very coarse skewed, 21% coarse skewed, 20% are symmetrical and fine and very fine skewed are 15% and 13% respectively (Table 3). But at BM-1 38% are very coarse skewed and 23% are coarse skewed. At BM-2, 46% are symmetrically skewed but at BM-3 30% are very coarse skewed. Samples from BM-4 are coarse skewed but at BM-5 about 23% samples are fine and very fine skewed but 38% are very coarse skewed. Percentage of coarse skewed samples and very coarse skewed samples are same at BM-I and BM-3. Sediment samples observed from here are positively skewed (66%) indicating that most of the sediment was fine and medium sized (Table: 2). It resembles that the beach is under accumulating.

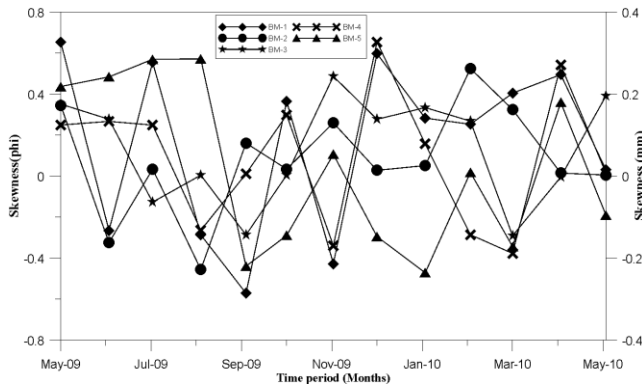


Fig. 6—Skewness of the sediment

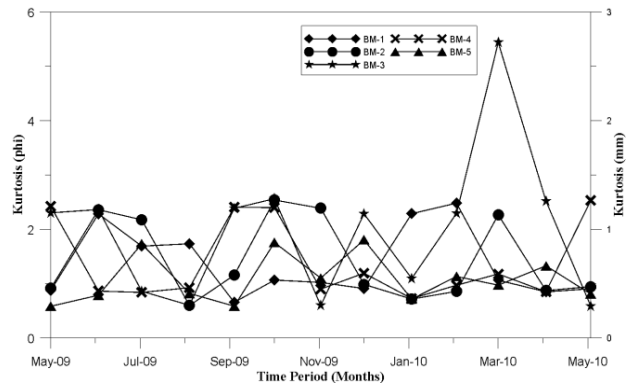


Fig. 7: Kurtosis of the collected sand samples

Table 3—percentage of Skewness characteristics of the sediment samples

Location	Skewness				
	Very fine	fine	Very coarse	coarse	Symmetrical
BM-1	23.07	07.69	38.46	23.07	07.69
BM-2	15.38	0	23.07	15.08	46.15
BM-3	0	23.07	30.76	23.07	23.07
BM-4	15.08	15.08	15.08	38.46	15.08
BM-5	23.07	23.07	38.46	07.69	07.69

Table 4—Kurtosis characteristics (in %) of the sediment samples

Location	Kurtosis					
	Very Platykurtic	Platykurtic	Mesokurtic	Leptokurtic	Very Leptokurtic	Extra Leptokurtic
BM-1	15.08	15.08	38.46	0	30.76	0
BM-2	0	0	23.07	07.69	38.46	0
BM-3	0	0	07.69	0	53.84	07.69
BM-4	0	0	15.08	15.08	30.76	0
BM-5	0	0	15.08	15.08	23.07	0

Across the Yarada beach at five different locations all the sediments varied between very platykurtic to extra leptokurtic (Fig. 7). Most of the samples are platykurtic (23%) Mesokurtic (20%) and very leptokurtic (35%) in nature. But extra leptokurtic samples are also observed during the survey. At BM-1 38.46% of the sample found to be Mesokurtic and 30% are very leptokurtic in nature. At BM-2 very leptokurtic nature (38.46%) is prevailing more but 23% of mesokurtic and platykurtic samples are also observed from here. 53% of leptokurtic samples are observed from BM-3 and 38.46% of platykurtic and 30% of very leptokurtic samples are observed from BM-4. At BM-5 also platykurtic nature (30%) prevailing more than mesokurtic and leptokurtic (15% each) (Table 4). Sediments from Yarada beach give very high peak than normal distribution because of sediments very leptokurtic nature.

Mean (ϕ) versus Sorting (ϕ)

Most of the sediments from intertidal regions of this beach are medium sands and which are moderately as well as moderately well sorted. During SW monsoon mean values suggest that most of the observed samples are medium with moderately as well as moderately well sorted but at BM-1 fine and

coarse sediments are observed and which are well sorted. But during NE monsoon medium sands with moderately well sorted are identified at all the locations except at BM-2. During transition period at all locations except BM-4 are characterized by fine sediments with moderately well sorted in nature. But at BM-4 sediments are moderately well sorted but are medium sized. Across the beach at intertidal region only few samples are poorly sorted because of waves, tides currents and also due to wind.

Conclusions

Yearly sediment data shows that sediment samples were predominantly sand. Grain size at intertidal regions varied rapidly across the Yarada beach. Obtained mean values suggest that medium size sediments are dominating more at Yarada beach. One year analysis of sediment data giving that D_{50} increased at BM-1 and BM-4 but at BM-2, and BM-3 and BM-5 D_{50} decreased while comparing the data from May 2009 and May 2010. And if considering effective grain size (D_{10}), which is also decreased in size except at BM-1 and BM-4. During SW monsoon D_{10} , and D_{50} are much higher than that of NE monsoon because of change in wave climate.

Analyzed sediments are moderately well sorted and medium sized across the beach which resembles that Yarada beach is not associated with wider coastal plains. Negatively skewed samples are found to be only 29% and remaining 71% are positively skewed. Hence the beach is observed as depositing beach. Sediments are characterized by very leptokurtic in nature means that distribution curves are not symmetrical.

Acknowledgements

Authors thank the Director of CSIR-NIO, Scientist-in-Charge, CSIR-NIO Regional Centre, Visakhapatnam for facilities and encouragement. The NIO contribution No is 5507.

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