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ASSESSMENT ON PERFORMANCE OF MODIFIED LONG SHOALS AT ENNORE

P. Subramanian [1], J.S. Mani [2] and K.M. Sivakholundu [3]

***Abstract**: The ecologically sensitive Ennore coast has distinct morphological characteristics; the long shoals oriented along the northeast direction acts as natural defense systems and contribute in protecting the coast from normal wave conditions. The construction of Ennore port has intercepted the free flow of long shore sediment transport, resulting in the erosion on down drift side, necessitating the need for immediate attention to safe guard the coast. The present study emphasized on geotubes and submerged reefs for their viability to cause wave dissipation and thus reduce energy which in turn will contribute in shore line stabilization. Results show that, the wave fields in the presence of the submerged structure and for the existing shoal configuration are almost same. The wave field simulated in the presence of wide low crested reef indicates that, the transmission coefficient, K_t reduces by 40 to 60% when compared with the performance of the geotube structure.*

Keywords: long shoals; geotubes; wide low crested reef; transmission coefficient

INTRODUCTION

Human intervention in the natural coastal processes has definitely produced an impact on the shoreline. To mention a few of them, the hot water discharges into the ocean, thermal and radioactive pollution, dredging, coastal construction and mining etc., have definite impact on the coastal equilibrium. In addition, construction of coast connected structures has resulted in coastal erosion resulting in loss of (i) valuable beaches, (ii) coastal agricultural lands, (iii) recreational facilities and (iv) natural habitats. Due to increase in man made activities along the coastal region, the natural recourses along the coast have started depleting, necessitating the need for immediate attention to safe guard the coast from these threats.

Submerged structures can be adopted to control wave transmission which in turn will contribute in shore line stabilization. Most important parameters in controlling the wave transmission are obviously the height of the structure and the water depth. One such attempt has been made in the present study involving a submerged structure. The main function of the structure is to protect the leeward area from the severe wave actions, by attenuating the waves

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passing over the structures. Submerged geotubes dissipate some of the incoming wave energy by causing the waves to break over the structure, thus reducing the transmitted wave energy. The structure traps the sediment entering into the protected zone, on the leeside, enhancing the beach building process.

Objectives of the present numerical model study are

(i) to determine the wave characteristics over existing long shoals and its influence on wave transmission.

(ii) to determine the change in wave characteristics in the presence of a submerged geotube structure and its influence on wave transmission.

(iii) to predict wave field for wide low crested reef and its influence on wave transmission.

STUDY AREA

Ennore coast is located at 13º 14´ N and 80º 20´ E, 17km north of Chennai. Fig.1 shows the Ennore coast along with natural and man made features. Construction of Ennore Port has caused erosion on the northern side of the port and accretion on the southern side of the port.

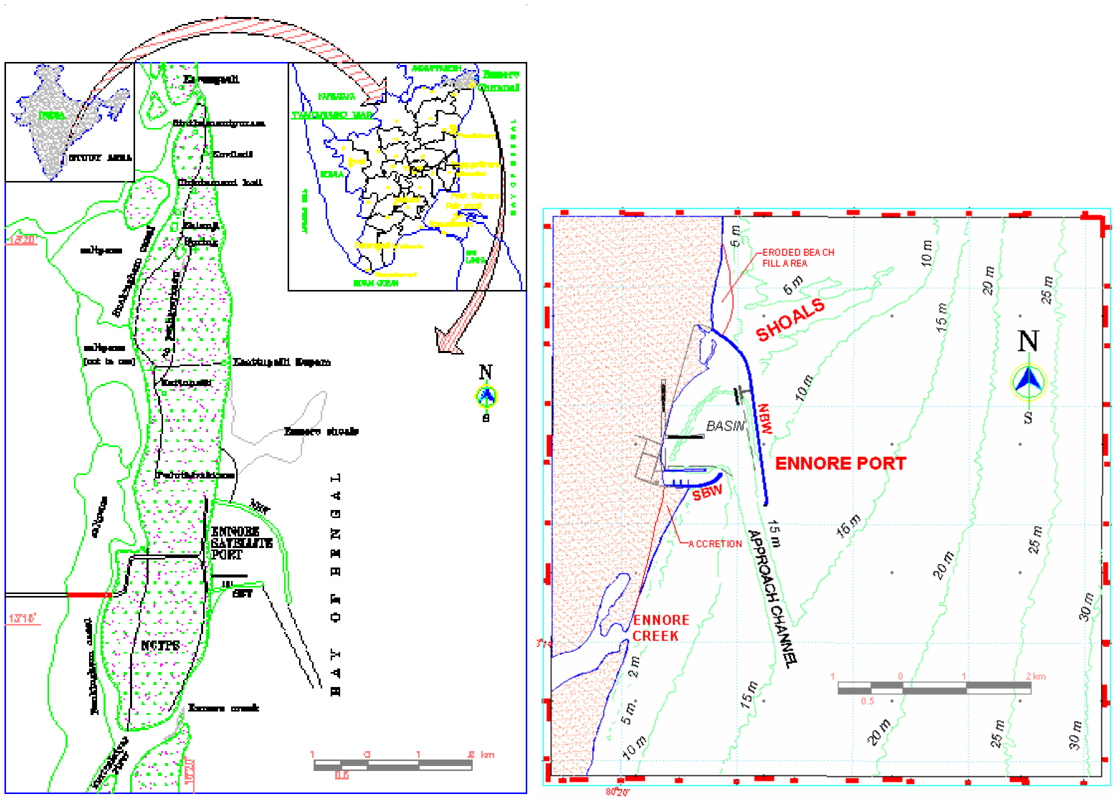


Fig.1. Ennore Coast Site Location Map

The process of northerly sediment transport and the south breakwater acting as a barrier resulted in growth of beach on the south side which extended up to the mouth of Ennore creek for a length of 2.6km (Fig.1). The construction of breakwaters of Ennore port has intercepted the free flow of long shore sediment transport, leading to lack of sediment supply to the down drift side resulting in the erosion along north of Ennore port.

The Shoreline Management Plan was prepared with remedial options such as beach nourishment, groins and offshore geotubes to prevent erosion of north Ennore coast. To protect the beach system, among the various alternatives for submerged structures, geotextile tubes were chosen to work as low-crested submerged structures for their viability to cause wave dissipation and thus reduce energy. Their main function was to reduce the incident wave energy on the beach, by controlling the wave-breaking process, to the required level that maintains the dynamic balance on the shoreline.

Geotextile tubes as Breakwaters

Various geo-systems like geo-tubes, geo-containers are being increasingly used as marine structures for coastal protection works like revetments, groynes, breakwaters and longitudinal reefs. Geo-tubes are large bags manufactured from a high tensile strength woven polypropylene geo-textile, with which a wide range of applications have developed due to its simplicity and cost-effectiveness. Each geo-textile tube is filled and submerged firmly just offshore to trap sand accumulation for additional beach space. Geo-textile tubes in breakwaters offer an economical solution for protecting coastlines.

Field measurements and data collection

The wave data was analyzed and the results classified as follows;

(i) Waves approaching from North East and South East directions.
(ii) Waves with period ranging between 6 and 10 seconds
(iii) Waves with height ranging between 0.3m and 2.7m

Chennai (Ennore coast) experiences two monsoon seasons separated by transitional periods of calm weather. Waves approach the Ennore coast from two directions viz., North Easterly for a period of 3 months during November to January; South Easterly for 7 months from March to September. Months of October and February are considered to be the transition period.
The bathymetry survey data of the year 2006 for study area (Ennore coast) was collected from Ennore Port. The survey data of the year 2000 for selected transects across the Ennore shoals (the area of interest) were collected from *RamanaMurthy* (2007) and compared with 2006 survey. The profile (cross section) across the shoals at transects of chainage (UTM44 Y co-ordinates) 1468000, 1468500, 1469000 and 1469500 of both the survey data were superimposed. Beach Morphology Analysis Package (BMAP) Version.2 of Coastal Engineering Research Center (CERC) USA was used for calculating the change in volume of shoals. The result (Fig.2) shows that, at Chainage 1468500Y the difference in volume per unit width is 1763.25 m^3/ m. This result implies that after construction of the north breakwater at Ennore port the sediment transport got intercepted which influenced the shoal configuration.

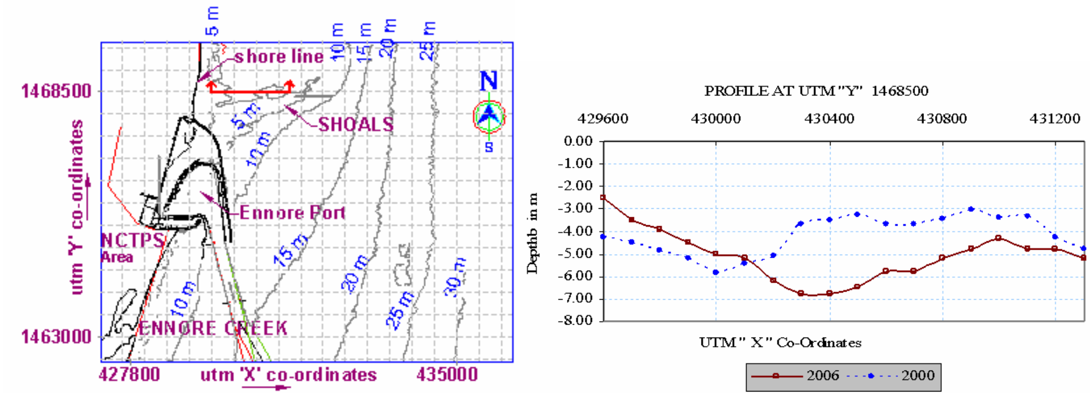


Fig.2. Profile of 2000 and 2006 survey; Location in plan (left) and cross section at Chainage UTM 1468500Y coordinate (right)

Numerical model studies

Refraction and diffraction of waves may have significant effect on a shoreline as they generally result in an uneven distribution of wave energy on the leeward side of the shoal. Wave modeling results provide information on wave propagation across the shoals and up to the shoreline, revealing areas of increased wave energy. In addition, one of the primary advantages of wave modeling is its ability to simulate multiple scenarios. The model domain were modified with different structural configurations (i.e., existing bathymetry, geo-textile tube structures and wide low crested reef setup), to determine the effect of various changes that have on the wave climate. Wave inputs were also modified to simulate a wide range of wave conditions (seasonal variations).

MIKE 21 PMS is based on a parabolic approximation to the elliptic mild-slope equation (*Berkhoff,* 1972) which is the governing equation for description of refraction, diffraction and reflection of linear time harmonic water waves on a gently sloping bottom. *Radder* (1979) has simplified with the use of parabolic approximation which reduces elliptic problem to parabolic form. This allows the problem to be solved as an initial value problem, which marches forward across the domain. *Kirby* (1986) extended the formulation to the case of waves propagating at a large angle to the assumed wave direction (x-axis). The model takes into account the effects of refraction and shoaling due to varying diffraction perpendicular to the predominant wave direction and energy dissipation due to bottom friction and wave breaking. The parabolic equation is solved using the Crank-Nicholson finite difference method. MIKE 21 PMS can be applied to the study of wave disturbance in open coastal areas and for computing wave fields in coastal areas with structures like groynes, detached breakwaters etc., when back-scatter (reflection into the incoming waves) can be neglected and diffraction is predominantly perpendicular to the main wave direction.

MODEL DOMAIN

The bathymetry data collected from Ennore port have been resolved on the spatial grid of 5m x 5m each with boundary domain of 10,000m x 14,000m for simulation. Bed levels were specified as negative values when they are below the datum and surface elevation of 0.65m is given to specify the tidal water levels relative to the refe~rence datum. The wave field propagating into the area of interest should enter the model through the offshore wave boundary (i.e. orienting the model such that waves enter through the offshore boundary). This was achieved by setting the origin of model domain at 438000, 1473500 (x, y values in UTM-44 coordinate system) and the model orientation of 192º with respect to north. The definition sketch of the area is shown in Fig.3.

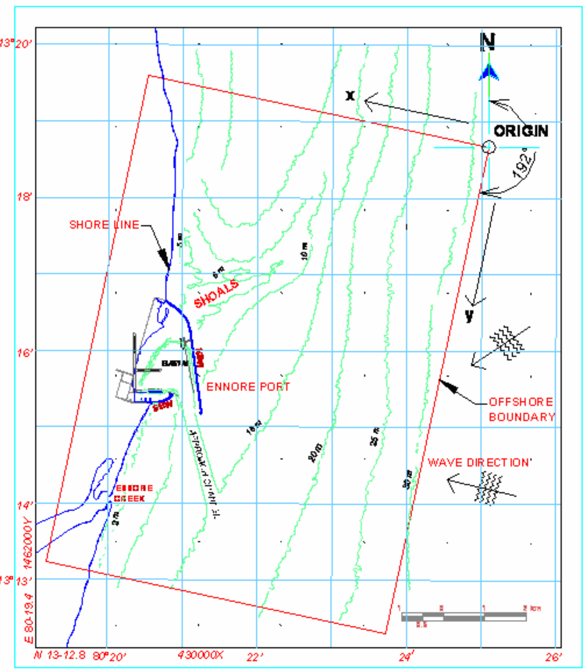


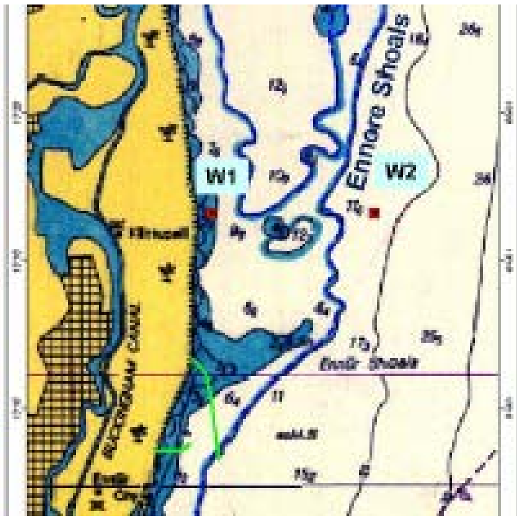
Fig.3. Definition sketch of the model area

It is essential that the x-axis of the grid is aligned within a limited angle with the dominant direction of wave propagation in the model area. The y-axis of the model measured clockwise with respect to true north. The lateral boundaries of model north and south were chosen as symmetrical. The bottom friction was specified as a constant of 0.002 (Nikuradse roughness parameter) for the entire model area. The parameter ‘α’ controls the rate of energy dissipation after breaking, ‘γ_1’ controls the amount of steepness related breaking, and ‘γ_2’ controls the amount of depth related breaking.

Validation of the Model

Validation of the model was carried out by comparing the wave heights obtained from the field investigations and from the numerical model. Comparison of results is given in tabular form, locations shown in Fig. 4.

Location	W1	W2	Remarks
Field measurement	1.00m	1.20m	In terms of H_s
	1.67m	2.00m	In terms of H_{max}
Numerical model	1.57m	1.97m	Transformed wave height



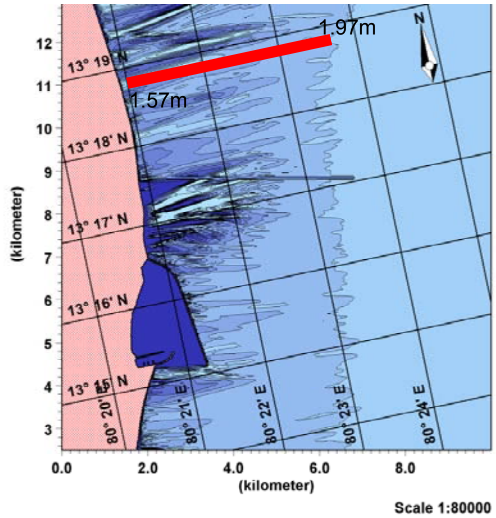


Fig.4. Validation of wave measurement; Location of field observations W1 and W2 (left) and wave transformation model (right)

RESULTS AND DISSCUSION

In the present study, wave characteristics were simulated in the offshore region and the results were obtained as the waves propagate over the shoals and in the nearshore region for the following conditions.

(i) Over existing long shoals (without geotube structure)
(ii) In the presence of geotube structure and
(iii) In the presence of wide low crested reef.

The following input wave data have been used for model studies;

Month	**Direction**	**Wave height** (H) in m	**Wave period** (T) in seconds	**Wave Angle (Θ)** with respect to North
Apr-05	SE	2.19	5.5	130.8°
Jun-05	SE	2.26	7.9	149.1°
Oct-05	NE	2.68	5.7	78.8°
Dec-05	NE	2.19	5.7	92.8°

The transmitted wave height on shoreward side of the submerged structure (H_t) were obtained from model studies for the given incident (input) wave height on seaward side of the submerged structure (H_i) and the ratio which gives wave transmission coefficient (K_t).
(ie.,) $K_t = H_t / H_i$ (*U.S. Army Corps of Engineers*, 1984)

Wave Model simulation over existing shoals, in the presence of geotube structure and its influence on the transmission coefficient

Numerical simulations over existing long shoals were conducted with the analysed wave data. The bathymetry of existing shoals have been modified by incorporating geotube structure of 3km long (Fig.5), with the orientation perpendicular to predominant waves from south east. Numerical simulations in the presence of geotube structure were also conducted, the results of wave (height) field for above inputs were compared with results of existing shoals and the differences in wave (height) field are shown in Fig.6. To find the transformed wave height results on the seaward and shoreward side of the structure, the results were plotted in profile series pattern (cross section) through shore points at every 100m intervals (Fig.5) along the direction normal to the geotube structure.

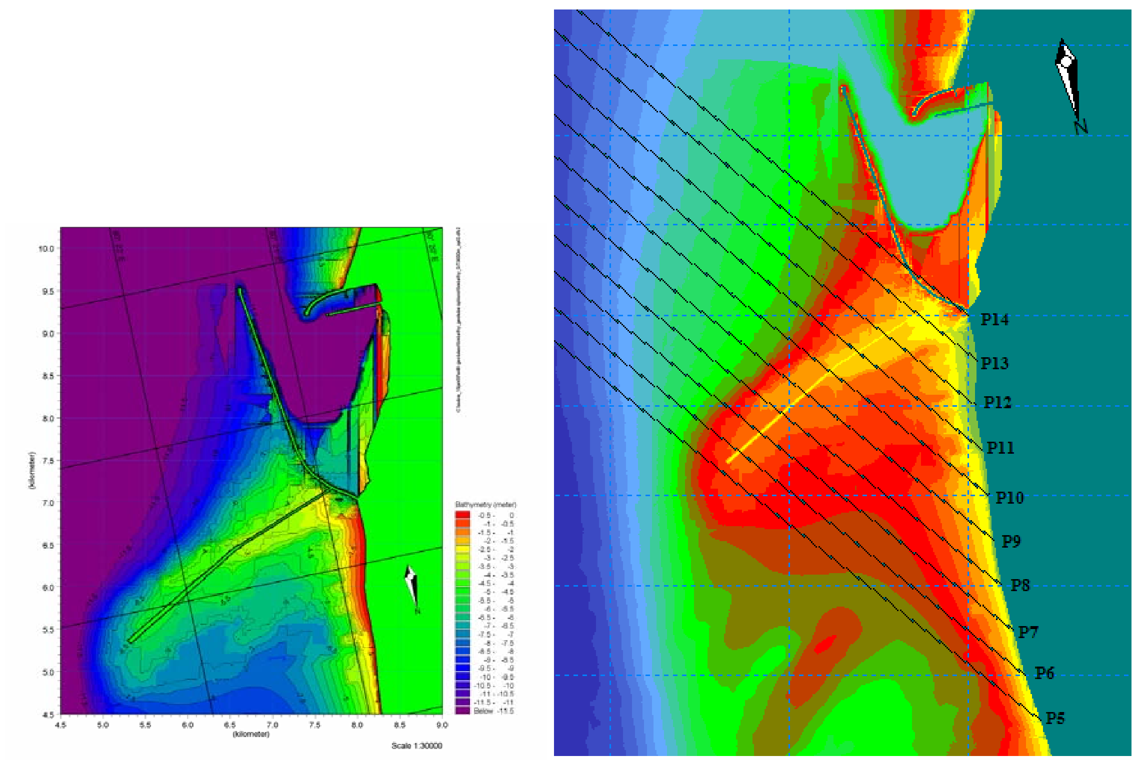


Fig.5. Geotube structure (left); Location plan of profile sections through points P5 to P14 (right)

From the wave height results, the transmission coefficients, K_t for the existing shoal configuration and with geotube structure configuration were obtained and the results are tabulated in Table.1. The value of transmission coefficient, K_t indicates that, for the modified configuration (Fig.7), the wave attenuation takes place only over the structure on the leeside, again the trend amplified in line with existing shoals configuration and it is almost same at nearshore points except for few cases.

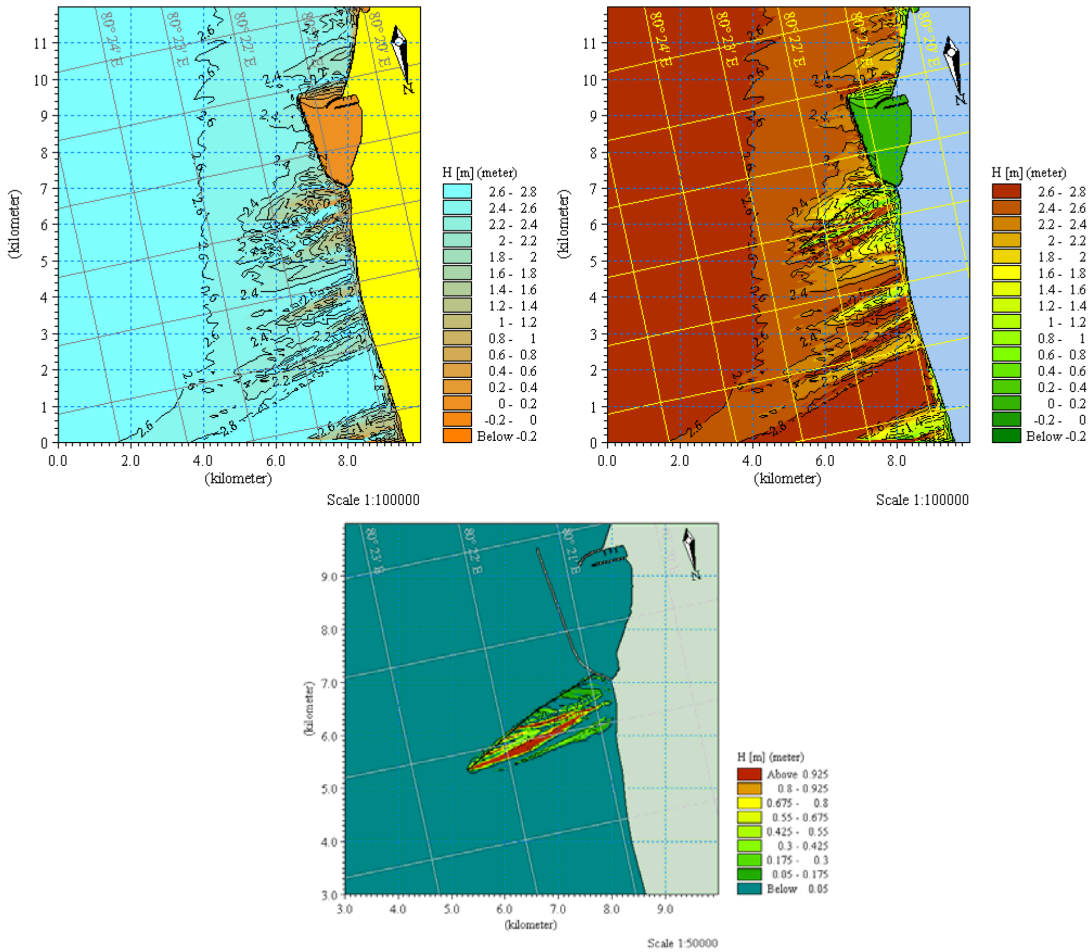


Fig.6 Transformed wave field over existing shoals and with geotube structure for given input of H=2.68m; T=5.7s; θ=79° (upper); Difference in wave field (lower).

Table.1. Transmission coefficient (K_t) for wave height results at points 500m from shore line over existing shoals and geotube structure

			PROFILE OF 100m INTERVALS AND POINTS AT 500m FROM SHORE LINE									
			P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
Input wave particulars: H=2.19m; T=5.5s; Θ=131°												
Apr-05	**Existing**	H_t	1.596	1.279	1.080	2.904	0.993	2.601	0.316	1.954	1.637	0.079
		K_t	**0.729**	**0.584**	**0.493**	**1.326**	**0.453**	**1.187**	**0.144**	**0.892**	**0.748**	**0.036**
	GT3	H_t	1.596	1.279	1.076	2.104	1.075	2.165	0.311	2.007	1.528	0.079
		K_t	**0.729**	**0.584**	**0.492**	**0.961**	**0.491**	**0.989**	**0.142**	**0.916**	**0.698**	**0.036**
Input wave particulars: H=2.26m; T=6.9s; Θ=149°												
Jun-05	**Existing**	H_t	0.841	0.799	1.402	0.844	2.749	1.810	1.657	2.053	1.551	0.021
		K_t	**0.372**	**0.354**	**0.620**	**0.373**	**1.216**	**0.801**	**0.733**	**0.909**	**0.686**	**0.009**

	GT3	H_t	0.822	0.769	2.457	0.790	2.733	1.589	1.692	2.012	1.349	0.021
		K_t	**0.364**	**0.340**	**1.087**	**0.349**	**1.209**	**0.703**	**0.749**	**0.890**	**0.597**	**0.009**
Input wave particulars: H=2.68m; T=5.7s; Θ=79°												
Oct-05	Existing	H_t	1.923	2.494	3.171	2.060	2.366	1.898	1.273	1.596	1.147	0.026
		K_t	**0.718**	**0.931**	**1.183**	**0.769**	**0.883**	**0.708**	**0.475**	**0.595**	**0.428**	**0.010**
	GT3	H_t	1.923	2.494	3.171	2.061	2.365	1.890	1.267	2.417	0.995	0.026
		K_t	**0.718**	**0.930**	**1.183**	**0.769**	**0.883**	**0.705**	**0.473**	**0.902**	**0.371**	**0.010**
Input wave particulars: H=2.19m; T=5.7s; Θ=93°												
Dec-05	Existing	H_t	2.220	2.055	1.878	1.771	1.630	0.657	2.070	1.043	1.038	0.036
		K_t	**1.014**	**0.938**	**0.857**	**0.808**	**0.744**	**0.300**	**0.945**	**0.476**	**0.474**	**0.017**
	GT3	H_t	2.220	2.055	1.878	1.771	1.630	0.649	2.200	1.356	1.001	0.036
		K_t	**1.014**	**0.938**	**0.857**	**0.808**	**0.744**	**0.296**	**1.004**	**0.619**	**0.457**	**0.017**

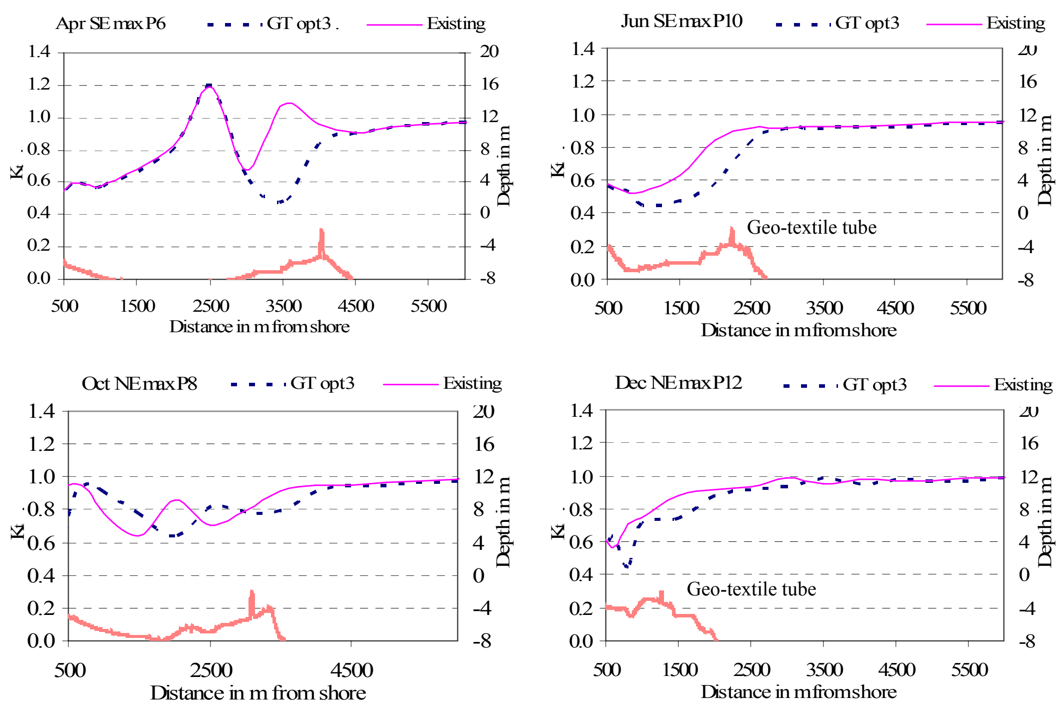


Fig.7 Transmission coefficient (K_t) on existing shoals and in the presence of geotube structure through points P6, P8, P10 and P12

Influence of wide low crested reef on the transmission coefficient

In light of the above results, an alternative structure viz., wide low crested reef was attempted. The main function was to reduce the incident wave energy on the leeside, by controlling the wave-breaking process, to the required level that maintains the dynamic equilibrium of the beach.

The wide low crested reef of 600m wide with depth of submergence as 2.1m and 3.15m for water depth of 6m and 9m respectively were adopted. The distance of the structure from the coast was maintained as 1500m from the shoreline (Fig.8) with a length of 3 km. Numerical simulations over wide low crested reef were carried out for the same wave input details as mentioned in the previous section and the results on wave field are shown in Fig.8.

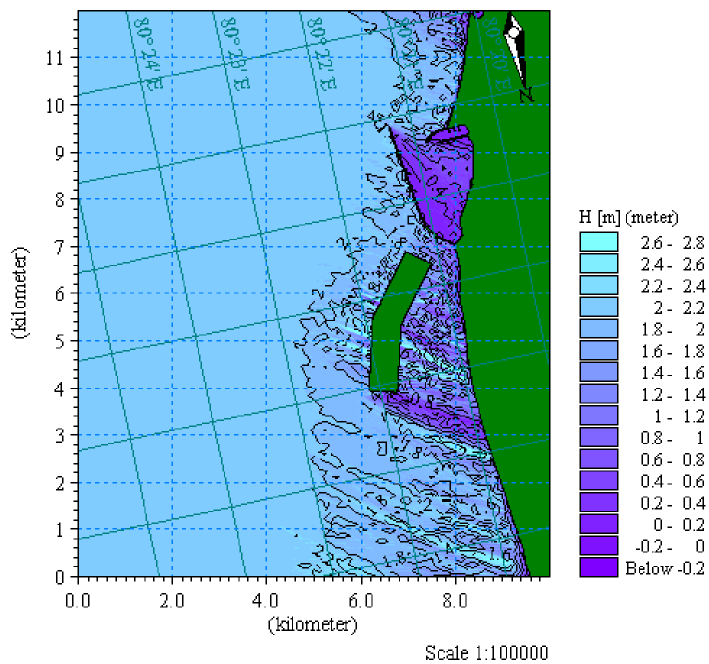


Fig.8 Transformed wave field on existing shoals in the presence of wide low crested reef for given input of H=2.19m; T=5.5s; θ=131°

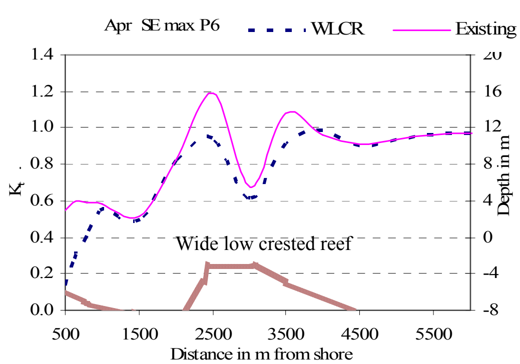
The profiles of wave transformation (in terms of K_t) on the leeside of the structure, at every 100m intervals were obtained and the results of the same are presented in Table.2. The plotted graphs (Fig.9) indicate that, the transmission coefficient, K_t reduces by 40 to 60% when compared with the performance of the geotube structure.

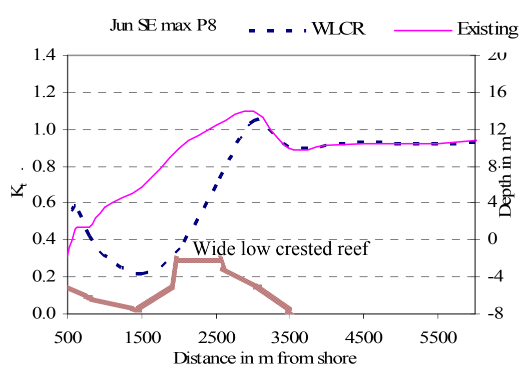
From the Ennore port expansion works under progress, it is expected to generate sand material of the order of 4×10^6 m^3 from capital dredging. Also earlier studies (*RamanaMurthy, 2007*) indicate that sand quantity of order 0.4×10^6 m^3 to 0.6×10^6 m^3 need to be dredged annually to maintain the port. With the above two sources, sufficient sand would be available for resizing the long shoals.

Table.2. Transmission coefficient (K_t) for wave height results at points 500m from shore line over existing shoals and wide low crested reef

	PROFILE OF 100m INTERVALS AND POINTS AT 500m FROM SHORE LINE									
	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14

Input wave particulars: H=2.19m; T=5.5s; θ=131°												
Apr-05	**Existing**	H_t	1.596	1.279	1.080	2.904	0.993	2.601	0.316	1.954	1.637	0.079
		K_t	**0.729**	**0.584**	**0.493**	**1.326**	**0.453**	**1.188**	**0.144**	**0.892**	**0.747**	**0.036**
	WLCR	H_t	1.066	0.288	1.086	0.485	1.343	1.279	1.361	1.695	1.348	0.104
		, K_t	**0.487**	**0.131**	**0.496**	**0.222**	**0.613**	**0.584**	**0.621**	**0.774**	**0.616**	**0.048**
Input wave particulars: H=2.26m; T=6.9s; θ=149°												
Jun-05	**Existing**	, H_t	0.841	0.799	1.402	0.844	2.749	1.810	1.657	2.053	1.551	0.021
		, K_t	**0.372**	**0.354**	**0.620**	**0.373**	**1.216**	**0.801**	**0.733**	**0.908**	**0.686**	**0.009**
	WLCR	, H_t	0.286	0.112	0.452	1.138	1.915	0.592	0.732	0.530	0.888	0.170
		K_t	**0.126**	**0.049**	**0.200**	**0.503**	**0.847**	**0.262**	**0.324**	**0.235**	**0.393**	**0.075**
Input wave particulars: H=2.68m; T=5.7s; θ=79°												
Oct-05	**Existing**	H_t	1.923	2.494	3.171	2.060	2.366	1.898	1.273	1.596	1.147	0.026
		K_t	**0.718**	**0.931**	**1.183**	**0.769**	**0.883**	**0.708**	**0.475**	**0.596**	**0.428**	**0.010**
	WLCR	, H_t	2.155	2.353	3.078	1.170	1.666	1.920	0.937	1.340	1.490	0.030
		, K_t	**0.804**	**0.878**	**1.149**	**0.437**	**0.622**	**0.717**	**0.349**	**0.500**	**0.556**	**0.011**
Input wave particulars: H=2.19m; T=5.7s; θ=93°												
Dec-05	**Existing**	H_t	2.220	2.055	1.878	1.771	1.630	0.657	2.070	1.043	1.038	0.036
		, K_t	**1.014**	**0.938**	**0.858**	**0.809**	**0.744**	**0.300**	**0.945**	**0.476**	**0.474**	**0.016**
	WLCR	H_t	2.603	2.463	2.132	0.930	1.902	1.406	2.463	0.929	1.214	0.038
		, K_t	**1.188**	**1.124**	**0.973**	**0.425**	**0.868**	**0.642**	**1.125**	**0.424**	**0.554**	**0.018**





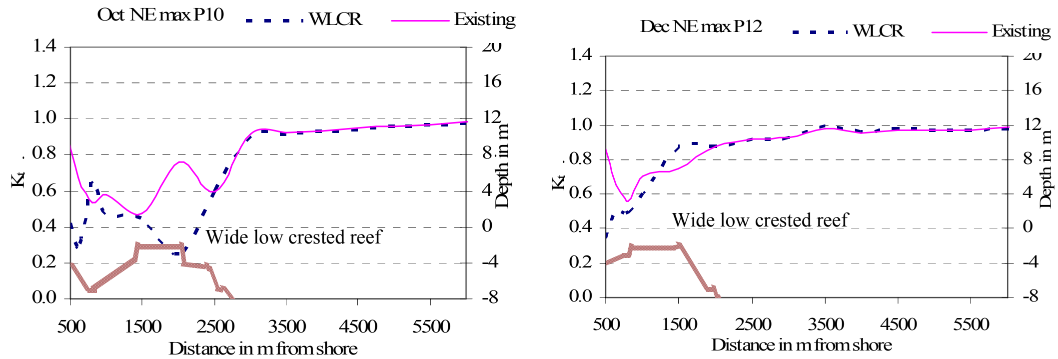


Fig.9 Transmission coefficient (K_t) on existing shoals and in the presence of wide low crested reef through points P6, P8, P10 and P12

CONCLUSIONS

Following are the conclusions drawn from the studies;

(i) With the existing configuration of long shoal, the reduction in wave transformation is of the order of 20% on the leeside of the long shoal.

(ii) No appreciable reduction in the transmission coefficient, K_t could be achieved due to the introduction of geotubes above long shoals.

(iii) By widening the existing long shoal to 600m and increasing its height by 5.85m to 3.9m (i.e., depth of submergence as 3.15m to 2.1m) would result in transmission coefficient (K_t), vary between 40 and 60%, a definite advantage when compared with the existing condition. The above performance can be achieved when structure is positioned at a clear distance of 1200m from the shore.

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REFERENCES

Beach Morphology Analysis Package **(BMAP)** Version.2 of Coastal Engineering Research Center (CERC) USA - User manual.

Berkhoff, J.C.W (1972) Computation of combined refraction-diffraction, Proceedings of 13th Coastal Engineering Conference., Vancouver, 471-490.

Danish Hydraulics Institute (DHI), Denmark **MIKE21 PMS** Parabolic Mild-Slope Wave Module User Guide and Scientific Documentation

Enrique Álvarez, Ramiro Rubio and Herbert Ricalde (2005) Shoreline restored with geotextile tubes as submerged breakwaters Geosythetics Magazine 24 (3), 1-8

Ing E. Alvarez, Ramiro Rubio, Herbert Ricalde (2007) Beach restoration with geotextile tubes as submerged breakwaters in Yucatan, Mexico Geotextiles and Geomembranes 25, 233–241.

Kirby, J.T., (1986) Rational approximations in the parabolic equation method for water waves, Coastal Engineering., 10, 355-378.

Radder, A.C., (1979) On the parabolic equation method for water wave propagation. Journal of Fluid Mechanics, 95, 159-176.

Ramana Murthy, M.V., (2007) Numerical and field studies on long shoals and beach-fill for coastal protection against waves and tsunami. Ph.D Thesis report.

U.S. Army Corps of Engineers (1984) Shore Protection Manual, Coastal Engineering Research Center, USA