International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 8, August - 2014

Shore Protection Using Geotextile Embedded Rubble Mound Breakwater

Lamanto T. Somervell
Research Scholar
Department of Civil Engineering,
National Institute of Technology, Calicut

Jyothis Thomas
Professor
Department of Civil Engineering,
College of Engineering Trivandrum,

Greeshma Nizy Eujine
Research Scholar
Department of Civil Engineering,
National Institute of Technology, Calicut

***Abstract*—Many conventional methods of shore protection like seawalls, rubble mound breakwater, groins and detached breakwaters have been designed by engineers to attenuate the wave energy which cause coastal erosion. These methods are sometimes expensive, ineffective and inefficient and are not eco-friendly.Geosystems have gained popularity in recent years because of their simplicity in placement, cost effectiveness and environmental aspects. In the present work physical model studies were conducted to study the efficiency of sub-aerial detached rubble mound breakwaters with geotextile filter media (coir fibre mat) below the armour layer as a wave attenuator in three different submergence conditions. Data acquisition system with 10 sensors was used to measure the wave attenuation. A stretch of 1.3 km along Poonthura – Valiyathurawas selected as the study area. The efficiency of the breakwater as a shore protection measure was determined based on the percentage of energy dissipated by thebreakwater and the change caused in the beach profile.The rubble mound breakwater with geotextile fibre media below the armour layer in zero-submerged condition was found to be the best of three types of breakwaters tested as it dissipated the maximum amount of wave energy.**

Keywords-shore protection;coastal erosion;geotextilebreakwater; wave energy; breakwater

I. INTRODUCTION

Coastal erosion is due to the action of wave energy in the coastal zone. This leads to loss of valuable beaches, agricultural lands, damage to coastal vegetation and stoppage of fishing activities. To minimize the wave energy engineers have designed many structures like seawalls, rubble mound breakwater, groins and detached breakwaters which can provide direct or indirect protection of the coast.

Sand filled geosynthetic elements such as groynes, berms, artificial reefs,etc can be used successfully to solve conventional coastal problems[1]. Similar breakwater structures covered with soft limestone-calcite rock were used to protect Amwaj Island from waves and tidal effects from the Persian Gulf [2]. Multi-Celled Sand-Filled Geosynthetic Systems withstand harsh marine conditions including exposure to waves, water-born debris, storm surge, sand abrasion and sunlight. These geosynthetic materials include both geotextile (porous) and geomembrane (non-porous) materials that are fabricated into very large containers that can be filled with sand and used for many applications, including systems for shoreline stabilization [3].Jyothis Thomas and Rebeccamma Thomas developed a design tool which can be used as an aid for the design of detached breakwater. Using this tool the design engineer can thoroughly study the long term effects on the shoreline with any detached breakwater configuration [4]. It was found fromexperimental investigation that the energy dissipation capacity of coir fibrewall was 91% and that of gabion seawall was 84% respectively [5].

In the present work physical model studies were conducted to study the efficacy of detached rubble mound breakwaters with geotextile filter media (coir fibre mat) below the armour layer as a shore protection method. The experiments were conducted under three submergence conditions such as sub-areial, zero submergence and submerged conditions. The percentage reduction in wave energy and change in beach profile were determined to assess the effectiveness of these breakwaters.

II. NEED FOR THE STUDY

The Kerala coast on the south west part of the Indian subcontinent has a long shoreline extending over 560 km of which 360 km is exposed to erosion [6]. It is one of the worst affected areas on the west coast of India due to coastal erosion. The coastal erosion has become a critical problem for Kerala which is facing acute shortage of landbecause of its narrow width and high density of population.Coastal erosion in Kerala is due to one or more of the different factors like heavy monsoon showers with thunder and cyclones, loose sandy sea shore, destruction of mud of alluvium, etc. The major erosion on Kerala coast takes place during south west monsoon. This leads to loss of valuable beaches, agricultural lands, damage to coastal vegetations and stoppage of fishing activities. Hence, the problem of establishing the coast of Kerala in the present position by suitable and effective protection measures is a matter of paramount importance.

ISSN: 2278-0181
Vol. 3 Issue 8, August - 2014

Beaches are one of the most important geomorphologic features of a coastal state like Kerala which is having great economic importance as they serve recreational purpose and act as a buffer zone to protect land and properties from wave attack.So to prevent coastal erosion and to dissipate wave energy, an appropriate coastal protection measure has to be designed. RCC or rubble mound breakwater is the only protection measure adopted in Kerala, since 1954.Different activities on the coastal belt are restricted by hard coastal structures. So there is an urgent need for evolving an eco sensitive, cost effective and aesthetic geo composite shore protection method, as a better option to prevent coastal erosion by reducing wave energy to desired level. It will also promote the development of tourism, recreational activities and coastal navigation.

III. STUDY AREA AND DATA USED

A stretch of 1.3 km along Poonthura – Valiyathura coast lying between 8°17'3" and 12°27'40"N latitude and 74°51'57" and 77°24'47"E as shown in Fig. 1 has been selected for the present study.

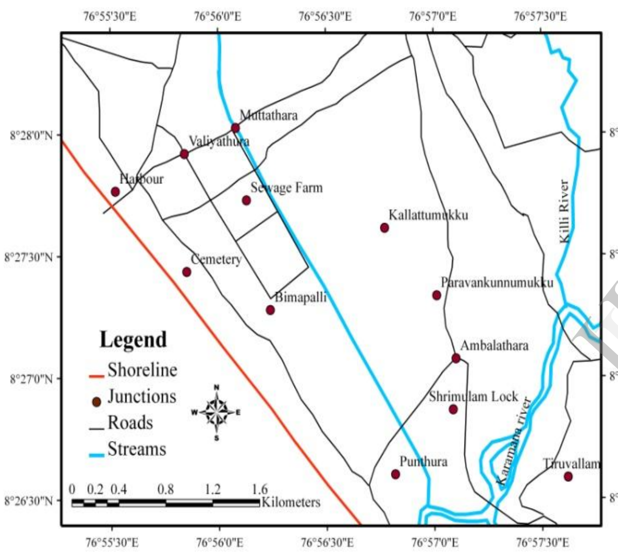

Fig 1. Study area

There are two monsoons, south-west and north-east. Strong south-west monsoon wind with speed 60 km/hr blow over the coast during south-west monsoon and the waves are very high during this period (3m).Wave energy is not uniformly distributed along the coast in this area and shows a general reduction towards north. The maximum recorded wave height is 5.1 m and the tidal range is about 0.60 m. Sediment is composed of medium sized sand and the shores are very steep during monsoon.

Various data collected for the coastal engineering study of this particular site are described below.

A. *Wave Data*

It includes wave height, wave period and wave direction. Four years of wave data from 1984 to 1988 measured at Valiyathura in Trivandrum was provided by the Centre for Earth Science Studies (CESS), Trivandrum [6].The predominant wave parameters during the rough season were selected for the model study.

Significant wave height, H = 3m

Wave period T = 9sec

Wave direction = 250°N

B. *Bathymetry and Beach Profile*

The bathymetry of the study area was obtained from hydrographic chart provided by Kerala State HarbourEngineering Department. The shore details and beach profiles [5] show that the study area is uniformly steep seawards and has a straight shoreline.

Study area is divided into five zones as depicted in Fig. 2

Zone 1: Coast - 200 m width with 1:100 slope

Zone 2: Backshore - 40 m width with 1:10 slope

Zone 3: Foreshore - 30 m width with 1:15 slope

Zone 4: Inshore - 250 m width with 1:75 slope

Zone 5: Offshore towards seaward side - 680 m width with 1:100 slope

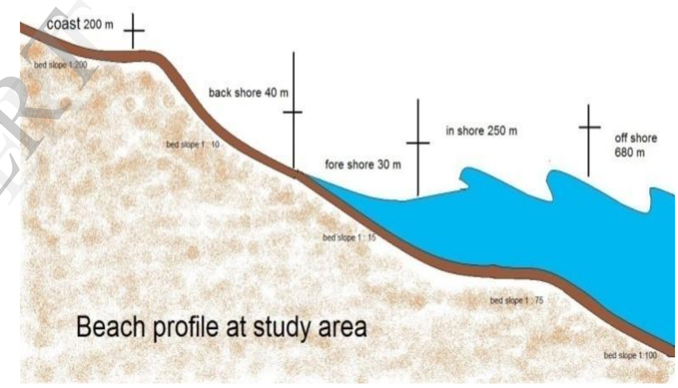

Fig 2. Beach profile at study area

IV. COIR GEOTEXTILES MAT

Coir is a 100% natural organic fibre extracted from the husk of coconut. One of the major uses of coir is in the manufacture of geotextiles that have large-scale applications in the fields related to soil engineering and water resources management. Detailed field-based investigations have confirmed the superior ability of coir geotextiles, over other natural fibres, to provide effective protection against soil erosion and in improving vegetation. It is 100% bio-degradable and environmental friendly. Coir geotextile are tough,durable, versatile and resilient. It posses high tear strength resistance and high tensile strength. It is Easy to install, patch up and maintain. The physical properties of coir fibreused in the present work are given below.

- Ultimate length - 0.6 mm
- Diameter/width - 16 micron
- Length - 6 to 8 inches

- Density - 1.4 g/cc
- Tenacity - 10 g/ tex
- Breaking Elongation - 30%
- Moisture regain at 65% RH - 10.5%
- Swelling in water - 5% in diameter

In the present study, unwoven coir fibre was sandwitched between two layers of woven geotextile and was used as filter media in the rubble mound breakwater as shown in Fig. 3.

Fig 3.Coir fibre mat used as filter media

V. DESIGN PRINCIPLES OF SEGMENTED DETACHED BREAKWATER

According to shore protection manual [7], the amount of energy reaching the lee of the structure is controlled by the width of gap between breakwaters (L_g) and the wave diffraction through these gaps. The gap width should be atleast twice the wave length (L) and the length of the structure (L_s) should be less than the distance offshore (Y).

The magnitude and direction of the predominant incoming waves also play important roles. The large, long period waves tend to diffract more into the lee of the breakwater than smaller waves resulting in a more pointed shoreline. Highly oblique, predominant waves induce strong long shore currents which restrict the amount of accretion in the lee of the breakwater. In this case breakwater can be oriented across the predominant wave direction.

For the waves that are extremely oblique to the shoreline, it is recommended that the breakwater be oriented parallel to the incoming wave crests. This will provide protection to longer section of shoreline for a given structure length, however it will probably increase the amount of construction material required for the structure since one end of the breakwater will be in deeper water than if it were oriented parallel to the shoreline.

VI. DESIGN OF BREAKWATER

Design of rubble mound breakwater mainly involves finding the various components of the structure such as weight of individual armour units, crest width, side slope, etc.Stability of the structure depends on the stability of individual blocks and stones. According to Hudson's Approach[7],

Weight of armourblock (W) is given by,

$$W = \frac{\gamma_r H^3}{\left(\frac{\gamma_r}{\gamma_w} - 1\right) K_D \cot\alpha} \quad (1)$$

Crest width of the breakwater,

$$B_c = nK_\Delta \left(\frac{W}{\gamma_r}\right)^{\frac{1}{3}} \quad (2)$$

Where, H is the significant wave height, α is the angle of structure slope measured from horizontal in degrees,γ_r and γ_w are the unit weight of armour unit and water respectively.n is the number of stones in one layer, $K_D$is the stability coefficient depending on the shape of armour unit, surface roughness, sharpness of edge and degree of interlocking and K_Δ is the layer coefficient.

Weight of stone in secondary layer,

$$W_1 \geq \frac{W}{10} \quad (3)$$

Thickness of secondary layer,

$$B_c = nK_\Delta \left(\frac{W_1}{\gamma}\right)^{\frac{1}{3}} \quad (4)$$

Weight of stone in core layer,

$$W_2 \geq \frac{W}{200} \quad (5)$$

The side slope of the breakwater was kept as 1 in 2. The values of $K_D$and K_Δ were taken as per shore protection manual (1984). The details of breakwater designed for the selected site conditions are given in Table I.

TABLE I. DETAILS OF BREAKWATER

Details	Prototype values
Stability coefficient, K_D	2
Number of stone, n	3
Layer coefficient, K_Δ	1
Depth of water at the site of breakwater, h	3.5 m
Deep water wave length, L_0	126m
Wave length at the breakwater, L	48 m
Gap width between breakwater L_g	255 m
Length of breakwater, L_s	130m
Distanceof breakwater from shoreline, Y	150m

The cross section of the rubble mound breakwater was designed in three layers. A coir fibre mat which acted as a geotextile filter media was placed in between the armour and secondary layers of the breakwater as shown in Fig.4. In this experiment the cross section of the breakwater is kept constant and the submergence was varied. The cross section of breakwaters in sub-areial, zero submergence and submerged conditions are shown in Fig. 4, Fig. 5 and Fig. 6 respectively.The outer layer consisted of individual rubble blocks of 5 tonne weight of approximately 1.5m size. The secondary layer consisted of rubbles weighing 0.5 tonne and diameter around 0.70m and the core layer consisted of rubble weighing 25 kg with size around 0.30m.

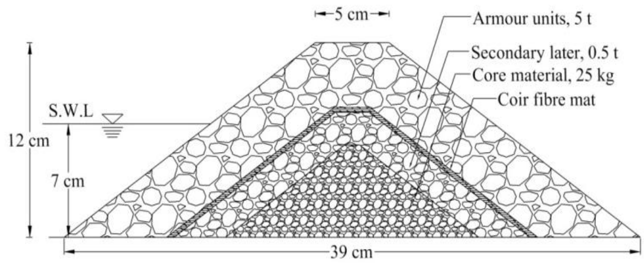

Fig 4.Breakwater in sub aerial condition
(All dimensions are in metres)

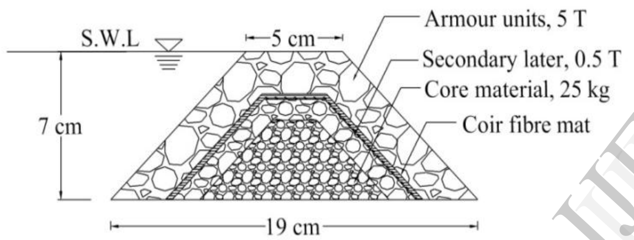

Fig 5. Breakwater in zero submergence condition
(All dimensions are in metres)

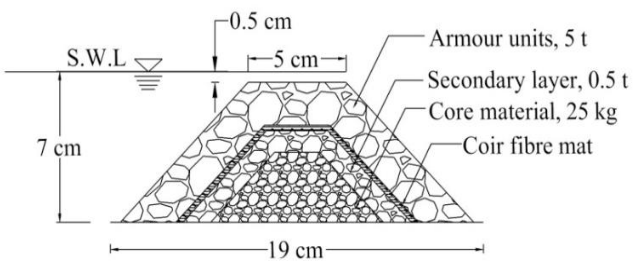

Fig 6.Breakwater in fully submerged condition
(All dimensions are in metres)

VII. EXPERIMENTAL SETUP

The physical model studies were conducted in a wave tank of size 13m x 12m x 0.4m of Coastal Engineering Laboratory of College of Engineering, Trivandrum. The wave generation paddle was approximately 13m long and fitted along one of the longer sides and shore was formed along the side opposite to the wave paddle. A single eccentric type wave generator was used in the model to simulate regular waves. The paddle was hinged at the bottom and the top was connected to two eccentric discs by connecting rods. The eccentric discsare connected to a drive shaft. A 230 volt, 3 phase induction motor was coupled to the drive shaft by a helical worm gear drive followed by a 3 step pulley and belt coupling. The periods and amplitude of the wave could be varied by proper adjustments on the eccentric discs.

The bathymetry of the selected site was reproduced in the wave tank with moving bed load. A distorted model was setup by choosing a horizontal scale of 1:100 and vertical scale of 1:50 so that the vertical exaggeration was limited to 2.The model was setup in such a way that the direction of wave was parallel to the side walls of the wave tank. For convenience of observation, a co-ordinate system was developed taking x-axis along the length of the wave tank and y-axis along the side perpendicular to it. The coordinates of the left corner of wave tank was considered as origin (0,0). In order to find out the co-ordinates of different points, the plan of the wave tank was first fitted in the map giving the plan of the proposal. The model setup was arranged to have a constant water level of 24 cm from the base of the tank. The bed profiles in the map were simulated in the tank by calculating the depth of sand according to the scale adopted. Thus the ocean bed at the selected site was reproduced in the model.The three breakwaters of length 1.3 m (prototype 130 m) each were arranged as shown in Fig. 7. In Fig. 7, B1, B2 and B3 represents rubble mound breakwater with coir fibre mat below armour layer in sub aerial, zero submergence and submerged conditions respectively. C1,C2…C10 represents the 10 sensors placed at different locations to measure the wave heights in the offshore, leeward side of the breakwater and in the gap between them. C1, C3 and C5 measured the wave heights on the leeward side and C2, C4 and C6 measured the wave heights on the offshore side of B1, B2 and B3 respectively. C7, C8 and C9 measured the wave heights in the gaps between the breakwaters and C10 measured the deep water wave heights.The gap widths between the three breakwaters are adjusted in such a way that there was no mutual interference between them.

The schematic representation of breakwaters and sensors are illustrated in Fig. 7 andbreakwaters in sub-areial, zero submergence and submerged conditions are shown in Fig. 8, Fig. 9 and Fig. 10 respectively.The model was run for 180 minutes and the wave heightswere stored in the data acquisition system,which were retrievedlater.

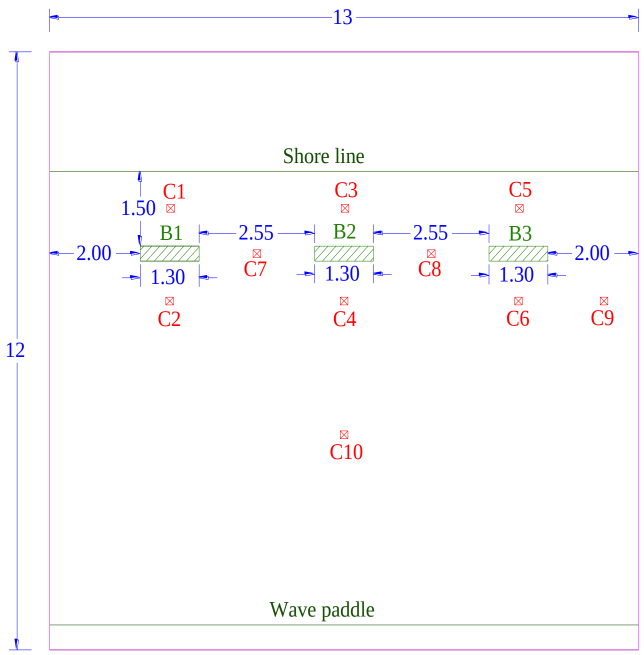

Fig 7. Schematic representation of breakwaters and sensors
(All dimensions are in metres)

Fig 8.Sub aerial breakwater

Fig 9.Breakwater in zero submerged condition

Fig 10.Submerged breakwater

VIII. RESULTS ANDDISCUSSIONS

A. *Wave Height Attenuation*

Wave heights were retrieved from the data acquisition system at every five minutes and the wave height attenuation due to each type of breakwater was determined and plotted in Fig.11 to Fig. 13. Some initial undulations of the wave height were observed, but as the time lapsed the wave heights became steady. So comparison of wave height attenuation and wave energy dissipation were calculated after the waves became steady. Itis seen from the graph that maximum wave attenuation was obtained in the case of breakwater with geotextile filter media in zero submerged condition.The maximum wave attenuation obtained in the case sub aerialbreakwater was 77.35%, in zero submerged condition was 84.81% and due to submerged breakwater was 74.5%.

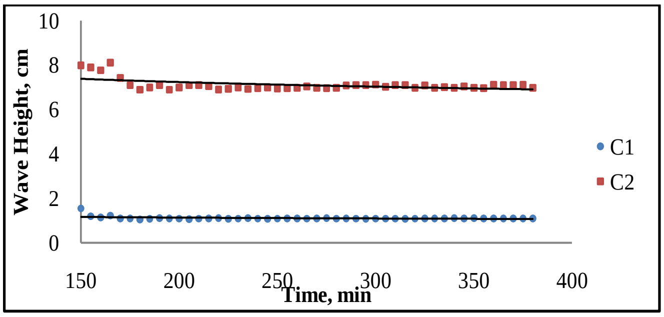

Fig 11.Wave height attenuation due to the breakwater in sub aerial condition.

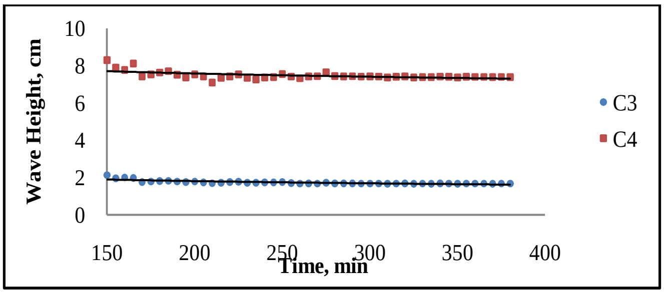

Fig 12.Wave height attenuation due to the breakwater in zero submerged condition.

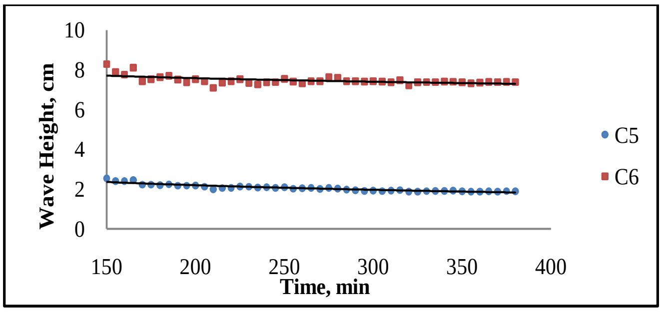

Fig 13.Wave height attenuation due to the breakwater in submerged condition.

B. Energy Dissipation

The energy/unit surface area dissipated by the breakwater was computed using the equation,

$$E = \frac{\rho g H^2}{8} (N/m) \qquad (6)$$

Where, ρ is the density of water and g is the acceleration due to gravity. The percentage reduction in wave energy with respect to timeof the three types of breakwaters tested, are shown in Fig. 14.

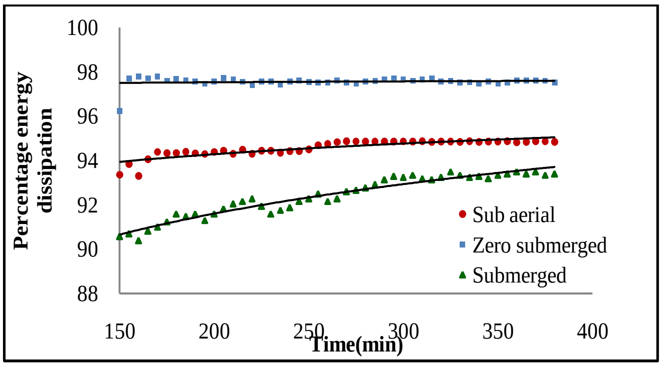

Fig 14.Percentage energy dissipation due to various type of breakwater

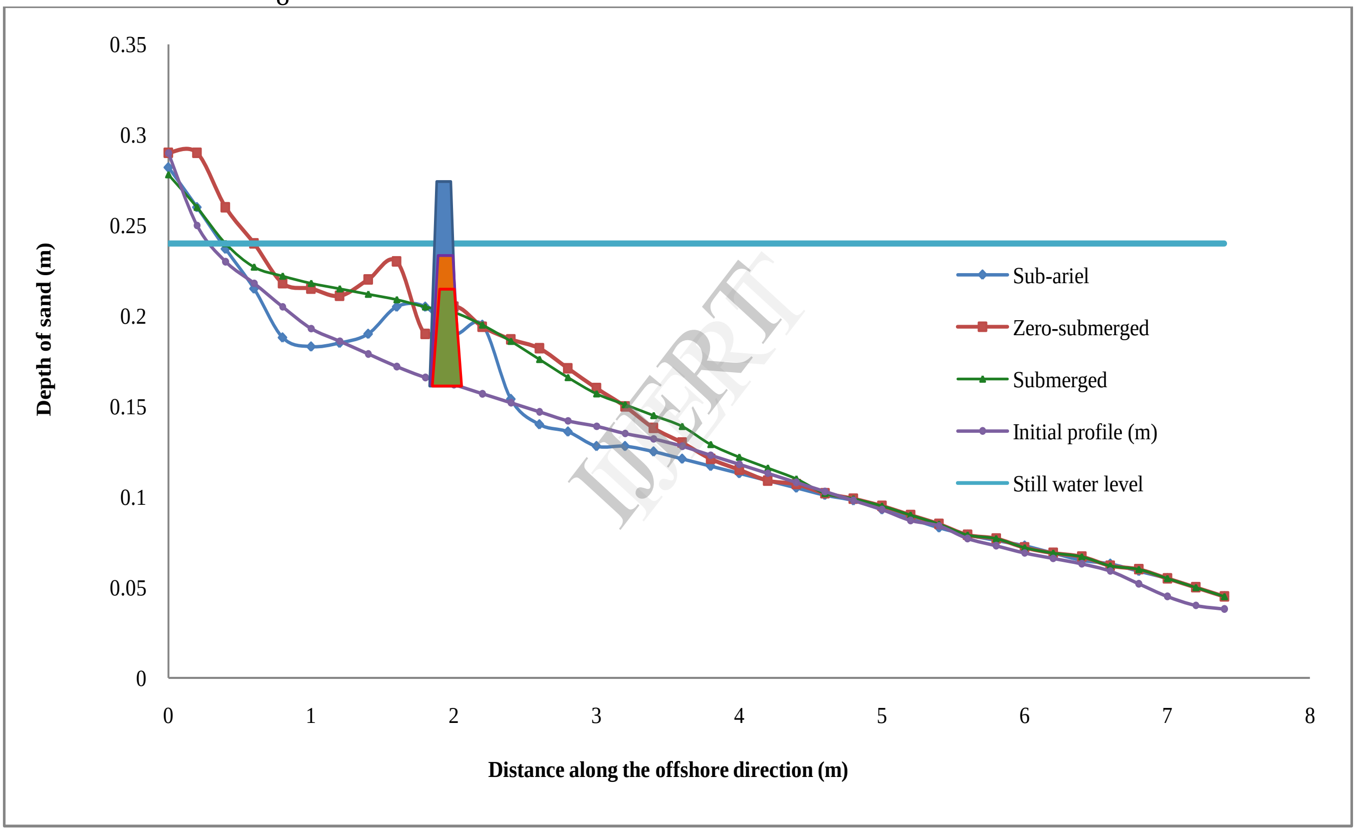

Fig 15. Bed profile across the breakwaters

C. Profile across Breakwaters

Fig. 15 illustrates the bed profile across the breakwaters in three different submergence conditions. It is observed that sand is eroded from the offshore and deposited in the front of the breakwater preventing toe erosion and accretion occurred on the leeward side for all the three cases. Maximum deposition was observed in the case of breakwater under zero submergence condition.

IX. CONCLUSION

Physical model studies were conducted to determine the efficacy of geotextile as a filter media in rubble mound breakwater below the armour layer. Of the three types tested, the rubble mound breakwater with geotextile filter media below armour layer in zero submerged condition was found to be the best suited shore protection measure for the Poonthura-Valiyathura reach in Trivandrum coast as it produced the maximum wave attenuation of 84.4% and maximum energy dissipation of 97.7%

REFERENCES

[1] S.J. Restall,L.A. Jackson and DrIng. Georg Heerten"The challenge of geotextile sand containers as armour units for coastal protection work in Australasia", Proceedings of the 15th Australasian Coastal and Ocean Engineering Conference, pp. 1-6.2001

[2] Jack Fowler, Rodolfo Arroyo, and Nicolás Ruiz "Riprap Covered Geotextile Tube Embankments" unpublished.

[3] Lee E. Harris and Jay W. Sample "The evolution of multi-celled sand filled geosynthetic systems for coastal protection and surfing enhancement", Reef Journal, vol.1 pp. 1-14. 2009

[4] Jyothis Thomas and Rebeccamma Thomas "Seashel – A tool for designing detached breakwater", Proceedings of second Indian National Conference on Harbour and Ocean Engineering, vol. 2 pp.1216 – 1226. 1997

[5] Asharaf Khan .A,RamanathaIyer,Jyothis Thomas andPadmakumar.G.P., " Shore Protection Using Natural Fibre CompositeSeawall"Proceedings of International Conference on Advances in Materials Mechanics and Management.vol.pp. 497-504. 2010

[6] Baba,M. and N.P. Kurian, "Long term wave and beach data of Kerala Coast- Part I: 1980-'84", Centre for Earth Science and Studies, Trivandrum, Technical Report No.57.1984

[7] CERC "Shore protection manual", Fourth ed, US Army WES.1984

[8] Shin,E., and Oh,Y. "Coastal erosion prevention by geotextile tube technology", Geotextiles and Geomembranes, Science Direct, pp. 264-277.2007