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Studies on shoreline stability at Mandovi estuary, Goa

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Study of wave parameters and beach processes indicate that the coast along the Mandovi estuary can be divided into 3 regimes depending upon the predominant forces controlling the coastal processes. The meandering of Mandovi river with strong tidal currents along the outer banks of the bend and the convergence of wave orthogonals during the southwest monsoon are found to be the main factors causing erosion along the beach in the vicinity of the Youth Hostel at Campal.

Mandovi estuary forms an integral part of the Mandovi-Zuari-Cumbarjua canal system on the west coast of India. The coastal processes along the coast in Mandovi estuary are very complex due to the formation of Aguada and Reis Magos sand bars at the river mouth (Fig. 1), meandering of the river, tidal currents, fresh water discharge and varying wave characteristics. The segment of the shoreline near Youth Hostal at Campal and Caranzalem beaches are subjected to erosion particularly during the southwest monsoon from June to September. The present study aims at evaluating the coastal processes along this region with a view to identifying the causes of erosion at the Youth Hostel and at certain stretches of Caranzalem beach.

Methods

In order to evaluate the beach stability and the associated nearshore environment, a study was undertaken along the shoreline from Campal to Cabo headland (Fig. 1). As the information on measured waves are not available for the Goa coast, the ship reported visual wave data were compiled from the Indian Daily Weather Report[2] for the grid area between lat. 15°-20°N and long. 70°-75°E for the period 1968-1973. Monthly visual observation on breaking waves were made for the year 1981.

The monsoon waves were recorded by deploying a Dutch Wave Rider buoy at 8 m water depth (Fig. 1) from June to August 1981 and waves were recorded for 20 min duration at every 3 h interval. The tides were measured near Verem jetty (Fig. 1) for comparing the tidal elevations with those measured at and predicted for the Mormugao Port.

One Aanderaa self recording current meter was installed at mid depth at water depth of about 4 m and current speed and direction were continuously recorded at 10 min interval from 7 June 1981 to 22 July 1981. Surface floats and fluorescent dye tracers were used to determine the longshore currents in the surf zone. Wave refraction studies were undertaken for different wave periods and incoming wave directions in order to identify the locations of wave energy concentrations. Monthly beach level measurements were carried out at 31 transects along the shoreline from Campal to Cabo headland. Foreshore and backshore sand samples were also collected at these transects and the grain size distribution was carried out using sieve analysis.

Results and Discussion

Wave roses for monsoon and fair weather period

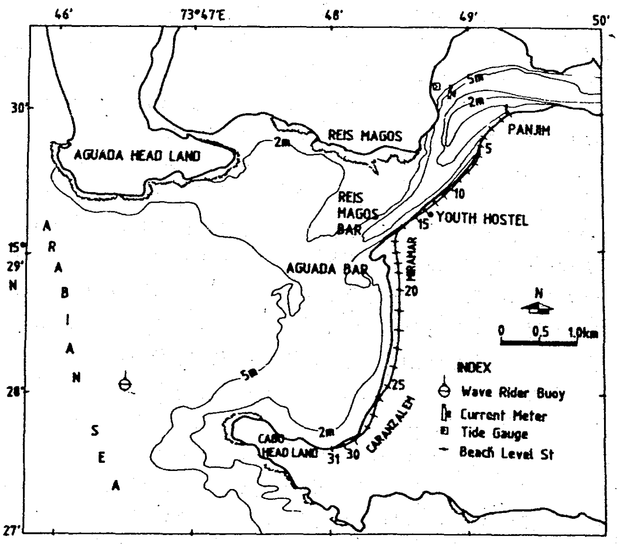

Fig. 1—Wave and current measurement locations and beach transects (beach level stations)

based on ship reported visual wave data are presented in Fig. 2. From the deep water, the waves approaching the shore are mostly from the W and the SW during the monsoon season (June to September) and from the NW during the fair weather season (October to May). The significant wave height (Fig. 3) varies from 1.9 to 4 m and the maximum wave height from 2.8 to 6.5 m. The predominant zero crossing wave period varies between 7 and 10 sec. The spectral width parameter varies mostly between 0.7 and 0.8 indicating distribution of wave energy in wide frequency band. The joint distribution of significant wave height and zero crossing wave period indicates that the monsoon waves are higher and steeper with wave steepness (H/L) ranging from 0.02 to 0.04 (Fig. 4). Visual observations indicate that the average breaking wave heights range from 1.2 m to 2.5 m during June to September with periods ranging from 8 to 10 sec. From October to May the breaking wave heights range from 0.5 to 1.5 m with periods 8 to 9 sec.

The tides are semi-diurnal and the comparison between the tide levels recorded at Mandovi estuary and those recorded at Mormugao Port shows a time lag of about 30 min and there is no significant difference in tide levels between these 2 locations.

The distribution of measured current speed and direction is presented in Fig. 5. The current speed varies from 0.3 to 1.3 $m.sec^{-1}$ with a short interval of slack period. The flow direction is towards S and SW during the ebb tide and is predominantly towards N and NE during the flood tide period. A time lag of about 2 to 3 h is observed between occurrence of maximum currents and high or low tide levels.

Measurements of longshore currents indicate that the current pattern near the Youth Hostel (tr. 14, Fig. 1) is mainly governed by tidal flows. The typical distribution of longshore currents measured during July 1982 is shown in Fig. 6. Strong longshore currents exceeding 40 $cm.sec^{-1}$ are noticed at certain stretches along the Caranzalem (trs 25 and 26) and the Miramar beaches (trs 16 and 22).

Numerical wave refraction studies show that the segments near the Youth Hostel (tr. 14) and the northern part of Caranzalem beach (trs 18 to 20) are subjected to wave energy concentration particularly when the waves approach from the W and the SW

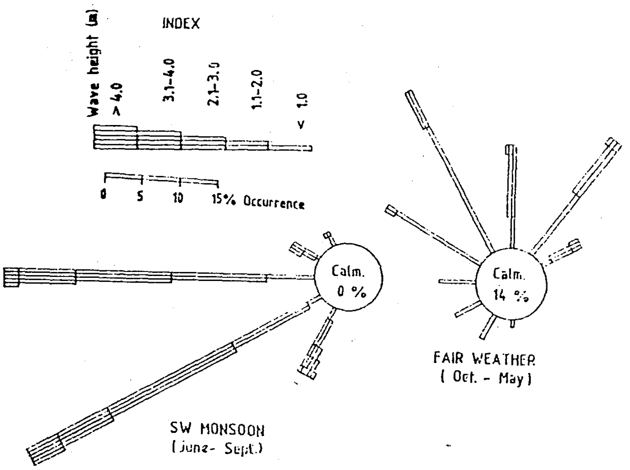

Fig. 2—Wave roses

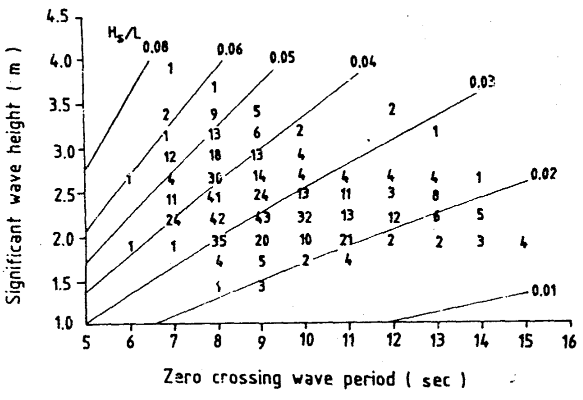

Fig. 4—Distribution of H_s and T_z

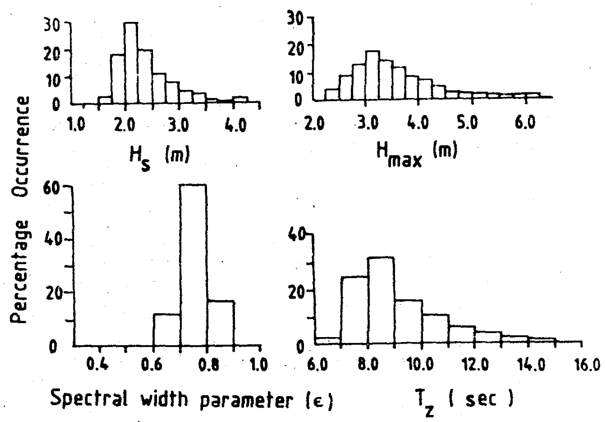

Fig. 3—Percentage distribution of wave parameters

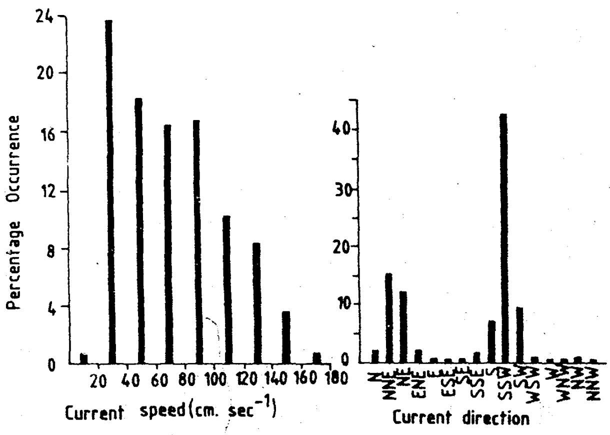

Fig. 5—Percentage distribution of current speed and direction

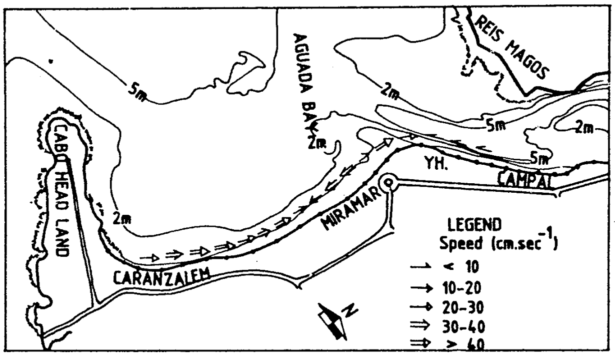

Fig. 6—Distribution of longshore currents (during 1 July 1982)

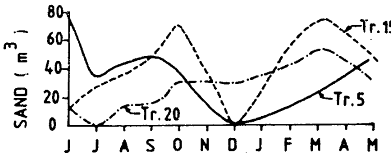

Fig. 7—Volume of sand per metre length of the beach

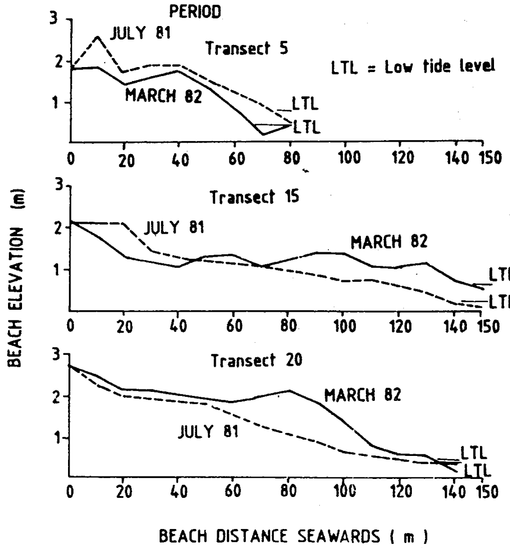

Fig. 8—Beach level variations

during the monsoon. This is observed to be one of the main reasons of severe erosion occurring at the Youth Hostel during the monsoon season.

Variation in the quantity of beach material (Fig. 7) at 31 transects in different months were computed from the monthly beach profile surveys. Beach profile changes occurring during the SW monsoon (July) and the fair weather periods (March) at trs 5, 15 and 20 are shown in Fig. 8. The study shows that the beach segments at trs 2, 5, 7, 8, 15 and 17 are subjected to erosion from November to February and the remaining part of the shoreline is subjected to seasonal erosion during the monsoon (June to September). Computation of monthly variation of sediment volume shows that a net loss of about 6 m^3 of sand per meter length of beach takes place at tr 8 in 1 y cycle. It is found that the beach near transect 8 is subjected to scouring due to concentration of tidal current along the outer bend of the meandering river channel.

Typical grain size distribution curves at trs 15 and 20 are shown in Fig. 9. Grain size of 50% sediments along the foreshore varied from 0.205 mm at tr 15 to 0.23 mm at tr 20 and 0.125 mm at tr 25.

The distribution of longshore currents (Fig. 6), the divergence of wave orthogonals from the refraction studies and the visual observation on the breaking wave characteristics between trs 1 and 6 indicate that this part of the coast is subjected to almost negligible wave action throughout the year. Further, the monthly variation of beach profiles shows that the sediment movement along this segment of the shore depends upon the season governed by the currents

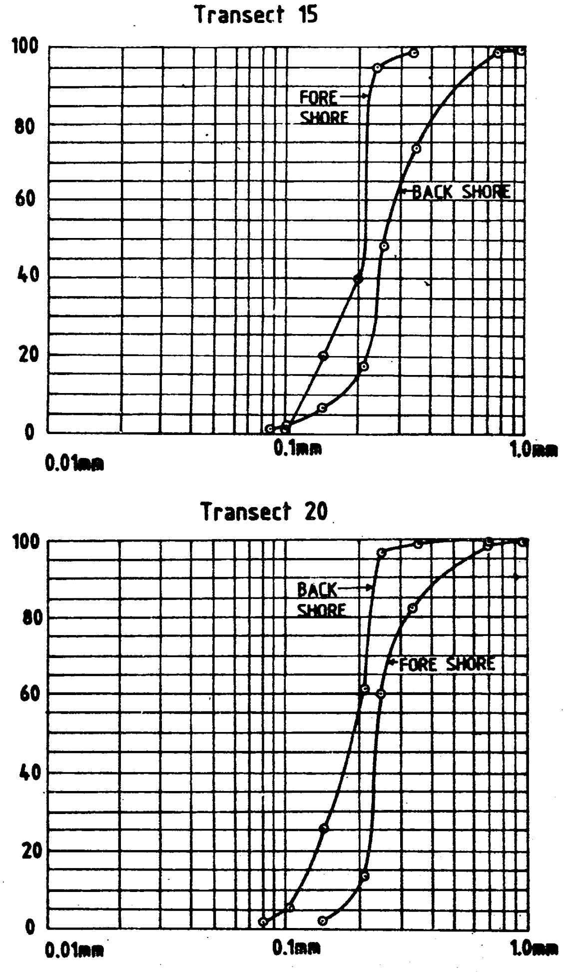

Fig. 9—Grain size distribution

caused by tidal and river flows. This shore segment is found to be fairly stable on an annual cycle. The above observations indicate that the predominant forces governing the coastal processes in this regime between trs 1 and 6 are the currents caused by the tidal and river flows.

The part of the coast between trs 7 to 15 is situated on the outer bend of the meandering river channel and is subjected to erosion and scouring due to concentration of strong tidal and river flows. In addition, the wave refraction studies and visual wave observations especially during the monsoon when the waves approach from west and southwest directions indicate concentration of wave energy near tr 14 where maximum erosion conditions prevail. Relatively coarser material with 50% grain size of about 0.205 mm (Fig. 9) on this beach segment implies that this region is exposed to high energy waves and currents. Hence, in this regime between trs 7 and 15, both the tidal currents and waves influence the coastal processes.

The part of the coast between trs 16 to 31 is generally wide and the wave orthogonals are found to diverge indicating the exposure to less wave energy. The consistency in the direction and magnitude of longshore currents (Fig. 6) indicate that this portion of the beach is influenced by the breaking waves and the effect of tidal current is very less. In addition to refraction, the beach segment from transects 24 to 31 is subjected to diffracted waves due to the presence of Cabo headland. The Aguada and Cabo headlands partly protect this portion of the shoreline against severe monsoon waves. The beach which is subjected to erosion during the monsoon (Fig. 8) due to steep and high waves, found to fully recover to its original condition during the fair weather season thereby completing an annual beach cycle. The above observations indicate that the predominant force governing the coastal processes in this regime of the coast between trs 16 and 31 is mainly waves.

Acknowledgement

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2 Anonymous, *Wave atlas for Arabian Sea and Bay of Bengal*, (Nat Inst of Oceanogr, Panaji, India) 1982.