Coastal Sediment Transport Study between Vembar-Kanyakumari

Nallusamy.R1, Rajamanickam.M2, Thenmolli.K.L3

1Research Scholar, Prist University, Trichy-Thanjavur Highway, Vallam, Thanjavur, INDIA
2Assistant Professor, Center for Geoinformatics, Prist University, Trichy-Thanjavur Highway, Vallam, Thanjavur, INDIA
3Post Graduate Student, Department of Civil Engineering, Prist University, Trichy-Thanjavur Highway, Vallam, Thanjavur, INDIA

ABSTRACT

The longshore current velocities recorded at different stations along the study area are Valinokkam (0.06 to 0.3 m/s), Keelmundal (0.04 to 0.31 m/s), Narippaiyur (0.01 to 0.39 m/s), Kannirajapuram (0.01 to 0.48 m/s), Vembar (0.04 to 0.42 m/s), Pachayapuram (0.12 to 0.40 m/s), Periyasamyapuram (0.11 to 0.44 m/s), Kalaignanapuram (0.02 to 0.38 m/s), Sippikulam (0.03 to 0.50 m/s), Kallurani (0.10 to 0.50 m/s) and Tuticorin (0.02 to 0.34 m/s), respectively. The breaker zone width ranges from 16 to 20 m with maximum during July, October and November (20 m). One can observe the variation of surf zone width from 15 to 22 m with a maximum during April (22 m). One can observe the variation of surf zone width from 15 to 20 m with highest during the months of February, May, November and December (20 m). The waves are approaching the coast predominantly from SE (45°) during SW monsoon, NW (20°) during northeast monsoon. Since the orientation of the shoreline long the study area is in general NS-EW direction, the waves hit the coast between N 110° and N 135° are of greatest significance in conjunction with littoral processes.

Keywords—— Current, Breaker Zone, Surf Zone, Coast, Shoreline

I. INTRODUCTION

The understanding of coastal sediment movement, on a continuing basis, in the nearshore environment is a fundamental for the designing civil structures of shore protection and for navigational plan. It is understood that this circulation of sediment, especially in the surf zone, is driven by complex networking of waves and the essential of prevailing sediments contributing to geomorphological changes of beaches. Predominatly, the alongshore intrinsic of wave energy combined with the real turbulence correlated with breaking waves settle the sediment movement quantitatively. This takes place in two ways: in a zig-zag motion on the beach face in swash-backwash as beach drift and as suspended/bed-load movement in the surf zone. Observation of sediment drift by empirical relationship formulated from quantitative estimates of littoral current by wave refraction research and field and laboratory analysis of the nature of circulation of sediment in the proximity of natural barriers have been made along different coastlines of the different place [1]. Along the coastline of India such quantitative determinations have been worked out different part of world [2][3][4][5][6][7][8][9][10]. The sediment movement along the shoreline of study area is chiefly governed by the forces concord with the incoming waves and the presence of sediments within the area. Generally, the rate and direction of littoral movement of sediment could be considered as a function, dependent on the alongshore component of wave energy and the physical characteristics of the available sediments such as coastal shape, coastal size, specific gravity, etc. This transport of sediments, which is one of the most important processes in the nearshore environment, is a prime tool for coastal zone development and management. The increasing pressure and concern on the preservation of the valuable coastal environments have led to the development of shore protection programmes. Conservation not only demands knowledge of what needs to be done but also requires a thorough check up of the basic processes that operating along the coastal environment. Considering the fragile nature of beaches and intense anthropogenic activities, coastal features have long been a subject of study by coastal oceanographers, marine geologists and engineers. The current investigation has been made to appreciate the sediment movement in associated with wave activity and coastal dynamics along the coast between Valinokkam and Tuticorin.

Waves, Currents and Tides

As the waves, tides and currents commit notably in the recirculation of the sediments to the depositional
basin. Waves are contribute major energy for the circulation of water and sediments within the nearshore zone. The nature of propagation of waves into the shallow region is essential. As the deepwater waves approach the coast, temporal changes in the wave height occurs due to changes in their velocity of propagation. This is known as the shoaling effect. Since the phase velocity is a function of depth in shallow water, when the wave front propagates over the bottom of variable bathymetry, the wave front bends and tries to get aligned to the bottom contours. This is known as the refraction of waves. Refraction causes convergence and divergence of wave energy along the wave crest. As the waveform finally approach the shore, the wave energy gets dissipated through shoaling, refraction, percolation and breaking. Much of this energy loss occurs due to the frictional effects. Knowledge of wave field is a pre-requisite to study the nearshore wave climate along any coastal environment.

II. METHODOLOGY

The waves propagating in shallow water undergo changes in wave height, length, celerity and direction of propagation primarily due to shoaling, refraction and bottom friction. For a given bottom topography and deep-water wave characteristics, the refracted orthogonal can be plotted by geometrical procedures [11] by numerical methods [12]. Numerical wave refraction procedure accessible in [13] was used in the present study. Wave refraction analysis was carried out for waves having period 8 s and 10 s and for the wave direction representing northeast monsoon and southwest monsoon.

LITTORAL SEDIMENT TRANSPORT

The littoral zone is the largest driving environment of the coast and one in which continuously moving of sediment is observed. The movement of coastal sediment in this zone based on three main factors namely: the nature of material present transport (size and density), assimilation of beach and other features of the coast and the angle of wave approach. Littoral transport play a major role in the development of depositional shoreline features like dune, spits and bars, and is contributing considerable coastal erosion and accretion [14]. The proper investigation of the monthly or seasonal littoral sediment transport is crucial for better coastal zone management and development. The longshore sediment transport rate is generally estimated based on empirical equation is used to calculate longshore energy flux in the breaker zone to the longshore transport rate. Many discussions have been carryout on the selection of best mathematical formula for calculating the longshore sediment movement [15][16]. By using the monthly average littoral environmental datas gathered at different locations of the coastal villages, the longshore transport rates are mathematically estimated. The deepwater wave data for the study region is calculated from the wave atlas for the Indian coast published by National Institute of Oceanography, Goa [17][18]. The following Walton and Bruno equation is used to estimate the longshore sediment transport rate.

\[
Q = \frac{1290 \, P \, g \, H_b \, W \, V \, C_f}{0.78 \, (5\pi/2) \, (V/V_o)}
\]

Where

- \(Q\) = longshore sediment transport rate in m³/year,
- \(P\) = mass density of the sea water = 1025 kg/m³,
- \(g\) = acceleration due to gravity = 9.81 m/s²
- \(C_f\) = the friction coefficient \(\approx 0.01\),
- \(H_b\) = breaking wave height in metre,
- \(W\) = surf zone width in metre,
- \(V\) = measured longshore current velocity in m/s,
- \(V/V_o\) = theoretical dimensionless longshore current velocity \(\approx 0.4\) (Languet – Higgins, 1970)

III. RESULTS AND DISCUSSIONS

Currents are monsoonal in character. The currents are varies with related to monsoonoal climate. During SW monsoon (May –October) the currents are bifurcated towards the NE from southeasterly movement that spurt across the entrance of Gulf of Mannar. In NE monsoon season (November to February), the flow is southward which signify mainly southwesterly movement of currents across the Gulf of Mannar [2]. The changes of monsoon have a bearing on the velocity of current and it is found to be variable in the study area. The longshore current velocities recorded at different stations along the study area are Valinokkam (0.06 to 0.3 m/s), Keelmundal (0.04 to 0.31 m/s), Narippaiyur (0.01 to 0.39 m/s), Kannirajapuram (0.01 to 0.48 m/s), Vembar (0.04 to 0.42 m/s), Pachayapuram (0.12 to 0.40 m/s), Periyasamypuram (0.11 to 0.44 m/s), Kalaaignapuram (0.02 to 0.38 m/s), Sippikkulam (0.03 to 0.50 m/s), Kallurani (0.10 to 0.50 m/s) and Tuticorin (0.02 to 0.34 m/s), respectively. It was slighter during the SW monsoon (June to October) and fair weather (March to May).
conditions. Its direction is northerly at the time of fair weather and SW monsoon seasons while towards southerly during NE monsoon period [19]. Wind induced by surface waves are the major source of energy input into the littoral zone. They are carrying the load of erosion of the coast and for the production of depositional beach features. In the present area of investigation wave parameters are contributing the variance in monsoonal cycle. Waves reaching the coast in SE, S and NE directions with wave period from 3 to 10 seconds. The breaking wave height noticed in the study area differ from 0.05 to 0.85 m during SW monsoon period and that of 0.10 to 0.60 m during NE monsoon period. The fair weather indicate the number of 0.05 to 0.50 m of breaking wave height. Due to the change in the wave climate, the surf zone width is varying from station to station. The variation in surf zone width calculated during the course of investigation is presented. At Valinokkam, the surf zone width ranges from 17 to 22 m with maximum during the months of November, December and February (22 m). At Keelmundal, the breaker zone width ranges from 16 to 20 m with maximum during July, October and November (20 m). One can observe the variation of surf zone width at Narippaiyur from 15 to 22 m with a maximum during April (22 m). Kannirajapuram depicts a variation of the surf zone width from 15 to 20 m with highest during the months of February, May, November and December (20 m). At Vembar, the surf zone width shows a fluctuation from 15 to 20 m with a rise up to 20 m during May to July and October to December periods. At Pachayapuram, the surf zone width varies from 14 to 18 m and with a mount during March and October. At Sippikulam, one may able to observe the variation of surf zone width from 14 to 20 m with a maximum during the months of January, April and August (20 m). Kallurani attests a variation in surf zone width from 12 to 18 m with a highest during November (18 m). In the case of Tuticorin, the surf zone width varies from 11 to 14 m with a peak during the months of June and September (14 m).

**Wave Refraction**

The waves from deep water when approach the shore undergo refraction due to variations in bottom topography and break at the coast giving rise to longshore and onshore/off shore flows. An analysis of wave refraction pattern becomes imperative 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 coast. In order to define a refraction pattern, specifics on (i) the orientation of the wave crest, (ii) wave size and (iii) the location of the contour lines that define the under water topography must be understood. The redistribution of wave energy due to refraction can be defined by drawing orthogonal (lines perpendicular to the wave crest) for a group of waves, travelling across the shallow zone. Wave energy is generally, convergent on promontories and divergent in embayment. Along straight coasts, wave energy is more or less evenly distributed. Wave refraction studies are utilised for demarcating the zones of wave divergence and convergence that are related to the littoral drift and sediment dispersion in the near shore region. A study of wave refraction along the beaches between Tuticorin and Valinokkam has been made to investigate the changes that occur in the wave characteristics near the coast as deep-water waves of different periods approach the coast from various directions. The refraction function and directions obtained from the wave refraction diagram have been used to infer the sediment transport pattern along the coast. (Fig. 2, 3, 4, 5, 6 and 7)
Figure 4. Wave Refraction Pattern for SSW Direction in 8 Seconds

Figure 5. Wave Refraction Pattern for SE Direction in 10 Seconds

Figure 6. Wave Refraction Pattern for NW Direction in 10 Seconds

Figure 7. Wave Refraction Pattern for NW Direction in 8 Seconds
IV. CONCLUSION

In the present area of investigation, the wave climate is characterised by the southwest monsoon (June-September), northeast monsoon (October–January) and non-monsoon periods (February–May). The predominant wave directions prevailing in the study region are referred in the wave atlas [3] as SE during SW monsoon and NW during the NE monsoon. As the study area shows a trend of EW-NS orientation, the waves are approaching the coast predominantly from SE (45°) during SW monsoon, NW (20°) during northeast monsoon. Since the orientation of the shoreline along the study area is in general NS-EW direction, the waves approaching the coast between N 110° and N 135° are of greatest significance in conjunction with littoral processes. Refraction diagrams have therefore been prepared for wave periods of 8 and 10 seconds approaching from N 110° and N 135° by following the Tarangam Programme. This programme was developed in the National Institute of Oceanography, Goa, on the basis of finite amplitude wave theory for computing the wave transformation factors [20]. The naval hydrographic chart [21] was used to assess the water depth at a point for drawing bathymetric contours. The wave refraction diagram for N 110° for periods of 8 and 10 seconds is presented in Fig. 6. In the refraction pattern of 8 seconds, convergent zones are noticed at Valinokkam, Mukkaiyur, Periyasamypuram and Kalaignanapuram areas. The remaining locations are noticed by low energy conditions. The refraction pattern of 10 seconds shows almost a similar behaviour with 8-second pattern. At Valinokkam and Mukkaiyur, the convergence of waves indicates the erosion of sediments from the nearshore zone. This depicts a low-energy environment with accumulation of beach materials.[22][23]. The coastal stretches between Vembar and Kallar (Vaippar zone), there are zones of low energy environment in conjunction with cell of high-energy conditions can be noticed (Fig. 5). This fluctuation in the energy conditions attests the presence of erosion and deposition in the same season. The higher energy condition is also corroborated with the spread of appreciable heavy minerals. At Tuticorin zone the divergence of wave rays is well understood from the analysis that assigns the depositional activities along the coastal stretch. Anthropogenic features such as the presence of harbour could be a possible reason for the continuous accumulation of sediments. As a result of accretion processes, the beach segment is discernible with shelly sands.[24] The figures (6) display the wave refraction pattern for N 110° (NE monsoon) wave directions for 8 and 10 second wave periods. In the wave period of 8 second, Valinokkam, Mukkaiyur, Narippaiyur, Kannirajapuram, Kalaignanapuram and Tuticorin (Fig. 5 and 6) show divergence of wave orthogonal whereas Keelmundal, Vembar, Periyasamypuram and Sippikulam depict zone of convergence. However at Kallar and Taruvaikulam one could not find the significant energy changes rather the shoreline stays in an inept condition (Fig. 8). For the same direction the pattern of 10 second period indicates a strong convergence at Keelmundal, Periyasamypuram and Sippikulam while a strong divergence is seen at Valinokkam, Mukkaiyur, Kannirajapuram, Kalaignanapuram, Taruvaikulam and Tuticorin. But in Narippaiyur, Vembar and Kallar display an inept condition during NE monsoon. (7) The circulated of waves energy from convergence to divergence in a particular station in different wave periods has been endorsed to the change in the quantum of sediment movement from one period to the other [25]. This has also been confirmed through the study of beach morphodynamics along the coastal stretch.

REFERENCES


