

BEACH DYNAMICS OF AN OPEN COAST ON THE WEST COAST OF INDIA

S. Jaya Kumar^{1*}, N.S.N. Raju² and R. Gowthaman¹

¹Ocean Engineering Division, National Institute of Oceanography, Dona Paula, Goa – 403004

²National Institute of Oceanography, Regional Centre, Visakhapatnam.

Abstract

In order to study the daily beach dynamics at an open beach in Goa, field investigations were carried out on the beach profiles, breaking wave parameters and long-shore currents for one month each during pre-monsoon and post-monsoon periods. Three transects on the Calangute beach, Goa, spaced about 250 m apart were selected. Pre-monsoon breaking wave heights were observed to be between 0.4 and 1.3 m and the wave period between 5 and 11 s, whereas, the post-monsoon breaking wave heights were between 0.35 and 1.4 m with the periods ranging between 8 and 15 s. Pre-monsoon long-shore currents were stronger (max. 1 m/s) and varying in direction compared to post-monsoon (max. 0.66 m/s) wherein the direction was predominantly north. Post-monsoon foreshore slopes were found to be mild and the berms wider compared to the pre-monsoon beaches. Inter-tidal beach sediments in the pre-monsoon period were coarse compared to post-monsoon sediments. Average estimated long-shore sediment transport rate in the study region indicates that the gross long-shore sediment transport was high during pre-monsoon compared to the post-monsoon. The net transport was southwards and about $0.013 \times 10^6 \text{ m}^3/\text{year}$ during the pre-monsoon and it was northerly and about $0.007 \times 10^6 \text{ m}^3/\text{year}$ during the post-monsoon. Whereas, the average gross transport rate was $0.02 \times 10^6 \text{ m}^3/\text{year}$ during the pre-monsoon it was $0.014 \times 10^6 \text{ m}^3/\text{year}$ during the post-monsoon.

Keywords: beach profiles, long-shore sediment transport, littoral environmental observations, beach sediments, breaking waves

1.0 INTRODUCTION

Studies on the beach dynamics provide understanding of the sediment movement and other related parameters which in turn provide information on the erosion or deposition pattern of the beach itself. The processes of beach erosion and accretion are seasonal and these processes over a long period ultimately result in either building up or recession of the coastline. Beach profile data provides information on variability of energy conditions of coastal environment.

Goa, located on the west coast of India has a coastline of about 125 km with more than seventeen beaches. Most of these are beautiful sandy beaches that attract tourists all over the world. These beaches are mostly used for recreational purpose. The studies related to

*Corresponding author, e-mail: jay@darya.nio.org

coastal processes and beach dynamics has been widely discussed in the literature (Veerayya, 1972; Murthy et al., 1975; Antony, 1976; Murthy et al., 1982; Wagle, 1987; Anand et al., 1991; Chandramohan et al., 1997; Chandramohan et al., 1998). Changes in beach morphology based on profile measurements have been earlier studied along the Goa coast by Veerayya and Varadachari (1975), Sastry et al., (1979) and Murthy and Veerayya (1985). Earlier studies carried out in this study region were either at micro-time scales of 30 minutes durations in a day (Veerayya et al., 1980) or over fortnightly intervals during a month (Veerayya et al, 1982) or over monthly intervals over a year (Veerayya et al., 1980) or once during a season (Chandramohan et al, 1997).

For this study, measurements on the beach profiles and littoral environmental parameters at three transects along the Calangute beach were carried out at daily intervals during February 1999 to March 1999 (pre-monsoon period) and during November 1999 to December 1999 (post-monsoon period). Detailed listing of the profiles and LEO are presented in Jayakumar, et al. (2001 & 2002).

2.0 STUDY LOCATIONS

Three reference stations were established (S1, S2 and S3) along the beach as shown in Fig. 1. The locations of the starting points (local bench marks) of the beach profiles for different transects are as follows: Station S1 is located at a distance of about 200 m north of the beach entrance. The starting point of the beach profile is at the foot of a concrete pillar present on the backshore region. Few beach shacks are present on the backshore nearer to this station. Influence of tourists is relatively less at this place compared to that near the entrance of beach. Station S2 is located about 50 m southwards of the entrance to the beach. The starting point of the beach profile is at the foot of a concrete platform. As this station is nearer to the beach entrance, this part is most visited by the tourists. Station S3 is at a distance of about 250 m south of the entrance to the beach. The starting point of the beach profile is at the foot of a concrete pillar. This station is not much frequented by tourists but most of the catamaran-type fishing boats are operated from this stretch of the beach.

3.0 METHODS

Littoral environmental parameters, viz., longshore current speed and direction, breaker height, breaker period, breaker angle, breaker type and surfzone width were observed daily following the CERC procedure for LEO program (Schneider, 1981). Magnitude and direction of the longshore currents were measured by releasing neutrally buoyant plate in the surf-zone. The distance travelled in 2 minutes was measured to estimate the long-shore current speed. The direction was taken as positive when the flow is towards the right hand side, while facing the sea and negative when the flow is towards the left hand side.

Daily variations in the beach profiles from local bench marks on the backshore to about 1 m

water depth were measured using ZEISS Automatic survey level and a graduated staff. The profile variations were measured at 5 m interval where there is little variation and at closer interval of 1 or 2 m wherever prominent variations along transect are seen. The graduated-staff readings along transect were reduced to the respective local benchmark and plotted with distance on the x-axis and reduced levels on the y-axis.

Surface sediments from the foreshore were collected twice during the pre-monsoon period and twice during the post-monsoon period. The sediments were prepared for analysis by thoroughly washing with distilled water to remove the dissolved salts and oven dried to remove the moisture. The sieve analysis of the oven dried sediment samples was carried out as per standard procedures (IS: 2720 Part IV - 1975).

4.0 RESULTS AND DISCUSSION

4.1 Breaking waves

At all the three stations, pre-monsoon breaking wave heights were observed to be between 0.4 and 1.5 m and the breaking wave periods between 5 and 12 s (Fig. 2). Waves were breaking mostly parallel to the coast and at times with a small angle less than 5° with respect to the coastline. Post-monsoon observations showed that the breaking wave heights were between 0.4 and 1.3 m with the breaking wave periods ranging between 8 and 15 s (Fig. 2). The waves were breaking almost parallel to the coast during post-monsoon period. Breaking wave angle varied between 5° clockwise to the coast and 2° counter-clockwise to the coast was observed during the pre-monsoon period and it varied between 2° clockwise to the coast and 3° counter-clockwise to the coast during post-monsoon period. Plunging and spilling type breakers were mostly observed during both the study periods at all the stations. Occasional spilling or collapsing type breakers were observed.

Pre-monsoon breaking wave heights were observed to be constant during the first three observations and increasing during the last two observations indicating an increase in the wave energy. During the post-monsoon observations, the breaking wave heights did not vary much. The pre-monsoon breaking wave periods were observed to be varying compared to post-monsoon wave periods where it was observed that they were more or less constant.

Variations in the breaking wave angle observed during the pre-monsoon period show that the waves were breaking clockwise to the coast during the beginning and ending of the study whereas the waves were breaking counter-clockwise during the middle of the study period. During the post-monsoon study period, the waves were mostly breaking counter-clockwise to the coast except towards the end of the study where the waves were breaking clockwise for three to four days.

4.2 Longshore currents

Observations on longshore current speed and direction during pre-monsoon period revealed that the upto current speed was between 2 and 62 m/minute (0.033 and 1.03 m/s). Longshore currents of the order of 1.1 m/s were reported earlier by Krishna kumar et al. (1989). During the post-monsoon, the absolute current speed varied between 2 and 40 m/min for this coast (0.033 and 0.66 m/s). The long-shore current direction was varying in either direction during the pre-monsoon period, whereas, it was mostly towards north during the post-monsoon period. High variability in direction and speed of longshore currents along Goa coast was earlier reported by Murthy and Veerayya (1985) based on monthly field observations over a period of five years. This variability in direction is due to spot observations that represent the prevailing conditions at that moment. Anand and Chandramohan (1991), based on one year field observations, reported that the longshore current mostly persisted around 0.4 m/s and was towards south during pre-monsoon and towards north during post-monsoon.

4.3 Surfzone width

Surfzone width at all the three stations varied from day to day. It was more or less similar on each day of observation at all the stations. During pre-monsoon observations, the surfzone width showed a variation between 2 and 60 m, whereas, it was observed to vary between 4 and 15 m during the post-monsoon period. Chandramohan et al., (1997) has reported that the surfzone width along the Goa beaches was narrow (<10 m) during November to February, which this study also more or less confirms.

4.4 Beach profiles

Typical pre-monsoon and post-monsoon beach profiles measured at stations S1, S2 and S3 are shown in Fig. 3. The pre-monsoon berms are observed to have a maximum width of 10 m compared to 20 m during post-monsoon observations. The average width of the beach from the local benchmark till the berm during the pre-monsoon was observed to be about 30 m whereas it was about 50 m during the post-monsoon.

During the pre-monsoon studies at station S1, the profiles were observed to be eroding compared to 17th February profile. The profiles at this station during 23rd February, 2nd March and 9th March were observed to be stable without much change. The last observation on 17th March showed high level of erosion compared to all other profiles. However, the foreshore slopes of the 17th February and 17th March profiles were found to be similar.

The pre-monsoon profiles at all the stations except for station S1 show erosion and deposition occurrence within short periods indicating that the beaches are in a transitional state. The post-monsoon beach profiles show that the beaches are accreting in the berm region and the slopes beyond the berm towards the water line are increasing. This is due to the occurrence

of short period waves during pre-monsoon and long period waves during post-monsoon season that the wave energy during the pre-monsoon period is higher compared to that during the post-monsoon and the building up of beach is in progress.

4.5 Beach sediments

The grain size analysis showed that the median sediment size (D_{50}) of the inter-tidal surface sediments varies between 0.23 and 0.52 mm during the pre-monsoon period and between 0.20 and 0.27 mm during the post-monsoon. These sediments were mostly of quartz and were sand sized particles. Surface sediments were coarse during the pre-monsoon and fine during the post-monsoon. Significant variation in the sediment size was observed at station S2 with D_{50} value of 0.195 mm during December and 0.52 mm during March. This variation is in tune with the beach slopes where the slopes are steep during pre-monsoon and relatively flat during post-monsoon. The sediment sizes during February are finer than those during March. This shows that the beach is steeping due to increase in the wave climate and approach of monsoon. The sediments at all the stations were of similar size in December but lesser than those in November indicating that the beach is flattening. This shows that the finer fractions of the sand particles are transported offshore or are kept in suspension during the pre-monsoon period thereby resulting in coarse sand on the beach. And the onshore movement of these fractions during the post-monsoon period results in a fine sediments on the beach.

Table 1. Beach sediments D_{50} values (in mm).

Season Stn. No.	Pre-monsoon		Post-monsoon	
	FEB. '99	MAR. '99	NOV. '99	DEC. '99
1	0.290	0.450	0.225	0.200
2	0.230	0.520	0.270	0.195
3	0.330	0.275	0.225	0.195

4.6 Longshore sediment transport

Using Walton's equation (Shore Protection Manual, 1984) the monthly longshore sediment transport rates are estimated. The average estimated longshore sediment transport rate revealed that the net and gross transport rates of pre-monsoon were higher than the post-monsoon period and uni-directional at all the stations. The average net transport rate during pre-monsoon was $0.012 \times 10^6 \text{ m}^3/\text{year}$ in southerly direction and during the post-monsoon it was about $0.007 \times 10^6 \text{ m}^3/\text{year}$ in northerly direction. The reason for occurrence of higher transport rate during pre-monsoon could be the effect of local environmental changes during the study period. Earlier studies carried out by Anand, et al., (1991), based on one year observation, that the annual net transport was $0.089 \times 10^6 \text{ m}^3/\text{year}$ towards south. The net transport was about $0.039 \times 10^6 \text{ m}^3/\text{year}$ during monsoon and during the pre-monsoon as well as the post monsoon it was $0.014 \times 10^6 \text{ m}^3/\text{year}$ and $0.056 \times 10^6 \text{ m}^3/\text{year}$.

The average gross transport rate obtained was $0.02 \times 10^6 \text{ m}^3/\text{year}$ during the pre-monsoon and $0.014 \times 10^6 \text{ m}^3/\text{year}$ during the post monsoon period.

Table 2. Longshore sediment transport.

Season	Pre-monsoon		Post-monsoon	
Stn. No.	Net(m^3/month)	Gross(m^3/month)	Net(m^3/month)	Gross(m^3/month)
1	0.16×10^5	0.22×10^5	0.081×10^5	0.087×10^5
2	0.045×10^5	0.28×10^5	0.094×10^5	0.095×10^5
3	0.08×10^5	0.23×10^5	0.104×10^5	0.105×10^5

5.0 CONCLUSIONS

Measurements carried out on the beach profiles, longshore currents, breaking waves and inter-tidal surface sediments at three stations at Calangute, Goa during pre- and post-monsoon periods. The observations show that during pre-monsoon the wave energy was high compared to the post-monsoon, the beaches were narrow, longshore currents were strong and predominantly moving southwards. The sediments were coarse during the pre-monsoon compared to post-monsoon which is also complying to the fact that the beach slopes are steeper during pre-monsoon and flat during post-monsoon. The net transport was southwards and about $0.013 \times 10^6 \text{ m}^3/\text{year}$ during the pre-monsoon and it was northerly and about $0.007 \times 10^6 \text{ m}^3/\text{year}$ during the post-monsoon. Whereas, the average gross transport rate was $0.02 \times 10^6 \text{ m}^3/\text{year}$ during the pre-monsoon and $0.014 \times 10^6 \text{ m}^3/\text{year}$ during the post-monsoon.

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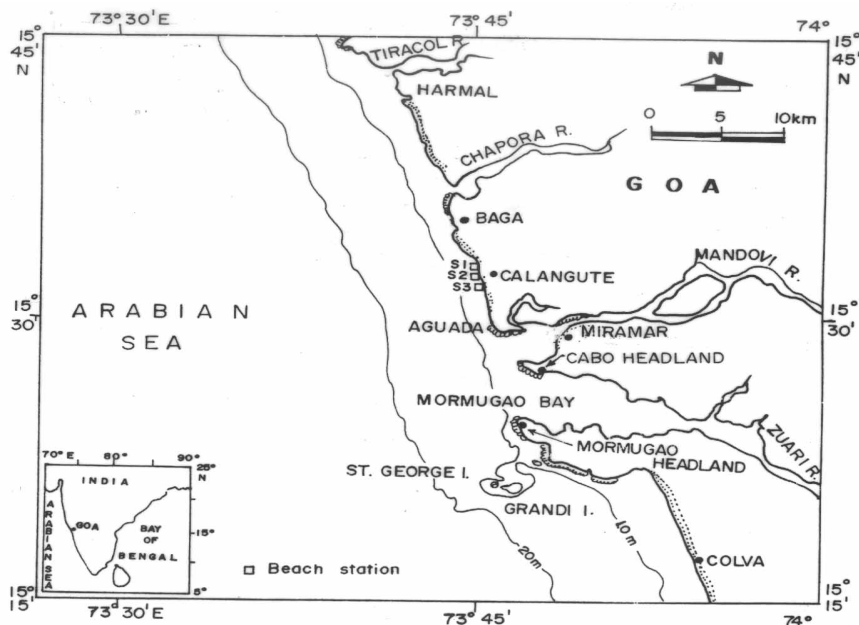


Fig. 1. Location map.

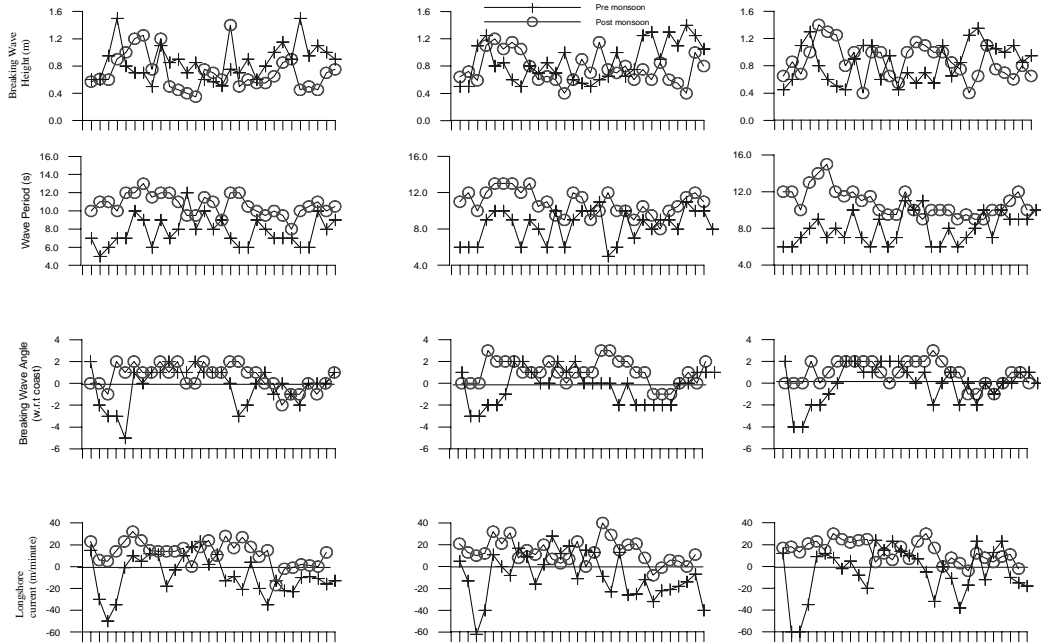


Fig. 2. Daily littoral environmental parameters off Calangute beach.

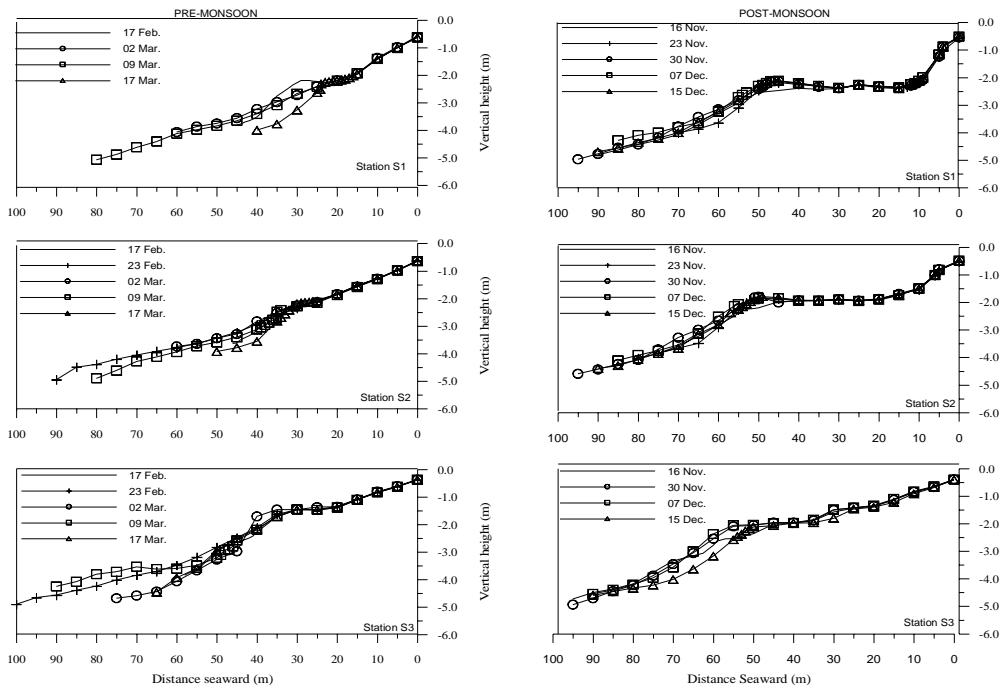


Fig. 3. Pre- and post-monsoon weekly beach profiles at Calangute.