Textural Characterization of Sediments Along Mandapam Coast, Ramanathapuram District, Tamil Nadu, India

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Abstract- *Study of Mandapam beach sediments was embarked upon in order to determine textural parameters, transportation mechanism and depositional environment. Texturally sediments are mostly medium sand, moderately sorted to moderately well sorted, coarse skewed to near symmetrical and leptokurtic to platykurtic in nature. Abundance of the medium sand demonstrates the prevalence of moderate energy condition in study area. Linear Discriminant Function (LDF) value study area indicates that sediments were deposited by Aeolian process under shallow marine and turbidity environment. Scatter diagram are drawn to establish the relation between different textural parameters. The bimodal distributions indicate mixing of sediments from two different sources. The CM pattern of Mandapam beach sediment shows a clustered distribution of sediments in the NO and OP sector, indicating a bottom suspension and rolling mode of deposition. The inference to be drawn from this study is that the variation in sedimentological parameters is governed by wave dynamics and littoral conveyance of the sediments.*

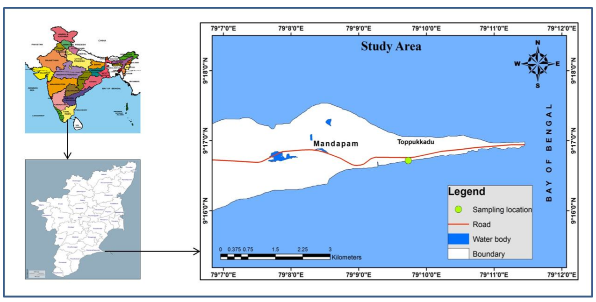
I. INTRODUCTION

Beaches are nonstatic and ever-changing landscapes formed by complex interactions involving sediment source, wave and wind energy, river discharge, precipitation intensity, and ambient geomorphology. The beaches are sensitive to changing climatic and environmental conditions involving variation in atmospheric pressures and subsequently generated winds (Simm, 1996). Several studies have linked the sedimentological, mineralogical, geochemical and geoenvironmental data on recent sediments to characterize and evaluate the evolution of a coastal area (Al-Edressi 2002; Zhang and Liu 2002; Birch 2003; Pekey et al. 2004; Al-Dughiem 2005; Zhang et al. 2007; Zubair et al. 2014; Reddad et al. 2016). Grain size parameters provide an insight in to the nature and the energy flux of the multivarious transporting agents and their purview of depositional environment. This helps in understanding the various processes affecting erosion and deposition. Thus, the knowledge of sediment size and textural parameters is one of the better tools to differentiate various depositional environments of recent as well as ancient sediments (Inman 1952; Dyer 1986; Folk 1974; Mason and Folk, 1958; Friedman 1961; Nordstrom 1977, Kumar et al. 2010). The aim of this study is to understand the textural parameters, transportation history and paleo environment of deposition of sediments near Mandapam area.

II. MATERIAL AND METHODS

Study was carried out near Mandapam area, a coastal town on the southeast coast of India on a small peninsular extension of the main land leading to Rameswaram Island, Ramanathapuram district, Tamil Nadu. This dynamic coastal zone is surrounded with Palk bay in the north, Rameswaram Island in the east, Gulf of Mannar to the south and connected to the main land at west. The sampling location falls between the latitude N 9°, 16′ 43″ and longitude E 79°, 9′ 44″ and forms part of survey of India toposheet No 58 O/4 on 1:50,000 scale (Map-1).

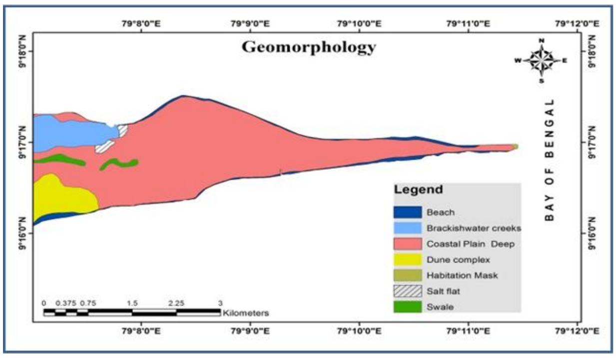
The study area characterized with unconsolidated sediments of quaternary age. Marine calcareous hardpan occurs as low terraces and platforms, with admixture of quartz, limonite and garnet concentrations. The coast of Mandapam area has several topographic expressions (Map- 2), which are the signatures of the interaction of marine and Aeolian processes. The beach is nearly flat and primarily composed of sandy materials, shelly matters



Map-1 Showing study area

and coral rubbles. Prominent depositional features like beach ridges, wave cut platforms, coral terraces composed of coral formations with calcareous evaporite deposits with erosional imprints of wave regimes like sea caves and notches found all along. Shrub stabilized irregular sand dunes found parallel to the coast line.

Sampling has been carried out during month of June 2016 by core sampling method using PVC (Polyvinyl Chloride) pipe of 2.5 inch diameter and of one meter length. Due to the presence of beach rocks core sample was taken to less than one meter. The core samples then capped and carefully carried to the laboratory and kept in the refrigerator. The exact sample locations were noted with the help of Global Positioning System (GPS) receiver. The core Sample was sub sampled with an interval of 5cm and transferred to clean dry polythene bags for laboratory analysis. In order to get true representative samples for sieve analysis, the air-dried samples were subjected to coning and quartering and amount of the sample was reduced to 100 gm. These representative samples were then washed with distilled water to remove salt content and further treated with 10% dilute hydrochloric acid to remove shells and organic content. Later these samples were washed frequently with distilled water and dried in hot air oven at 60°c temperature. Sieve analysis was performed using a series of standard ASTM test sieve (From #25 to #325 sieve sizes) of quarter phi interval to get uniform size fractions in Ro-Tap sieve shaker for 20 minutes. The grain size data obtained after sieving is processed to calculate all the statistical parameter such as Mean (Mz), Standard Deviation (σI), Skewness (Ski) and Kurtosis (KG). Linear discriminant function (Sahu, 1964) was used for understand depositional environment of the sediments. CM plot prepared as suggested by Passega to understand the transportation mechanism. The G-Stat software package was used for obtaining the CM diagram.



Map-2 Showing Geomorphology of the study area

III. RESULTS

Mean

Mean grain diameter, the most widely used distribution parameter, is regarded by most authors (Folk, Ward, 1957; Passega, 1964) as an indicator of the average energy of the transport and as sedimentation agent. In the study area, the vertical mean size ranges between 1.087Φ (At 5cm depth) and 1.907Φ (At 70cm depth) with average mean of 1.574Φ (Table-1). The mean size indicates that all of the samples belong to medium sand category. The distribution of medium sand in this region might have accrued from the dislodging of coarser sediments by the panning action of high velocity waves and also high energy environment (Venkatramanan, 2011).

Standard Deviation

Graphic standard deviation measures sorting of sediments and indicate the fluctuation in energy conditions of depositional environment but it does not necessarily measure the degree to which the sediments have been mixed (Spencer, 1963). The sorting variations observed, attribute to the difference in water turbulence and variability in the velocity of depositing current (Kashyap and Khan, 1982). The values obtained in the study area vary between 0.618Φ (At 25cm depth) and 0.955Φ (At 5cm depth) with average mean of 0.711Φ (Table-1). The standard deviation value suggest that most of the sample belongs to moderately sorted (78%) character which may be due to onshore winds which transport fine grained sediments further landward, leaving behind coarser particle at the berm and forming the dune field long this stretch. Presence of moderately well sorted (22%) character indicates low to fairly high energy current (Friedman, 1961; Blott & pye, 2001).

Skewness

The graphic Skewness measures the symmetrical distribution, i.e. predominance of coarse or fine-sediments. It reflects the symmetry or asymmetry of the frequency distribution of the sediment and the measure of the particle size. If the skewness is negative, the sample is coarsely skewed, that means the mean is towards the coarser side of the median. When the skewness value is positive the sample is described as finely skewed i.e., the mean is towards the finer side of the median. Skewness value of the study area ranging between -0.291Φ (At 45cm depth) to 0.122Φ (At 90cm depth) with an average of -0.101Φ (Table-1). Accordingly most of the samples are coarse skewed (50%) and near symmetrical (39%) with a few shows fine skewed (11%) nature. The negative skewness indicates high energy nature of the beach deposits in general (Friedman, 1961) and multidirectional sediment transport (Martins 1965). Near symmetrical nature of sediments indicate variation in energy condition during deposition.

Kurtosis

The graphic kurtosis (KG) is the peakedness of the distribution and measures the ratio between the sorting in the tails and central portion of the curve. According to Cadigan (1961), it is also a function of internal sorting or distribution. Kurtosis value of the sediments in study area ranges from 0.813Φ (At 10cm depth) to 1.447Φ (At 40cm depth) with an average value of 1.116Φ (Table-1). Most of the samples fall under leptokurtic (56%) character whereas few belong to mesokurtic (22%) and platykurtic (22%) character. The leptokurtic behaviour of sediment indicates the variation of energy conditions of the depositional basin. The variation in kurtosis value indicates reflection of the flow characteristics of the depositing medium (Cardigan, 1961).

Table -1 Graphic measure from grain size analysis sediments

Depth	Mean	St.dev	Skewness	Kurtosis	Remarks
5	1.087	0.955	0.110	0.866	MS,MS,FSk,PK
10	1.233	0.701	0.018	0.813	MS,MWS,NS,PK
15	1.367	0.772	-0.023	1.021	MS,MS,NS,MK
20	1.727	0.872	-0.280	1.143	MS,MS,CSk,LK
25	1.837	0.618	-0.017	1.093	MS,MWS,NS,MK
30	1.847	0.633	0.092	1.130	MS,MWS,NS,LK
35	1.593	0.759	-0.275	1.329	MS,MS,CSk,LK
40	1.620	0.626	-0.280	1.447	MS,MWS,CSk,LK
45	1.583	0.748	-0.291	1.268	MS,MS,CSk,LK
50	1.640	0.785	-0.223	1.206	MS,MS,CSk,LK
55	1.620	0.879	-0.241	1.204	MS,MS,CSk,LK
60	1.783	0.811	-0.124	1.172	MS,MS,CSk,LK
65	1.823	0.767	-0.062	1.087	MS,MS,NS,MK
70	1.907	0.718	0.002	1.048	MS,MS,NS,MK
75	1.660	0.824	-0.176	1.266	MS,MS,CSk,LK
80	1.627	0.833	-0.213	1.207	MS,MS,CSk,LK
85	1.173	0.780	0.042	0.880	MS,MS,NS,PK
90	1.210	0.803	0.122	0.875	MS,MS,FSk,PK
MIN	**1.087**	**0.618**	**-0.291**	**0.813**	
MAX	**1.907**	**0.955**	**0.122**	**1.447**	
AVG	**1.574**	**0.771**	**-0.101**	**1.116**	

MS- Medium Sand, MWS- Moderately Well sorted, MS- Moderately sorted, FSk- Fine Skewed, CSk- Coarse Skewed, NS- Near Symmetrical, LK- Leptokurtic, MK- Mesokurtic and PK- Platykurtic.

IV. LINEAR DISCRIMINANT FUNCTION (LDF)

According to Sahu (1964), the variations in the energy and fluidity factors seem to have excellent correlation with the different processes and the environment of deposition. However, as there is strong penchant to find out the total effect of the various parameters on the grain size variations in the beaches, the process and environment of deposition has been deciphered by Sahu's linear discriminant functions of Y1 (Aeolian, beach), Y2 (Beach, shallow agitated water) , Y3 (shallow marine, fluvial) and Y4(Fluvial Deltaic and Turbidity). Linear Discriminant Function (LDF) value of study area indicates that sediments were deposited by Aeolian process under shallow agitating water and Beach process in shallow marine and turbidity environment (Table-2).

Table -2 Showing linear discriminant function values (Sahu, 1964)

Sl.No.	Depth	Mean	Std.Dev	Skewness(Ski)	Kurtosis(KG)	Y1	Remarks-Y1	Y2	Remarks-Y2	Y3	Remarks-Y3	Y4	Remarks-Y4
1	5	1.087	0.955	0.110	0.866	-0.505	Beach	76.881	Sh. Agitated water	-7.672	fluvial(deltaic)	0.417	turbidity
2	10	1.233	0.701	0.018	0.813	-2.583	Beach	51.594	Beach	-3.953	ShallowMarine	0.692	turbidity
3	15	1.367	0.772	-0.023	1.021	-2.669	Beach	60.598	Beach	-4.837	ShallowMarine	0.746	turbidity
4	20	1.727	0.872	-0.280	1.143	-3.351	Aeolian	76.937	Sh. Agitated water	-6.161	ShallowMarine	0.940	turbidity
5	25	1.837	0.618	-0.017	1.093	-5.143	Aeolian	53.818	Beach	-2.818	ShallowMarine	1.171	turbidity
6	30	1.847	0.633	0.092	1.130	-5.106	Aeolian	55.257	Beach	-2.986	ShallowMarine	1.171	turbidity
7	35	1.593	0.759	-0.275	1.329	-3.556	Aeolian	62.759	Beach	-4.587	ShallowMarine	0.918	turbidity
8	40	1.620	0.626	-0.280	1.447	-4.333	Aeolian	51.070	Beach	-2.966	ShallowMarine	1.011	turbidity
9	45	1.583	0.748	-0.291	1.268	-3.577	Aeolian	61.597	Beach	-4.456	ShallowMarine	0.917	turbidity
10	50	1.640	0.785	-0.223	1.206	-3.572	Aeolian	66.155	Sh. Agitated water	-4.930	ShallowMarine	0.935	turbidity
11	55	1.620	0.879	-0.241	1.204	-2.919	Aeolian	76.165	Sh. Agitated water	-6.312	ShallowMarine	0.857	turbidity
12	60	1.783	0.811	-0.124	1.172	-3.933	Aeolian	71.083	Sh. Agitated water	-5.347	ShallowMarine	1.022	turbidity
13	65	1.823	0.767	-0.062	1.087	-4.331	Aeolian	67.179	Sh. Agitated water	-4.631	ShallowMarine	1.079	turbidity
14	70	1.907	0.718	0.002	1.048	-4.895	Aeolian	63.738	Beach	-3.975	ShallowMarine	1.168	turbidity
15	75	1.660	0.824	-0.176	1.266	-3.410	Aeolian	70.618	Sh. Agitated water	-5.477	ShallowMarine	0.924	turbidity
16	80	1.627	0.833	-0.213	1.207	-3.239	Aeolian	71.020	Sh. Agitated water	-5.610	ShallowMarine	0.894	turbidity
17	85	1.173	0.780	0.042	0.880	-1.935	Beach	58.344	Beach	-4.995	ShallowMarine	0.601	turbidity
18	90	1.210	0.803	0.122	0.875	-1.931	Beach	61.322	Beach	-5.305	ShallowMarine	0.613	turbidity

V. SCATTER PLOTS

Scatter plots between different statistical parameters throw light on information regarding the energy condition, medium of transportation, mode of deposition etc. Passega, Visher, Folk, Ward and others described that these trend and interrelationship exhibited in the scatter plots might indicate the mode of deposition and in turn aid in identifying the environments. An attempt has been made here to utilize these plots in the study area and to understand the geological significance using four size parameters (Figure-1).

Mean vs. Standard deviation

The mean vs. standard deviation plot of sediment shows an increase in sorting with decrease in size of the sediments. Griffiths (1967) explained that both mean grain size and sorting are hydraulically controlled, so that in all sedimentary environments the best-sorted sediments have mean size in the fine sand size range.

Mean vs. Skewness

The Mean vs. Skewness plot of Sediment shows negative skewness with decrease in sediment size but at finer end it shows positive skewness value which may be due to the variations under the influence of littoral current.

Mean vs. Kurtosis

The relation between mean-size and kurtosis (Fig - 2C) is complex and theoretical (Folk and Ward, 1957). The mixing of two or more size-classes of sediments, which basically affect the sorting in peak and tails i.e. index of kurtosis. Scatter plot between Mean and Kurtosis shows that with decrease in sediment size, kurtosis value increases. The plot of present values shows that the sediment-admixture is dominated by medium-sand. The varying proportions of sediments mixed with dominant sand mode makes the sorting worse, particularly in the tails; hence, there is a presence of platykurtic and leptokurtic to very leptokurtic condition also (Ashok. et.al., 2009).

Standard deviation vs. Skewness

The plot between standard deviation and skewness of Mandapam area shows that, decrease in sediment sorting gives a negative skewness value. The plot indicates that better sorted sample shows very small fluctuations in the skewness values and they are mostly sand dominant. But towards the poorly sorted part, there is a wide vertical scattering owing to the modal differences among the population towards fine and coarse skewness. The trend of the plot may be due to the modern dominance and mixing of different modes of population (Reghunadh *et.al.,* 1995).

Standard deviation vs. Kurtosis

The plot between standard deviation and kurtosis shows that standard deviation decreases with increase in kurtosis value which infers that, most of the sample shows leptokurtic behaviour with increase in sorting value.

Skewness vs. Kurtosis

The plot between skewness and kurtosis shows that kurtosis value decreases with increase in skewness value. Friedman (1962) showed that most sands are leptokurtic and are either positively or negatively skewed. This could be explained by the fact that most sands consist of two populations: one predominant population and one very subordinate, coarse (leading to negative skewness) to fine (leading to positive skewness).

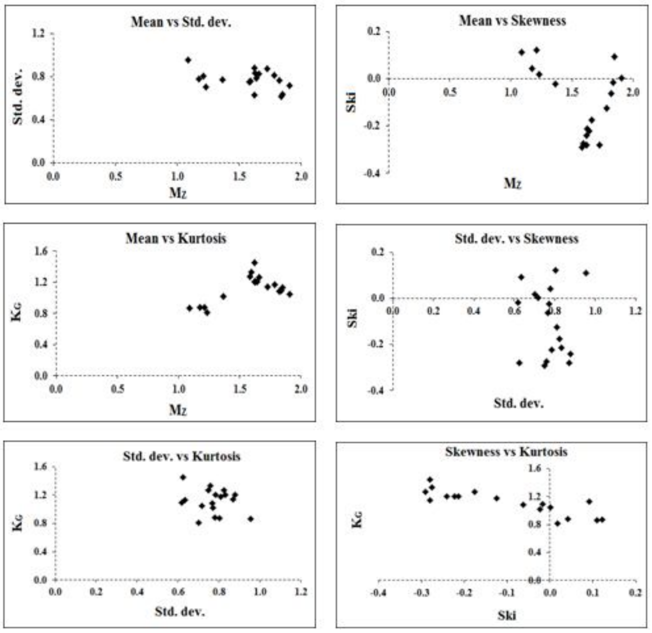


Figure-1 Showing Scatter plot between statistical parameters

VI. FREQUENCY CURVE

Frequency curve exhibit the pictorial representation of actual weight percentage of different fraction of sediments. According to Friedman and Sander (1978), the size factor mode is the peak of a simple frequency curve. The mode is important statistical parameter, especially the sediments containing several subpopulations each of which has its own mode. The presence of several modes in sand suggests that the particles have been derived from several parent deposits. In such multi-population (polymodal) sands, the phi value and magnitude give information on fraternization of sediments. Change in the mode reflects the history of the sand. The frequency distributions for most of the samples of Mandapam area dominated with bimodal (50%) nature with a few displays unimodal (28%) and polymodal (22%) distribution at different depths (Figure-2). The bimodal distributions indicate mixing of sediments from two different sources and observed below 30cm depth. Dominant presence of 1.5Φ and 2Φ size suggests the possibility of keeping a specific environment of segregation under a similar force of hydrodynamic condition.

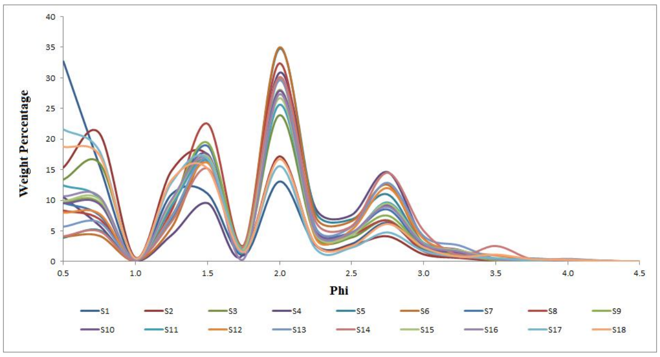


Figure-2 Showing frequency distribution of sediments

VII. C-M PLOT

Passega (1957) introduced C-M plot to evaluate the hydrodynamic forces working during the deposition of the sediments. It is a relationship of ‘C’ i.e. coarser one percentile value in micron and ‘M’ i.e. median value in micron on log-probability scale. Passega (1964) divided the CM pattern into different sector namely NO, OP, PQ, QR, and RS for different mode of transport. The plotted result of sediment shows that all the samples fall in NO and OP sector indicating bottom suspension and rolling condition of deposition (Figure-3).

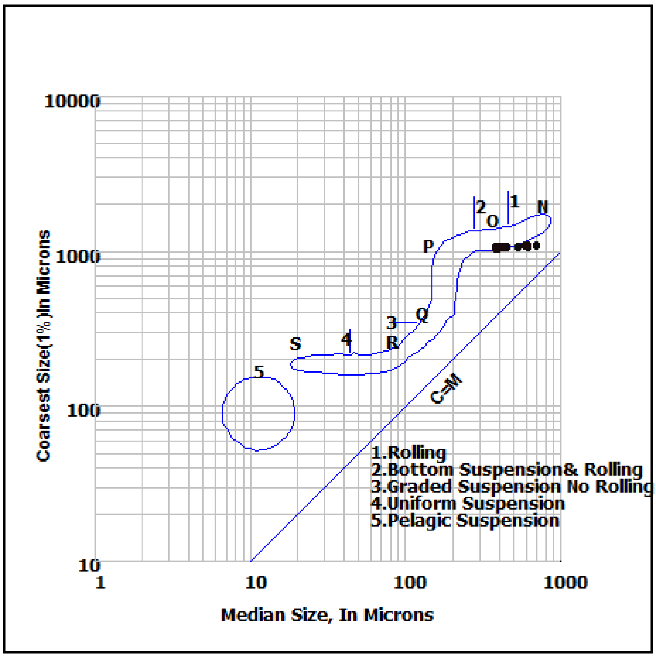


Figure- 3 Showing CM diagram (Passega, 1964)

VIII. CONCLUSION

The textural parameters of coastal sediments of Mandapam indicates mostly medium sand , moderately sorted to moderately well sorted, coarse skewed to fine skewed, leptokurtic to platykurtic in nature. Dominance of medium sand infers moderate energy conditions of deposition. The sediment, in general, show dominantly coarse skewed to near symmetrical in nature. Variation in kurtosis value from leptokurtic to platykurtic infers energy fluctuation of depositing medium. Linear Discriminant Function (LDF) value study area indicates that sediments were deposited by Aeolian process under shallow agitating water and Beach condition in shallow marine and turbidity environment. Scatter diagram clearly establish the relation between different textural parameters. The CM plot of the study area shows that all the samples were deposited as bottom suspension and rolling condition.

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