Wave refraction and longshore current patterns along Calangute beach (Goa), west coast of India

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Wave refraction study for most predominant waves with 6, 8, 10 and 12 sec period and approaching from directions WNW, W and WSW has been carried out along the Calangute beach. The energy distribution and probable longshore/offshore current pattern are qualitatively assessed. The degree of refraction is less and no abnormal energy concentrations occur along this stretch. The waves after breaking give rise to many opposing flows forming circulation cells along the entire stretch. Zones of quasi-permanent rip currents are identified at Calangute and Candolim sections for 10 sec period waves approaching from WNW and W.

The waves from deeper water when approach the shore undergo refraction due to variations in bottom topography and break at the coast giving rise to longshore and onshore/offshore flows. An analysis of wave refraction thus becomes important as it determines the nearshore circulation pattern and also the wave energy distributions along the coast. This is the principal source of energy which controls the erosion/accretion or overall stability of the coastline, sediment transport, etc. The present study is made to understand wave energy and wave height distributions and probable longshore current patterns at Calangute beach, Goa.

Calangute beach is 7.5 km long sandy and almost straight and is well known for its stability. The bottom contours here run almost parallel to the coast. Medium to very fine sands cover the sea bottom up to 8 m of water depth and beyond that silty clays prevail. Antony has studied wave refraction, rip currents and sediment transport along Calangute beach using graphical method. Murty et al. have carried out field observations in this area to measure the littoral currents in the surf zone. The shoreline dynamics, longshore currents, sediment transport, etc. have also been studied along Calangute beach earlier. The present study has been carried out using numerical method of wave refraction using computer, which supports the location of permanent rip current zones identified in the earlier studies but has clearly demarcated more number of rip current zones.

Materials and Methods

Bathymetric chart Nos. 2022 and 215 (N H O. corrected up to 1977 and 1984 respectively) have been used for the present wave refraction study. In order to satisfy the deep water conditions of all predominant waves which have to be studied, the deep water limit of computation has been fixed around 120 m of water depth. Care has been taken to choose the grid boundary on the other 2 sides so as to accommodate even the extreme wave directions. Each grid has a size of 900m x 900m in the deep water, but when traced towards the shore, this grid size has been considerably reduced to 300m x 300m to obtain maximum accuracy within the limits of computation. The depth values, digitized at every grid point, form the primary input data for the analysis. Nine arbitrary stations are fixed approximately 800m apart for the convenience of understanding the areas of higher and lower energy levels along this stretch.

The waves coming from MNW, W and WSW with periods 6, 8, 10 and 12 sec are predominant, of which the 10 sec period waves are more frequent throughout the year. Wave refraction diagrams for the above waves have been constructed following the numerical method on TDC 316 and ND 520 computers. The wave refraction diagrams for 10 sec period waves approaching from MNW, W and WSW are prepared. The refracted orthogonals are traced from the deep water limits towards the shore but the part of the refracted orthogonals from 15 m
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Fig. 1—Wave refraction diagrams for waves approaching from (a) WNW, (b) W and (c) WSW [T_w = 10 sec].

Results and Discussion

The rays traced from deep water for 10 sec period waves for all 3 directions, WNW, W and WSW (Fig. 1, a–c), show no abnormal wave energy concentrations along this stretch. The orthogonals show refraction of no significance beyond 10 m contour (but slightly refract towards the shore). This is because of the nature of the bottom topography which runs almost parallel to the coast. At st 3, close to the coast, bottom contours bulge slightly offshore. Irrespective of the wave directions, orthogonals converge near st 3 giving rise to higher wave energy levels, while at the sides of this (near st 2 and 4), there are zones of divergences giving rise to areas of low wave energies. The waves approaching from west experience least refraction as they are near normal to the shore. One can notice that the areas of convergence shift considerably when a change in the direction of wave occurs.

The refraction coefficient (K1) is distributed around 1 along the study area irrespective of the period and direction (Fig. 2) which indicates the absence of abnormal energy concentrations. There is a slight tendency for WNW waves to refract towards south (maximum \( \theta' = 20^\circ \)) while the waves from W refract irregularly showing no tendencies in particular. But the WSW waves show a northward tendency (maximum \( \theta' = 30^\circ \)). A close look at the wave orthogonals reveals that in general, the waves approaching this coastline, irrespective of their deep water directions, after the refraction over the shallow depth contour are only shown in the figures. To examine the energy concentration/angle of approach of the waves, the direction function \( \beta' \)—which is defined as the angle subtended by the wave ray to the normal drawn to the shoreline—and the refraction coefficient (K1) are presented for all predominant waves. The wave height (h) is calculated along the ray paths using the relation \( h = h_0 K_1 K_2 \), where K2 is the shoaling coefficient and \( h_0 \) is the deep water wave height, assumed to be 1 m in the present study. These wave heights are transferred into grid points using 2 point Lagrangian interpolation and contoured for equal wave heights at intervals 0.05 m and only 10 sec period waves are presented. The locations of wave breaking have been found using the relation \( h_b = 0.83 d_b \) where \( d_b \) is the depth of wave breaking and \( h_b \) is the breaker height. The probable longshore/offshore flow directions deduced from the wave refraction diagrams and wave height distribution along this stretch for 10 sec period waves for the three different directions are also presented.
low shelf have a tendency to refract towards north or appear to be coming from southerly quadrant.

The wave heights are distributed from 0.9 to 0.95 m at around 15 m of water depth and show a gradual increase towards the shore in all the cases of wave approach (Fig. 3a-c). There is no abnormal increase in the wave height as the maximum wave height occurred is only 1.3 m. The zones of higher and lower wave heights occur almost alternately but with an uneven spacing along this coast. This asymmetric distribution of wave heights give rise to flows along and across the shore. From the regions of high wave energy, water may flow to the areas of low wave energy to maintain equilibrium, thus generating longshore currents. These currents may even flow against the waves when they turn seaward in the areas of divergences as rip currents. The probable longshore/offshore currents generated by refraction of waves/wave height distribution are presented in Fig. 4 for 10 sec period waves for 3 different directions. This qualitative presentation of the alongshore currents clearly shows that the flow system existing along this coast is not a simple one and there must be a number of circulation cells existing along with meandering flows depending on the direction of wave approach. Near sts 4 (Calangute) and 6 (Candolim) there are quasi-permanent zones of rip currents for the waves approaching from WNW and W.

Eventhough these rip current sites are more or less permanent for both the wave directions, the intensity of these rip cells might be different along and normal to the shore. From Fig. 4 it is evident that the rip current zone near st 6 (bc) has a wider spread compared to the one near st 4 (a).

Antony in his wave refraction studies through graphical method along this beach reported that there are certain zones of wave energy concentrations and the longshore currents during a particular season depend mainly on the direction of the predominant waves. He has identified zones of rip currents near Candolim and Baga during monsoon season and also reported that the rip currents near Candolim are active during fair weather season also. Murty et al. through their field observations made in different months using dyes, located several rip zones along this beach. They also have observed that the part of the beach between Calangute and Candolim is more vulnerable to rip currents. Murty and Veerayya while studying the longshore currents and associated sediment transport in the nearshore areas of Kerala and Goa, mainly through wave refraction diagrams, reported a number of cel-
Fig. 3—Wave height distribution for waves approaching from (a) WNW, (b) W and (c) WSW ($P_w = 10$ sec)

Fig. 4—Probable longshore current directions for 10 sec period waves approaching from WNW, W and WSW. Areas near st. 4 (a) and st. 6 (bc) show zones of quasi-permanent rip currents.

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Lular patterns of flows for waves of near normal incidence while meandering flows—either in an up coast or down coast direction—for waves approaching the shore from a direction different from the normal to the shore. In general, these studies reveal the fact that the longshore current directions are highly variable along this coast supporting the present study. The zones of rip currents identified earlier are almost the same as found in this study. But it is noticeable that more number of rips have been observed in this study compared to the earlier studies. The numerical method of wave refraction using computer, followed in this study, is much more precise and reliable compared to the graphical method followed in the earlier studies.

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References


