

# WAVE REFRACTION IN RELATION TO BEACH STABILITY ALONG THE COAST FROM CAPE RAMAS TO KARWAR!

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## ABSTRACT

Results of wave refraction and beach profile studies are presented for a stretch of 35 km shoreline comprising of Loliem beach which is separated by rock promontories from comparatively stable beaches on either side of it. The study reveals three distinct phases in the annual cycle of the Loliem beach: (i) erosion from mid-May to August, (ii) deposition from September to November, and (iii) a comparatively stable period from December to May. There is a maximum sand cover during the month of April about 2 m thick. By the end of June most of the sand cover is removed, exposing the rock substratum. For waves approaching from  $240^\circ$ , Loliem forms a region of diverging littoral currents for all periods, whereas those approaching from  $270^\circ$  with 5 and 8 sec periods cause southerly transport. Higher period waves, however, for the same direction produce divergence. When the wave direction is  $300^\circ$ , only 5 sec waves are found to cause uniform southerly transport while all the other periods give rise to diverging littoral currents. No waves are seen to produce converging littoral currents at Loliem.

## INTRODUCTION

The climate of west coast of India is characterised by the monsoonal alterations of the wind systems and the associated wind waves which give rise to interesting variations in the sediment transport pattern along the coast. Several authors have studied the general pattern of sediment transport along the west coast of India using wave refraction diagrams (Das et. al. 1966, Reddy and Varadachari 1972, Antony 1976). The present paper deals with the wave refraction and littoral transport along a 35 km stretch of shoreline on the central west coast of India from Cape Ramas to Karwar which is characterised by the Loliem beach separated by rock promontories from comparatively stable beaches on either side of it.

Waves approaching a shoreline at an angle undergo refraction due to variation in water depths. However, though the waves tend to become parallel to the coastline as a result of refraction, they more often than not approach and break at an angle to the

shore causing a longshore or littoral transport of water and suspended material. The bottom topography, direction of the deep water wave approach and wave periods determine the pattern of the wave front in shallow water. The result of wave refraction is a change in wave height and direction besides the generation of littoral currents. Littoral currents also occur between the regions of convergence and divergence of wave energy caused by wave refraction (King, 1959; Johnson, 1956). Sediment movement along any given stretch of open coast is governed by the forces associated with waves, the availability of sediment for movement and the physical characteristics of the beach material. As much as 80% of the sediment transported by wave action takes place in the area shoreward of the breaker zone (Mason, 1953) and is mainly due to the littoral currents combined with the agitating action of the breaking waves (Grant, 1943). This sediment movement takes place either in suspension or by rolling a zig-zag motion along the beach face (Johnson, 1919; Saville, 1950).

REGION OF STUDY

The shoreline from Cape Ramas to Karwar is mostly sandy with a few rock outcrops near Cape Ramas and Loliem point (fig. 1). There are a few small islands between Loliem point and Karwar. North of Loliem, two riverlets join the sea at Mashem and Talpona. There are a number of beaches in this region and of these, three beaches, near Loliem point are relevant to the present study. The Loliem beach is about 600 m long and has a maximum width of about 40 m. On either side of the Loliem beach is a rocky promontory which extends about 200 m into the sea. The beach is backed by a high rocky plateau, which has a coconut grove on its seaward slope. A small stream at the southern end of the Loliem beach cuts a channel across the beach during the post-monsoon months. The Talpona beach, north of Loliem, is comparatively stable and extensive. To the south of Loliem is the Polem beach which is also comparatively stable.

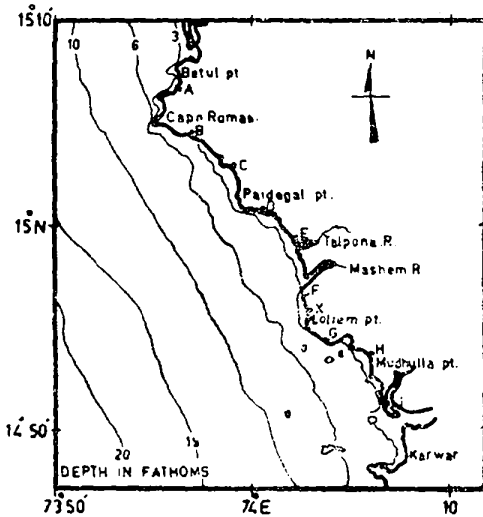


Fig. 1 Map showing Region Under Study.

METHOD OF STUDY

(a) Waves:- The waves that commonly impinge on a coastline and cause sediment movement are the swell waves. Hence swell statistics have been evaluated from the ship observations reported in the Daily

Weather Reports of the India Meteorological Department for the 3° grid between 14°-17° N and 72°-75° E for the years 1971-1973. Table I gives the monthly variations of the percentage frequencies of direction, period and height for this 3° grid. Wave statistics thus obtained are taken as representative deep water wave characteristics for the purpose of the present study.

(b) Wave refraction:- The predominant deep water directions of wave approach to the shore in this region are 240°, 270°, 300° and 330°. There is a negligible percent (1%) of waves approaching the coast from 180° and 210°. The predominant periods range from 5 secs to 14 secs. Hence wave refraction diagrams have been prepared using the method of Arthur, Munk and Isaacs (1952) for the deep water wave directions and periods listed below.

Direction (degrees)	Periods (Sec)
300	5,8,10,12,14
270	5,8,10,12,14
240	5,8,10,12,14

Wave refraction diagrams have been drawn using bathymetric charts corrected upto 1953. The refraction functions along the 3.5 m line have been evaluated following the method of Pierson, Neumann and James (1955) for the 9 stations A to I whose locations have been shown in Fig. 1. The directions of the littoral currents have been obtained by noting the angle between the wave orthogonal and the shoreline. Fig. 2(a-c) gives the directions of the littoral currents while Fig. 3 gives the variation of the refraction function along these stations for the various directions of approach and periods of waves studied.

(c) Beach studies:- Monthly observations of the profile changes of the Loliem beach were carried out at station X (fig. 1), using the standard method of two graduated poles. The profiles are represented in fig. 4 (a & b). Using these profiles the monthly changes in volume of sand per unit length (one meter) of the beach has been calculated and depicted in fig. 5.

RESULTS AND DISCUSSIONS

The energy concentration in the wave front is directly proportional to the wave height at the shoreline. Most of the energy released when waves break near the shore results in the churning up of the sediments.

A small part of the energy is used to generate longshore currents. From the longshore current velocities that have been calculated using the theoretical formula derived by Inman and Bagnold (1963), the known settling velocities for various grain sizes (Graf 1971) and the grain size distribution obtained from the analysis of sand samples collected from Cape Ramas to Karwar, it is seen that for breaker heights less than about 1.25 m no appreciable amount of sediment is carried by the littoral currents and sediment already in suspension is deposited. The sediment movement is found to be only a rolling zig-zag motion on the beach face resulting in a very slow along-shore movement. For breaker heights greater than about 1.4 m an appreciable amount of sediment is carried away by littoral currents. Convergence of littoral currents leads to localisation of sediment in suspension giving rise to deposition. The breaker heights are approximately given by  $RH_0$ , where  $R$  is the refraction function and  $H_0$  is the mean deep water wave height. Thus the shoreline stability during a year can be studied using the wave statistics (table I), littoral currents (fig. 2a — 2c) and refraction functions (fig. 3). In the case of deep water waves approaching from  $330^\circ$ , the littoral currents are directed towards south all along the coast under study and the refraction functions are all less than

1.0. The erosional and depositional characteristics of the beaches under study will be discussed below.

(a) December and January: The predominant direction of wave approach is  $330^\circ$  and mean deep water wave height is about 1.4 m, the refraction functions along the 3.5 m line are of the order of 0.75. Thus the breaker heights being less than 1.25 m there is not much churning of beach material. No deposit can be expected at the regions of converging littoral currents due to absence of sediments in suspension. Thus the beaches show neither erosion nor deposition.

(b) February and March: The direction of waves approaching the shore is  $330^\circ$  and  $300^\circ$ . The predominant period is 5 sec and mean deep water wave heights are 1.5 m in February and 1.0 m in March. The littoral current is southerly as seen from fig. 2 c. Thus in February, there is a slight erosion at stations A and D the breaker heights being 1.4 m and the sediment carried away by littoral currents gets deposited at stations E, F, G, H and I leading to a slight build up of beaches in these localities, the breaker heights being about 1.2 m. In March, the breaker heights being less than 1.0 m, the beaches along the coast show no erosion or deposition.

Table—I

Percentage frequencies of Swell waves in the  $3^\circ$  grid ( $72^\circ$  —  $75^\circ$  E and  $14^\circ$  —  $17^\circ$  N).

Month	Direction W. r. t. N					Period in secs					Height in m.					
	0° —	210°	240°	270°	300° 330°	5	8	10	12	14	0.5	1.0	2.0	3.0	4.0	5.0
January	76	—	—	6	18	35	29	—	12	24	13	50	25	12	—	—
February	33	—	—	25	42	83	—	8	8	—	17	33	42	8	—	—
March	36	—	11	21	32	94	—	6	—	—	47	32	21	—	—	—
April	25	—	13	25	37	63	13	19	—	—	50	31	13	6	—	—
May	5	13	30	26	26	57	22	9	9	4	4	35	57	—	—	—
June	—	38	48	14	—	29	43	24	—	5	—	—	15	35	20	30
July	10	29	48	13	—	48	35	10	6	—	—	3	32	42	10	13
August	8	33	46	13	—	38	38	21	4	—	—	—	32	32	32	5
September	4	22	26	35	13	45	36	—	5	14	8	35	48	9	—	—
October	37	9	36	18	—	36	27	18	—	18	36	9	55	—	—	—
November	64	—	12	—	24	59	6	12	—	24	18	41	41	—	—	—
December	56	—	—	—	44	69	13	—	—	19	6	50	44	—	—	—

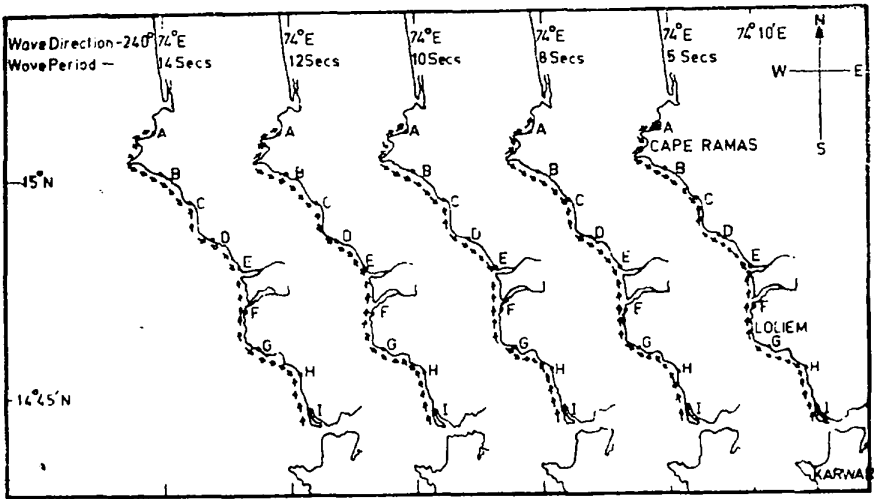


Fig. 2a Littoral transport for waves approaching from 240°

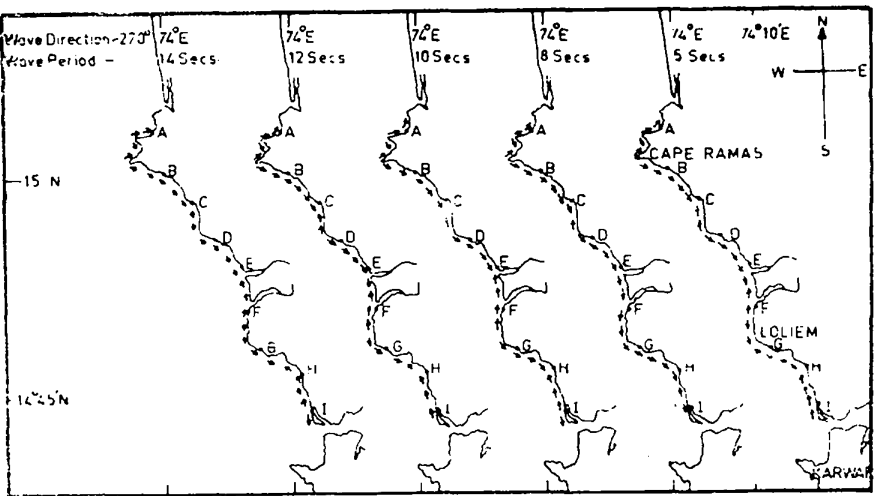


Fig. 2b Littoral transport for waves approaching from 270°

(c) April: The predominant wave periods are 5.8 and 10 secs, while the wave directions are 330° and 300°. Mean deep water wave height is 1.0 m. The littoral currents are southerly with a few regions of convergence and divergence as seen from fig. 2c. The 10 secs. waves with a direction of 300° give rise to breaker heights of 1.4 m at D, leading to erosion of sediment which is deposited at E where the littoral currents converge. At all other places along the shore there is no erosion or deposition.

(d) May: Predominant wave directions are 270° 300° and 330° while wave periods are 5 and 8 secs. The mean deep water wave height is 1.5 m. Erosion would therefore be reasonably expected at all stations, the breaker heights being greater or equal to 1.4 m. However, the convergence of littoral currents at C, H and in between E and F tends to negate this erosional tendency. The divergence at F aggravates the erosion, especially, towards the end of the month when the waves with a direction of 270° begin to become very frequent.

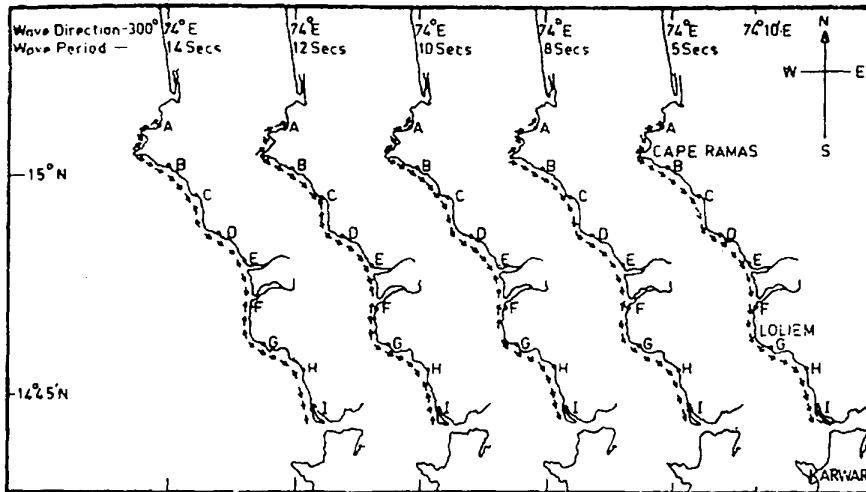


Fig. 2c Littoral transport for waves approaching from  $300^\circ$

(e) June, July and August: While the predominant wave directions are  $240^\circ$  and  $270^\circ$ , the wave periods are mainly 5, 8 and 10 secs. The mean deep water height is 3.5 m in June and 3.0 m in July and August. All along the shore there is severe erosion. At C and E, however, converging littoral currents prevent excessive erosion. At D, the erosion will be fairly low due to the low R value while at F, divergence of littoral currents will increase erosion inspite of the relatively low R value. The littoral current pattern is complex as is seen in fig 2a and 2b.

(f) September: Wave directions of  $240^\circ$ ,  $270^\circ$  and  $300^\circ$  and wave periods of 5, 8 and 14 secs are most frequent. The mean deep water wave height is 1.6 m. There is convergence of littoral currents at C, H and in the region from E to F fig. 2a, 2b & 2c. These convergences will nullify the erosional effect of the waves, which give rise to breaker heights greater than 1.4 m. Thus all along the coastline there is erosion except at C, H and the region between E and F where there is deposition.

(g) October: The directions of the waves approaching the shore are  $270^\circ$  and  $300^\circ$ , while the predominant wave periods

are 5, 8, 10 and 14 secs. The mean deep water wave height is 1.40 m. The erosional effect of waves is less than in September and there is a greater rate of build up of the beaches in the region of convergences. However at F the littoral convergence is weakened appreciably due to the absence of waves with a direction of  $240^\circ$ . Thus at F the rate of deposition will be lower than in September.

(h) November: The predominant wave periods are 5, 8 and 14 secs while wave directions are  $270^\circ$  and  $330^\circ$ . The littoral drift will be mainly southerly with a few weak convergences due to the waves from the west ( $270^\circ$ ). The mean deep water wave height is 1.30m. The low R value at D, E and F and convergences at C and H result in deposition of sediment at these stations. The sediment will be mainly from B and G where there will be strong erosion.

A close scrutiny of the results from wave refraction studies on the shoreline stability at E, F, X and H shows a very good agreement with the beach profile studies carried out at these stations. A study of the beach profiles at X Fig (4a & b) and the graph showing the change in volume of sand per metre of the beach Fig (5) reveals

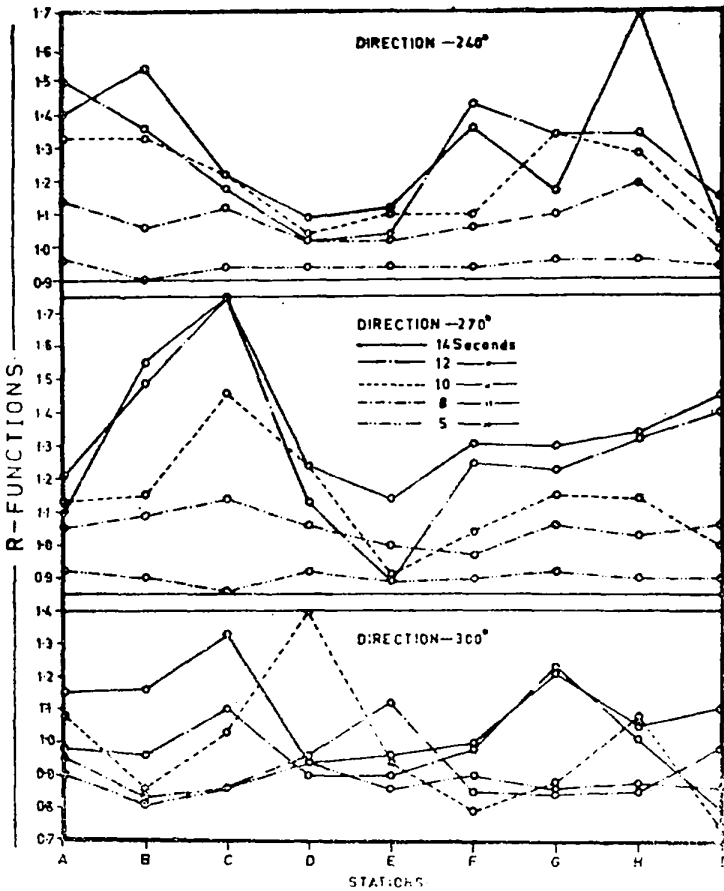


Fig. 3 Variation of Refraction function from Cape Ramas to Karwar.

three distinct phases in the yearly cycle of the beach. (i) Erosion from mid-May to August, (ii) deposition from September to November and (iii) a comparatively stable period from December to May. There is a maximum sand cover during the month of April. From mid-May the erosional forces become active and by the end of June most of the sand cover has been removed exposing the rocky substrata to the wave action. The depositional forces start in the beginning of September and gradually the beach builds up till by December there is once more a 40 m wide strip of sand. The depositional forces gradually weaken from September to November. Erosion and deposition does take place from December to

May, but on a very small scale compared to the months of June to October. In contrast, the two beaches (E and H) north and south of Loliem show small fluctuations in their sand cover over a one year period. Both the beaches are extensive in length as well as breadth. The beach to the south at Polem (H) does, however, show more erosion than at E during the monsoon.

#### ACKNOWLEDGEMENT

The authors are grateful to Dr. S. Z. Qasim, Director, National Institute of Oceanography for his keen interest in the study. Thanks are also due to Dr. V.V.R. Varadachari, Deputy Director, National Institute of Oceanography for his guidance and for

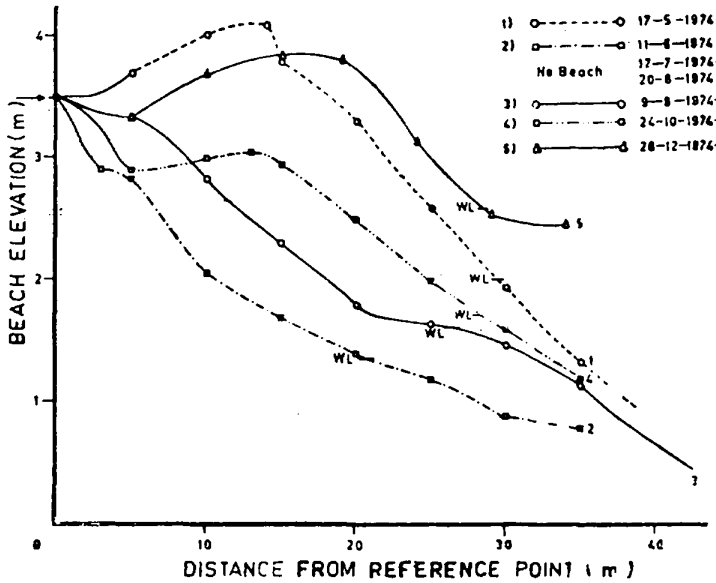


Fig. 4a Beach profiles at Lollem (May to December, '74)

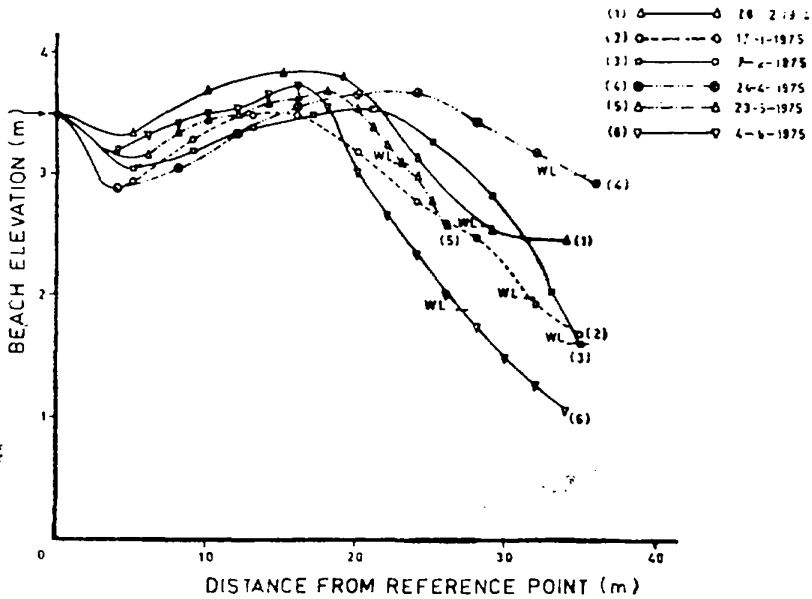


Fig. 4b Beach profiles at Lollem (December '74 to June '75)

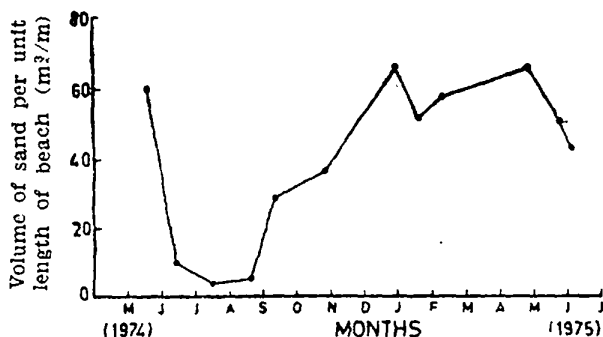


Fig. 5 Monthly variation of volume of sand per unit length of Beach at Lollem.

critically going through the manuscript. The studies were carried out as a part of a project sponsored by the Government of

Goa, Daman and Diu. The financial assistance provided by the Goa Government is gratefully acknowledged.

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