

# EFFECT OF VISAKHAPATNAM HARBOUR STRUCTURES ON THE LITTORAL ENVIRONMENT

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## A B S T R A C T

The Visakhapatnam outer harbour was constructed in 1975. From March to September of the year, about  $0.45 \times 10^6 \text{ m}^3$  of sediment is being dredged from the sand trap on the updrift side of the harbour and bypassed on to the downdrift side of the harbour to replenish the sand lost from the beach and to prevent erosion on the downdrift Visakhapatnam beach. This paper contains the results of beach profile studies indicating the effect of beach nourishment on the stabilization of the Visakhapatnam beach. Longshore transport rates were computed using different empirical formulae and the results were compared with field observations and dredging records. Studies carried out along the beaches on either side of the harbour, revealed that the Visakhapatnam beach on the north of the harbour was eroding whereas the Yarada beach on the south of the harbour was accreting indicating that the quantity of the bypassed material is not adequate to keep the beach in stable equilibrium. An additional volume of about  $10^5 \text{ m}^3$  would be required annually to keep the Visakhapatnam beach in a state of dynamic equilibrium.

## I N T R O D U C T I O N

### Location and Geomorphology

Visakhapatnam is situated at latitude  $17^{\circ}41'34'' \text{ N}$  and longitude  $83^{\circ}17'45'' \text{ E}$  on the east coast of India, approximately mid-way between Calcutta and Madras. It is the second largest port city in the country having commercial and strategic importance. Visakhapatnam harbour is situated in the Meghadrigedda river estuary. The commissioning of the outer harbour as well

as the fishing harbour has spurred fishing and commercial activities at Visakhapatnam. The coastal zone in the vicinity of the harbour has not only provided necessary impetus for the development of a big township but also provided scope for enhanced fishing and recreational activities. A large shore-based steel plant is under construction at about 10 km south of Visakhapatnam adding further importance to this part of the coastal zone.

The shoreline at Visakhapatnam aligns in a north-east and southwest direction (Fig. 1). The coast here is comprised of promontories, rocky outcrops and plains interspersed with pocket beaches. Bight-like formations, one called Uppada Bay and another called Lawson's Bay exist on the north of Visakhapatnam at a distances of 21 km and 6 km respectively. About 10 km south of Visakhapatnam harbour there is a bay formation called Gangavaram Bay. Dolphin's Nose Hill partly protects the entrance channel of the Visakhapatnam harbour (Fig. 1). The shoreline between the fishing harbour and the Kailasa Hill range consists of sandy beaches with rocky protrusions at a few places interrupting the normal littoral drift. Isolated rocky outcrops can also be observed in the surf-zone at a few locations. On the north of the fishing harbour, opposite to the Nature Cure Hospital, general erosion conditions prevail. It is observed that during the most part of the year, the waves break over the revetment wall protecting the coastal road. On the southern side of the harbour, there is a small hillock called Red Hill protruding into the sea. Beach sediments in this region is characterised by medium to fine sand composed mostly of quartz with traces of Magnetite and Ilmenite. The hills in this area are composed of Khondalites and charnockites. Sandy soils are present in the plains along the shoreline. The width of the continental shelf in this region varies between 35 to 40 km (Rao, Machado and Moorthy, 1980). Between Kutukonda and Uppada, the bottom topography upto a depth of 40 m deepens at a fairly rapid rate with an average gradient of 1 : 140. Between 40 m and 70 m depth, the ocean bottom is almost flat. The shelf edge occurs at about 130 m depth.

### History of Development

Earlier to 1933, a limited volume of sea trade was carried out by means of lighters plying between the shore and ships anchored offshore. In 1933, the harbour outer channel was dredged to a depth of about 8 m. The problem of maintaining the dredged depth became difficult because of large northerly littoral drift prevailing along this region. To prevent the silting of the entrance channel and the erosion of the shoreline north of the entrance channel, an island breakwater of about 300 m length on the southern side of the entrance channel was constructed by grounding two old merchant ships. They were filled with sand, boulders and concrete and the sides were

protected by boulders. This breakwater was so aligned as to allow the littoral drift to pass through the gap between it and Dolphin's Nose Hill and to settle in a sand trap in the lee of the breakwater, where a dredger could operate during most part of the southwest monsoon season. Part of the dredged material was discharged by means of a floating pipeline to the north of the entrance channel, thus maintaining the continuity of littoral drift and the remainder was hopped to the dumping grounds. This breakwaters made of two rock filled sunken ships caused erosion along the Visakhapatnam beach (Lafond and Prasade Rao, 1954). Over the years the volume of cargo handled at Visakhapatnam Port has gradually increased. In order to provide the additional berthing and loading facilities, an outer harbour was developed in 1975 by the construction of long breakwaters as shown in Fig. 1. The south breakwater about 1500 m long extends upto 18 m water depth and is detached from the shore to form a sand trap. The east breakwater of about 1000 m length constructed at about 8 m water depth functions as an offshore breakwater. A groin connects this breakwater at the mid-section to the shoreline. Further on the north, a small breakwater has been constructed for the development of a fishing harbour (Fig. 1). To reduce erosion and stabilize the Visakhapatnam beach, about  $0.45 \times 10^6 \text{ m}^3$  of sediment is being bypassed by pumping the sediment from the sand traps on to the southern side of the harbour.

#### Climat and Nearshore Oceanography

The climate of Visakhapatnam is dominated by the monsoons and cyclonic storms which divide the year approximately into four seasons (Ince and Jamieson, 1974). (i) The northeast monsoon from end of November to February with predominantly northeasterly winds. (ii) The premonsoon period from March to mid May when the winds shift to southwesterly direction and frequent cyclones occur. (iii) The southwest monsoon from mid May to mid October with predominantly southwesterly winds, and (iv) The post-monsoon period from mid October to end November with variable weather and occurrence of frequent cyclones. The average rainfall in this region is about 975 mm. During the southwest monsoon the rainfall is about 500 mm and during the northeast monsoon it is about 370 mm. The cyclonic storms generated in the Bay of Bengal during the northeast monsoon often increase the intensity of rainfall in this region. The atmospheric air temperature varies from 19°C to 33°C in an year.

In general, waves approach from south during March to September and from east during December to February. October to November is the transition period during which the wave direction changes from south to east. From January to April, sea is usually calm with the average wave heights not exceeding one metre. From May to September during southwest monsoon, sea becomes rough, with the average wave heights varying between 1

and 3 m. From October to December, the sea remains calm other than cyclonic days when the wave heights even exceed 5 m. Wave periods vary from 6 to 12 sec. However, for the greater part of the year, it persists between 8 and 10 sec.

#### DETAILS OF STUDY

Sixteen stations on the northern side and eight stations on the southern side of the harbour were established and monthly beach level variations were observed for about 14 months from January 1978 to February 1979 (Chandramohan, Narasimha Rao and Panakala Rao, 1981). The annual longshore transport rate was computed using the following two longshore energy flux formulae (Shore Protection Manual, 1975).

$$Q = 7500 \times \frac{\rho g^2}{64\pi} T (H_o K_R)^2 \sin 2 \alpha_b \dots\dots (1)$$

$$Q = 7500 \times 20.5 \times T H_o^2 \sin \alpha_b \sin \alpha_o \dots\dots (2)$$

where,

- $\rho$  = density of sea water in lb/ft<sup>3</sup>
- $g$  = acceleration due to gravity in ft/sec<sup>2</sup>
- $H_o$  = deepwater wave height in feet
- $K_R$  = refraction coefficient
- $\alpha_b$  = breaker angle
- $\alpha_o$  = deepwater wave angle
- $T$  = wave period in sec
- $Q$  = Annual longshore transport rate in cubic yards.

The monthly average wave height, period and direction (Table 1) compiled from the ship observations reported in the Indian Daily Weather Reports were used for computing the longshore transport rates.

#### RESULTS AND DISCUSSION

The variation in beach sediment volume shows that the depositional and erosional conditions along this region differs from place to place. This could be expected because of the undulating shoreline with a number of rocky promontories acting as littoral barriers in the area as described previously. In general, a major part of the beach undergoes erosion during southwest monsoon and deposition during northeast monsoon and calm weather period. Typical beach level variations near stations 9 and 11 are shown in fig. 2. It is quite interesting to note that the beach levels at station 9 undergo erosion in northeast monsoon and deposition in southwest monsoon, whereas it is reversed at station 11.

From the analysis of beach profiles, it was observed that the total volume of sand subjected to beach changes is about  $0.92 \times 10^6 \text{ m}^3$  in between Kailasa Range Hill and fishing harbour (called Visakhapatnam beach) and  $0.46 \times 10^6 \text{ m}^3$  in between Dolphins Nose Hill and Yarada Konda Hill (called Yarada beach). During the annual cycle, with reference to the minimum beach level the Visakhapatnam beach had the least quantity of sand of  $0.24 \times 10^6 \text{ m}^3$  in August and the largest quantity of sand of  $0.63 \times 10^6 \text{ m}^3$  in March. On the other hand, the Yarada beach had the lowest quantity of sand of  $0.15 \times 10^6 \text{ m}^3$  during September and November and the largest quantity of sand of  $0.34 \times 10^6 \text{ m}^3$  during March to May.

Using the longshore energy flux formula (1), the annual longshore transport rate is  $0.94 \times 10^6 \text{ m}^3$  towards northeast during March to September and  $0.28 \times 10^6 \text{ m}^3$  towards southwest during October to February. The net longshore transport is towards northeast and it is about  $0.66 \times 10^6 \text{ m}^3$  in a year. The quantity of monthly transport rate is shown in Fig. 3. The longshore energy flux formula (2) shows that the annual longshore transport is  $0.81 \times 10^6 \text{ m}^3$  towards northeast during March to September and  $0.26 \times 10^6 \text{ m}^3$  towards southwest during October to February. The net longshore transport is towards northeast and is about  $0.55 \times 10^6 \text{ m}^3$  in a year.

Saxena, Vaidyaraman and Srinivasan (1976) reported that along the Visakhapatnam region the net littoral drift is about  $0.70 \times 10^6 \text{ m}^3$  with a predominantly northerly drift of  $0.63 \times 10^6 \text{ m}^3$  during the southwest monsoon and a southerly drift of  $0.18 \times 10^6 \text{ m}^3$  during the northeast monsoon. Ince and Jamieson (1974) reported from the extensive dredging records maintained by the Visakhapatnam Port Trust (1941 to 1965), the mean northerly drift was about  $0.55 \times 10^6 \text{ m}^3$  and the mean annual southerly drift was about  $0.12 \times 10^6 \text{ m}^3$ . The average annual net drift was estimated to be about  $0.43 \times 10^6 \text{ m}^3$  towards north. The values estimated by the authors using the longshore energy flux formulae are found to be somewhat higher than the values reported by Ince and Jamieson (1974).

The pattern of longshore transport indicates that during the southwest monsoon and calm weather period the Yarada beach accretes and the Visakhapatnam beach erodes whereas during northeast monsoon period the conditions are reversed. Considering the net drift in an annual cycle, accretion conditions prevail at Yarada beach and erosion conditions prevail at the Visakhapatnam beach.

During the period of study it is noted that the Yarada beach experienced an annual net accumulation of about  $12,000 \text{ m}^3$  of sand (Chandramohan, Narasimha Rao, Panakala Rao and Prabhakara Rao, 1984). During the same period of time, the Visakhapatnam beach on the downdrift side experienced a net annual loss of about  $75,000 \text{ m}^3$  of sand (Chandramohan, Narasimha Rao and Panakala Rao, 1981). Chandramohan (1982) reported based on the mathematical model studies that the Yarada beach is showing net

accretional trend whereas the Visakhapatnam beach indicates net erosional trend. The predicted shoreline for the present bypassing rate in the vicinity of the harbour breakwaters using the mathematical model is shown in Fig. 4. This study shows that the Yarada beach is in accretional trend thereby causing reduction in sediment supply to the downdrift Visakhapatnam beach. It may be observed here that the sediment bypassing rate to the Visakhapatnam beach can be increased by an additional amount of  $0.10 \times 10^6 \text{ m}^3$  (Chandramohan, 1982) for stabilizing the downdrift Visakhapatnam beach. This is not likely to have any adverse effect on the Yerada beach.

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**TABLE 1****Monthly Average Wave Characteristics**

<b>Month</b>	<b>Wave height (m)</b>	<b>Wave period (sec)</b>	<b>*Wave direction (deg)</b>
<b>January</b>	0.50	8	- 60
<b>February</b>	0.65	8	- 60
<b>March</b>	0.60	8	15
<b>April</b>	0.75	8	30
<b>May</b>	1.20	8	45
<b>June</b>	1.00	8	75
<b>July</b>	1.00	8	60
<b>August</b>	1.20	8	60
<b>September</b>	0.90	8	60
<b>October</b>	0.80	8	- 15
<b>November</b>	0.90	8	- 60
<b>December</b>	0.60	8	- 75

\* (+) Sign indicates angles clockwise to the cost

(-) Sign indicates angles anticlockwise to the cost.

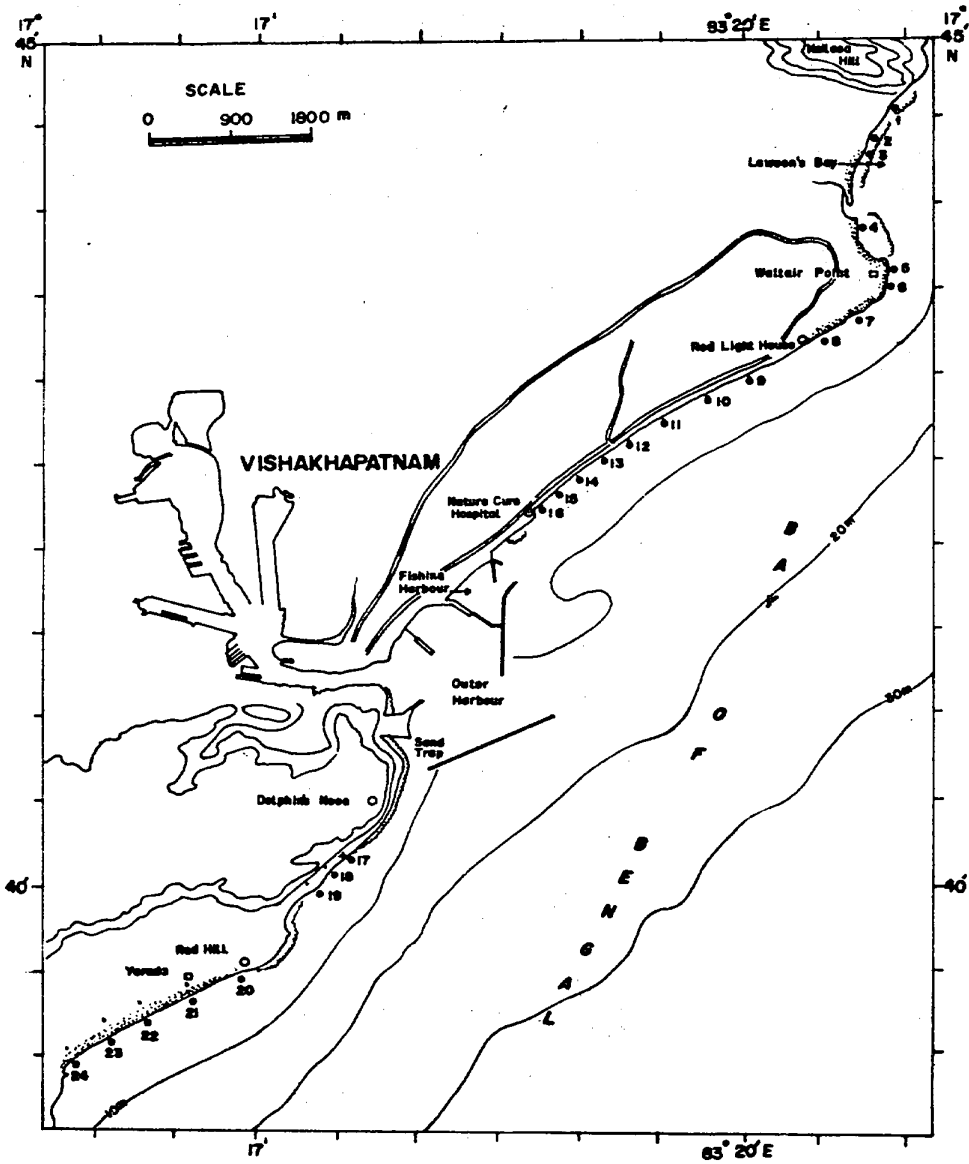


Fig.1. Location map of Vishakhapatnam.



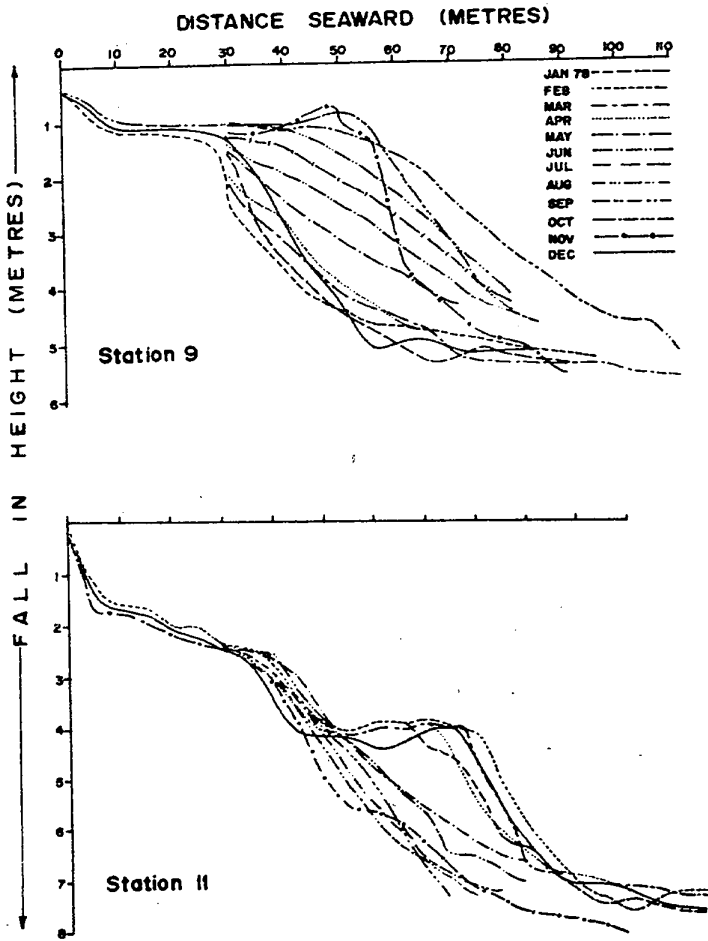


Fig.2. Changes in beach level.

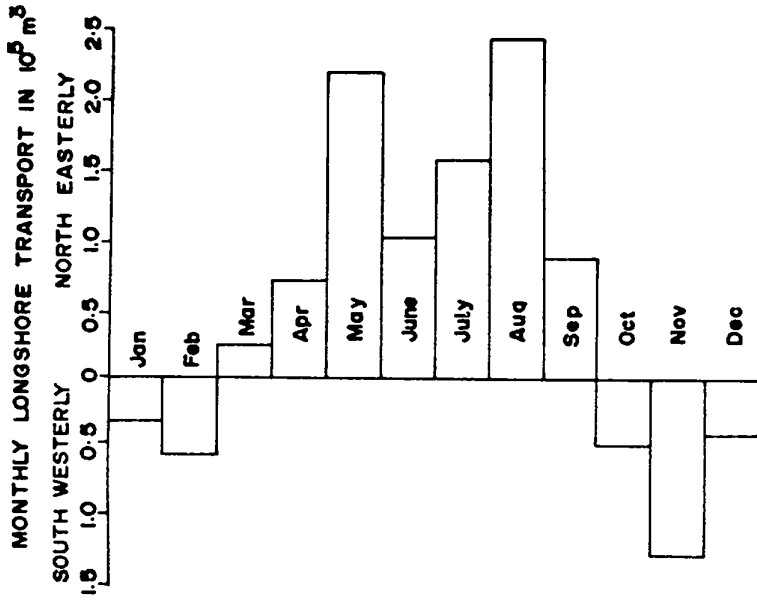


Fig. 3. Monthly distribution of longshore transport.

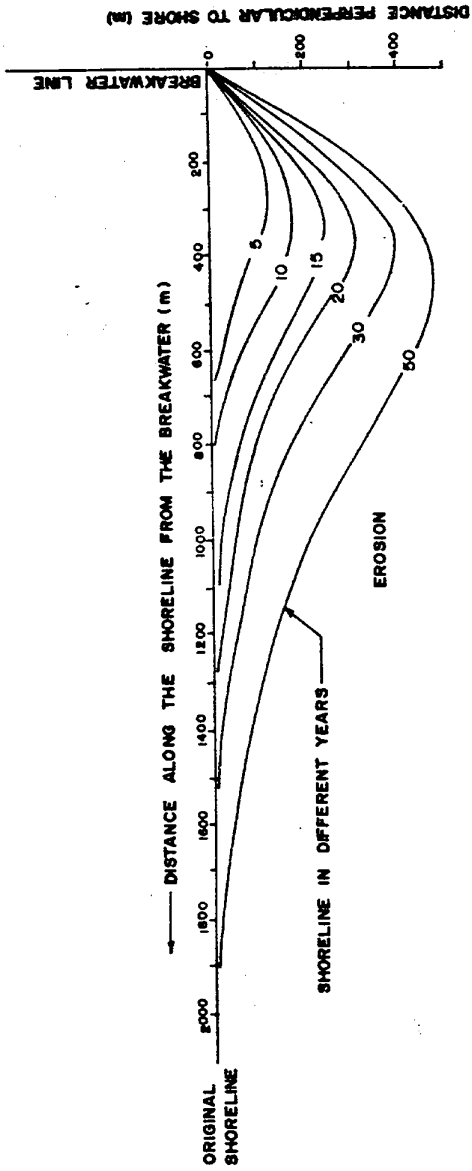


Fig. 4. Predicted shoreline along Visakhapatnam beach for present bypassing rate.