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Importance of Location & Alignment of Geotextile Tubes for the Coastal Protection Measures

B.R.Tayade[a]*, A.V.Mahalingaiah[b] , N.V.Gokhale[c] , M.D.Kudale[d]

[a&c]*Scientist'B', Central Water and Power Research Station,Khadakwasla,Pune-411024, India*
[b] *Scientist'D', Central Water and Power Research Station,Khadakwasla,Pune-411024, India*
[d] *Scientist'E', Central Water and Power Research Station,Khadakwasla,Pune-411024, India*

Abstract

The placement of the geotextile tubes plays a functional role in the performance of the overall protection scheme. The placement path of geotextile tubes is the crucial decision for the designers. The geotextile tubes are widely used as a reef structure, well below the Mean Sea Level. The requirement of the beach width is the main criterion to decide crest level of the nearshore reef structure. In case of beach nourishment project the un-segmented row of tubes placed below MSL can be used as a dual purpose. Firstly, it acts as an offshore reef & helps the trapping of sediments during the downrush and secondly, as a barrier for the offshore movement of the existing nourished sand. The recurring periodic expenditure of the beach nourishment would also decreases after the beach stabilization within 2-3 years. Based on onshore-offshore movement or alongshore littoral drift, the solutions in the form of parallel offshore reef or perpendicular groyne field with sand-filled geotextile tubes are decided. The importance of site specific design with geotextile tubes in accordance with the needs & site conditions etc. are discussed in details with few case studies.

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Keywords: Geotextile Tubes; Groyne; Beach Nourishment; Offshore reef etc.

1. Introduction

In the conventional system for mitigating the coastal erosion, hard solutions like seawall, offshore breakwaters &

* Corresponding author. Tel.: +91-9422121839 ; fax: +91-20-24381004 .
*E-mail address:*bhushan1231@rediffmail.com

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groynes are normally suggested. These solutions are made up with quarry stones or various types of concrete blocks. These traditional forms of the coastal structures are expensive to build & maintain because of the non-availability of heavy rock. Also, the construction requires heavy machineries. Furthermore, the massive rubblemound protection work is not preferred from aesthetic point of view. More environment friendly structures are need of time.

Geotextile tube technology has proven to be an economical alternative to the hard solutions. They are used for slope/bank protection, guide bunds etc. in the riverine problems. The tubes are made up with woven or non-woven polypropylene/polyester fabrics. The tubes exhibits high strength, while having good workability and physical toughness and are relatively cheap. They are permeable fabric, which is able to hold back material while water flows through. Geotextile tubes are large tubes filled with sand slurry mix. The mix usually consists of dredged materials from the nearby area. The trends in the design of coastal protection are transformed into sustainable soft solutions in terms of material used for the hard solution. In the recent years, geotextile technology has widely spread all over the world due to its simplicity & less impact on the coastal environment. Despite the lack of proper design criteria such as hydraulic stability, structural functionality and perspective of their behavior during and after construction, the geo-textile technology has attracted the coastal engineers and has become the effective solution for the coastal protection.

Apart from the geotextile tube design or its hydraulic stability, placement of the tubes plays important role in its functionality. The field experience is of great help for the engineers to improve the design of coastal protection works using the geotextile tube technology. The geotextile tube without combinations of any other materials is considered under the category of temporary protection. Combination of tubes with other materials or add-on components of protection work provide better shelter against the sea forces for the tube. Also, selection of appropriate alignment and placement of geotextile tubes partially ruled out the provisional performance of the system. Protection from the UV rays throughout the life span of the tubes enhances the longevity and reduces the early deterioration of the tube. Tubes can be appropriately covered with sand, if they are to be used for sand dune retention or it can be fully submerged in the sea water permanently or periodically. Allowing this, the life span of geotextile tube can substantially increase.

2. Case studies

The use of geotextile tubes are widely accepted in India day by day. The construction of reclamation bunds, navigation channels for the ports/harbours associated with large dredging, benefited by the use of geotextile tubes. The dredged material is generally available at ease for the filling of the tubes and the tubes can be used for the reclamation purpose. This saves the construction cost of the reclamation bund and also disposal cost of the dredging material to a great extent. Based on these criteria a scheme with geotextile tubes was suggested at LNG Terminal at Cochin. In the absence of data and studies required for understanding the behavior of the coastline, a sacrificial temporary protection with geotextile tubes helps in planning for the coastal protection schemes. This methodology was used for the beach rejuvenation at Devbag coastline in Maharashtra. In order to hold the sand nourishment as well as to help partial breaking of waves in the surf zone, a protection scheme with geotextile tubes were suggested at Dahanu & INS Hamla near Mumbai.

The experiences with the few case studies of completed projects using geotextile tubes in coastal areas are discussed in detail.

2.1. Geotextile tubes at Devbag, Malvan, Maharashtra

Eroded stretch at the village Devbag was protected with sand-filled geotextile tubes on urgent basis. The tubes were aligned parallel to the coast, near the eroded vertical cliff. The total length of protection was about 150 m, in which, 50 m portion lies on the creek side, while 100 m lies on the sea side. A small groyne (25 m long) in a form of 3.0 m dia. tube was also provided at the mouth of a creek. The recommended geotextile tubes are of 3.0 m and 1.0 m diameter and 20 m length each. The tubes take elliptical shape after filling of sand. The geotextile tubes installed at the site worked satisfactorily as an immediate temporary protection work for the two seasons. Later, tubes placed at eroding coastline suffered some damages. Despite the damages, these geotextile tubes used as a temporary coastal protection measure saved further recession of the shoreline. A 25 m long groyne at the tip of the spit indicates some deposition on northern side. These indications of deposition of sand proved very useful for the planning of stabilization of the coastline.

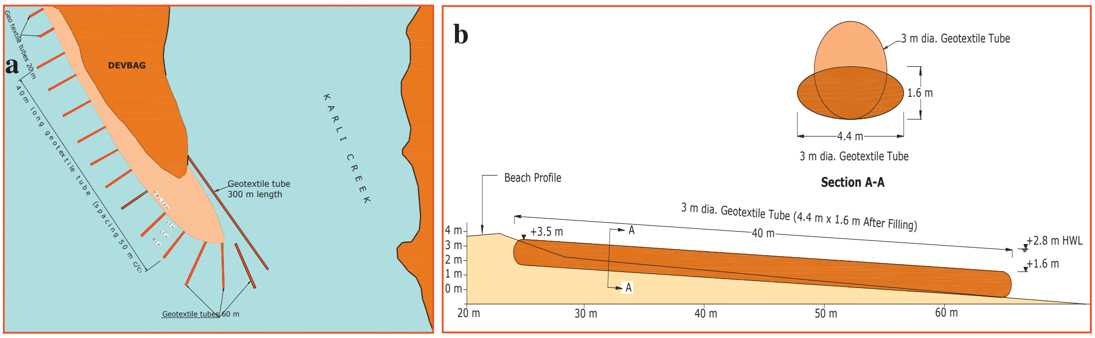

Fig.1. (a) Layout of groyne field (b) Cross-section details of geotextile tube at Devbag.

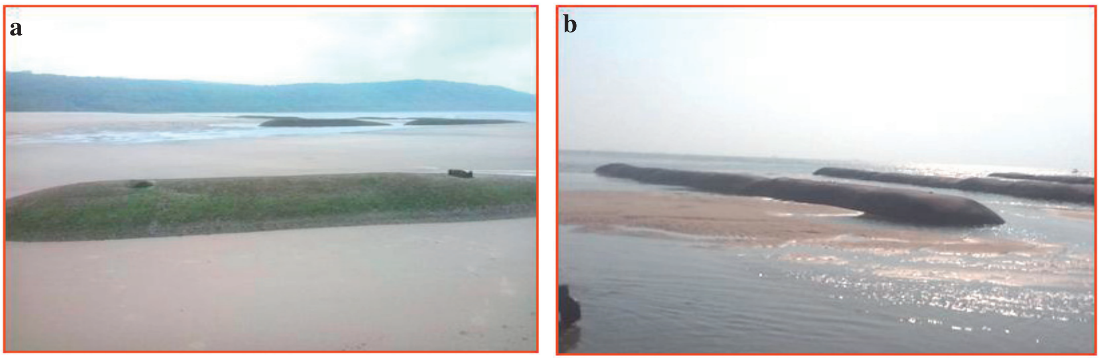

Fig.2. Photograph showing (a) Partially buried geotextile tube (20 m) (b) Geotextile tubes (40 m)

In the second stage development, it was planned to stabilize the coastline by providing groyne field with geotextile tubes. The previous experience of the 25 m long groyne shows that alongshore movement of drift was towards south direction (towards creek mouth). A series of groynes with geotextile tube were planned to cover about 600 m length of coast. A series of groyne with spacing 50 m and ascending length from north to south is shown in Fig. 1(a). Groynes of different length 20 m (2 nos), 40 m (9 nos.), 60 m (3 nos.) & a 300 m long for differentiating the boundary of mouth of the creek were suggested. Tubes of diameter 3.0 m were laid from el. +3.0 m to el.0.0 m (average). A typical cross-section of the geotextile tube is shown in Fig.1 (b). A 3.0 m dia. geotextile tube takes an elliptical shape (approx. 4.4 m wide and 1.6 m height) after sand filling. Sand for filling of the geotextile tube was borrowed from the offshore region with the help of mechanical pumps.

A groyne field with geotextile tubes has faced two monsoon seasons since the inception. Overall the field is intact and no major damage is seen. The beach elevations are enhanced considerably with widening of the beach width at the spit. Few photographs of the groyne field with geotextile tubes & built up beach are shown in Fig. 2 (a) & 2 (b).

2.2. Groynes and protection bund at Cochin

The LNG terminal at Cochin was facing severe problem of siltation in and around its terminals due to littoral drift. The existing 130 m long rubblemound spur for preventing siltation in the vicinity of terminal was insufficient to prevent southward littoral drift, as most of the drift was being bypassed and deposited in the vicinity of the terminal (Fig.3 (a)). Sand deposited on the back side of the terminal has slipped into the dredged area during the monsoon season. Also, heavy tidal currents enhanced the sedimentation in the dredged area of LNG terminal. To overcome these siltation problems a solution of extension of the existing northern spur by 500 m up to about -3 m depth contour was suggested. Additionally, a 150 m long groyne and a shore protection bund behind the LNG jetty were also suggested (Fig.3 (b)).

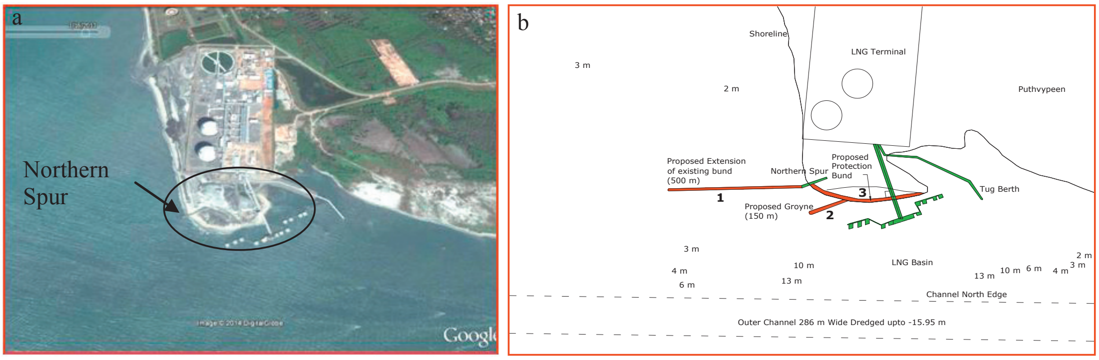

Fig.3. (a) Location of Petronet LNG Terminal (b) Solution in three folds- to arrest the siltation at Petronet LNG Terminal.

Mathematical model studies for littoral drift & shoreline changes were carried out to assess littoral drift distribution and changes in shoreline at the proposed location for the post extension scenario of the existing spur. The net alongshore transport (0.66 million cum) is towards south and occurs majorly during SW monsoon (Mathematical model studies… CWPRS short note, 2014). The alignment of the 500 m groyne is considered parallel to the navigational channel of the Cochin Port & starting from +1.0 m depth contour at tip of the existing spur and upto –3.0 m towards offshore. The groyne makes an angle of about 22^0 with the existing spur towards north.

Two different diameters of geo-textile tubes with main 3.0 m dia. & secondary 1.0 m dia. for the scour protection were suggested. The main 3.0 m dia. geo-textile tubes were provided as a stacking (2+1) manner as shown in Fig. 4. Two 1.0 m dia. geo-textile tubes were provided at the base on either side of the main tubes. A 3.0 dia. geo-textile tube was provided above the two tubes for achieving the desired crest level of the structure. The height of the 3.0 m dia. and 1.0 m dia. tubes after the sand filling would be approximately 1.60 m and 0.50 m respectively. The weight of 3.0 m dia. geo-textile tube and 1.0 m dia. geo-textile tube after 80% filling with sand would be approximately 9.0 t and 1.1 t per running meter respectively. The 3.0 m dia geo-textile tubes were mainly provided to take main brunt of the wave attack and to hold the expected sand deposition. The 1.0 m dia. geo-textile tubes placed on the either side of the 3.0 m dia. geo-textile tubes as a toe-berm were provided to take care of the probable scour. Both the tubes were provided with overlap of 3 m by alternate laying method (Pilarczyk Krystian W., 2000). After filling of the sand, the crest level of the groyne is at el. +3.80 m at the tip of the existing bund & el. -0.2 m at the end of the bund.

In order to trap the sediment movement from the west direction and to provide additional shelter zone for the averted sediments, a 150 m long groyne was suggested. The purpose of this groyne is to prevent movement of sediment coming from the west direction towards the back side of LNG Terminal. The cross-sectional details of the 150 m groyne are shown in Fig.4. The bed levels of the groyne are varying from +1.0 m at the root of groyne to -1.5 m at the end.

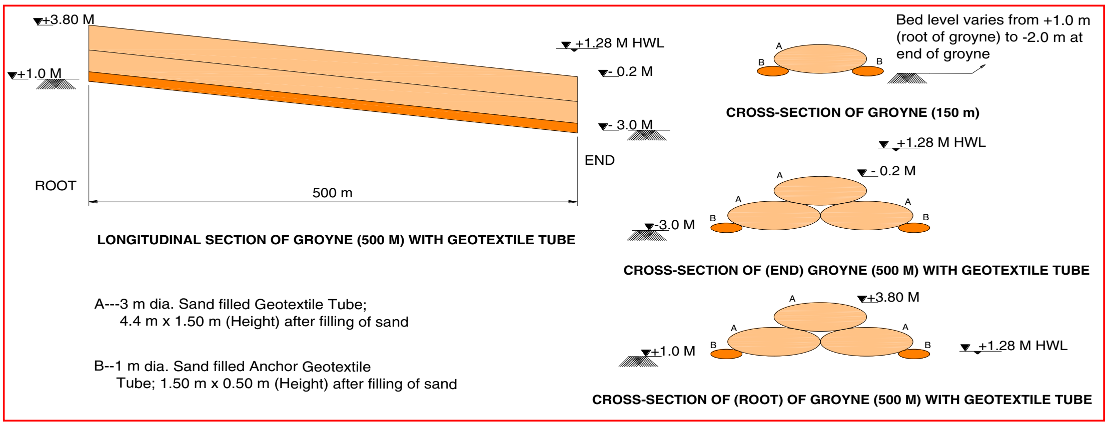

Fig.4. Cross-section details of groynes

The problem of accumulation of sand in the basin of LNG terminal was aggravated as the spur was bypassed by the drift due to insufficient length of spur. The dredged material was dumped on the back side of the Terminal. Due to the wave action and tidal currents these materials have started moving on the backside area of the Terminal. The heap of dredged material makes a steep and unstable slope behind the LNG terminal. It was suggested to make stable beach profile with mild slope in the order of 1:10. The shore protection bund with three geo-textile tubes (3.0 m dia.) arranged in stacked manner (2+1) was suggested. The sand-filled geo-textile bags (0.70m x0.15 m) were suggested in the excavated trench to provide lateral support to the geo-textile tubes (Design of groynes… CWPRS short note, 2014). These geo-textile tubes are arranged in the excavated trench at -1.0 m level. The top level of the protection bund is +1.80 m, which is achieved after filling of the sand.

Based on the completed work, it is found that considerable drift is arrested by the extended groyne. The movement of the dredged material on the backside of the LNG terminal is restricted by the construction of bund and terminal is getting free from accumulation of siltation. The geotextile tube was suggested because of its flexibility & quantum of work (length) in less duration. Since, arresting of drift or avoiding siltation in the terminal area was on top priority, the geotextile tubes were the better solution. Moreover, the dredged sand at the back side of

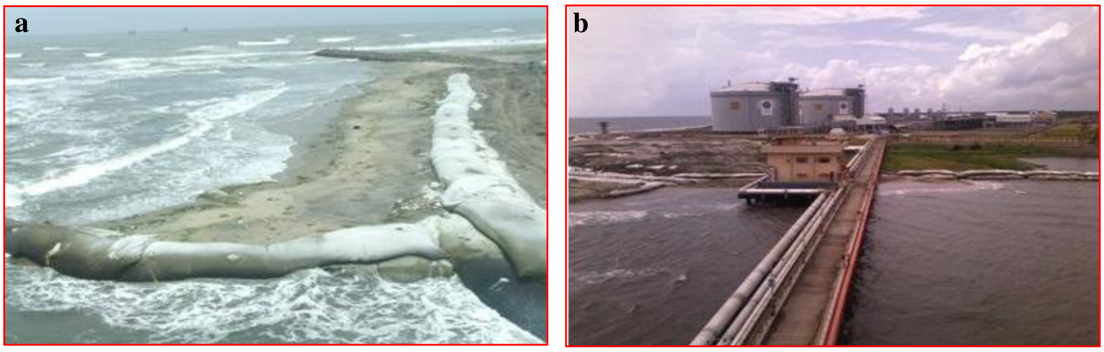

Fig.5. Geotextile tube protection bund & 150 m long groyne (a) View from jetty towards west direction with existing spur (b) View from jetty towards north direction with LNG plant.

terminal was used for the filling of the tubes, which resulted in the reduction of the cost of filling materials to some extent. Also, the cost of transportation of dumping of dredged materials to the deep offshore region was saved.

Generally, flexibility and soft touch promotes the geotextile tubes selection inside the harbour, where maneuvering of ships is a routine operation. Few photographs of completed portion are shown in Fig.5.

2.3. Geotextile tubes used as a nearshore reefs

Geotextile tubes are widely used in the construction of the nearshore detached bund/reef parallel to the coast. It can be combined with beach nourishment, which helps rapid stabilization of the beach. As such, the reef can be of dual purpose viz. allowing overtopping of the waves for the sand deposition and secondly, it holds the nourished/deposited sand on the beach. Generally, the emergent bunds for the purpose of holding sand are constructed at the nearshore region without gap and special attention has to be provided for the turbulence created by the breaking waves. Crest elevation/width and the alignment/location of the nearshore bund play key role in deciding the design details. Use of geotextile tubes as a nearshore bund for holding the nourished sand is the new trend adopted in India instead of conventional rubblemound structure.

2.4. Unsegmented geotextile tubes at INS Hamla, Mumbai

INS Hamla is a naval establishment located at the Aksa-Marve coast at the mouth of the Manori creek, Malad, Mumbai. The coast at the INS Hamla has been facing sea erosion since last few years. In order to mitigate the erosion, a 900 m vertical UCR wall was constructed at the eroding coast along with the beach nourishment.

In order to hold the beach nourishment, a 3.0 m dia. geotextile tube with top at MSL (+ 2.6 m) and 1.0 m dia. tube at the toe level as a scour protection were provided. In order to attain a top level of + 2.6 m, a series of tubes was placed at the bed level of +1.0 m. and 50 m away from the proposed retaining wall (Fig.6). The geotextile tubes laying and beach nourishment work were completed in 2010. It was observed that the beach was stabilized in a couple of years and geotextile tubes were buried up to el. +1.5 m (Fig.7).

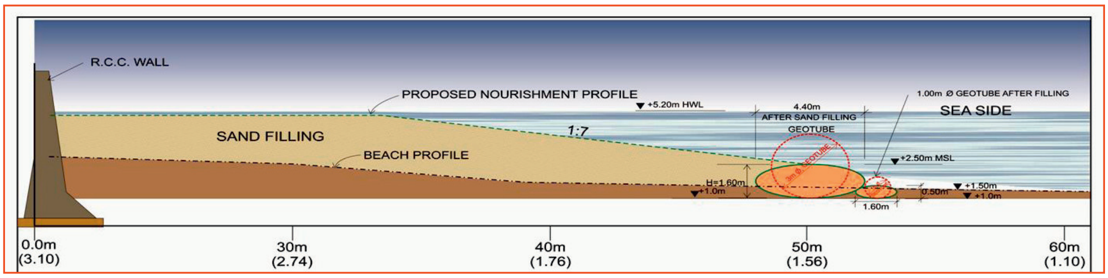

Fig.6. Cross-section details of beach nourishment and geotextile tube at INS Hamla

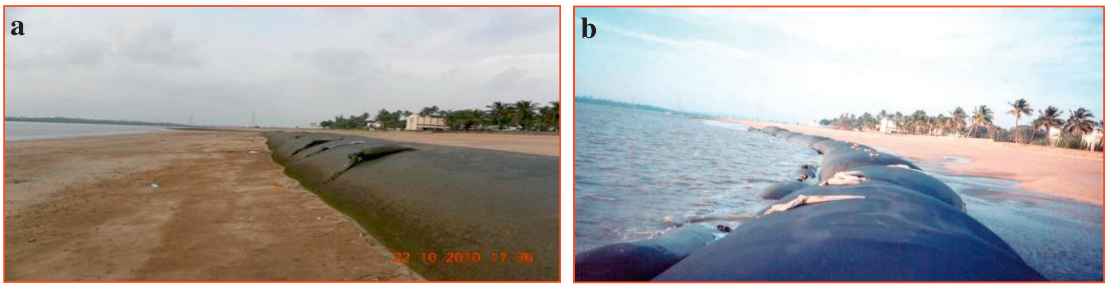

Fig.7. Formation of sand infront of geotextile tube & stable beach profile at INS Hamla

2.5. Geotextile tubes at Dahanu,Maharashtra

Dahanu is situated at a distance of about 110 km North of Mumbai. The beach at Dahanu is extensively used by the tourists for the recreational activities. About 400 m length of the beach is protected by constructing PCC retaining wall with steps towards sea side to facilitate the tourists. The beach is also enhanced by providing beach nourishment.

In order to hold the nourished sand, a series of offshore reef with sand-filled geotextile tubes was constructed in the year 2010-11. A row of 3.0 m dia. geotextile tubes were placed with top level at + 5.1 (+3.5 m bed level at MSL) & at a distance of about 120 m away from the coast. 1.0 m dia. geotextile tubes were placed at the toe of the 3.0 m dia. tubes as a scour protection. The height of the 3.0 m dia. and 1.0 m dia. geotextile tubes after the sand filling were 1.60 m and 0.50 m (approx) respectively. The series of geotextile tubes placed with their top 1.1 m below HHWL is helping in arresting the sand on the beach. The performance of the geotextile tubes as a nearshore reef is impressive and has served the purpose. Few photographs after implementation of the project are shown in Fig.8.

Fig.8. Photographs of nearshore reef geotextile tubes at Dahanu

3. Discussions

Nearshore reef at INS Hamla and at Dahanu is designed to hold the nourished sand and accretion of sand due to transmission phenomenon is the secondary purpose. The locations and the alignment of the reef structure is interrelated to the beach width requirement & also effectiveness/functional role of the reef in varied water levels and incident wave heights. If reef is placed at the greater depths, then the nourished sand over the beach may not get appropriate obstruction elevation and easily wash out due to the waves at higher water levels. Placement of sand-filled geotextile tubes at deeper depths requires sophisticated machinery and normally this machinery is not readily available. The construction cost of these structures would be higher and it may be the major constraint for smaller projects.

Contrary, if reef placement is at higher elevation, then there is a menace of vandalism to the geotextile tube cause by wave action. Hence, it is of utmost importance to decide appropriate placement levels of the reef, where the reef can satisfy both the criteria. Normally, the reef is placed at MSL or below to avoid early damages (e.g. reef laying at INS Hamla). However, where the beach slope is flat and there is restriction of achieving desired depths, the crest level of reef can be placed at higher levels. In this case, trenching at the desired level is not a possible option due to the continuous tidal fluctuations. Also, placing of the lower diameter tube is not a better option due the stability criterion and restriction to the thickness of the beach nourishment. A typical example of this type is laying of geotextile tube at Dahanu (at el. +5.10 m).

In case of placement of orthogonal structures to the shore, the assessment of alongshore drift is necessary to evaluate along with the direction. Shoreline evaluation & littoral drift assessment can be carried out with the help of mathematical modelling for sedimentation & hydrodynamics studies for the area under interest. These studies can help in deciding the span of the structure, bearing with shore, quantum of drift to be deposited on updrift side and probable erosion on the downdrift side. For small projects, the observation for the obstruction of drift by any protruding structures or headlands situated nearby to the proposed site is most useful. It exhibits approximate estimation of quantum as well as direction of the alongshore drift. In the present case studies for LNG Terminal, the mathematical model studies for sedimentation and shoreline evaluation were carried out for deciding the length and angle of groyne with the shoreline. It was found that the alignment parallel to the existing navigational channel of the Cochin Port is the best suited for the maneuvering of the ships and probable siltation on updrift side (Mathematical model studies… CWPRS short note, 2014). In case of Devbag site, the past experiences with the sacrificial groyne are most useful for deciding the placement and alignment of the groyne. It is beneficial for the small project to evaluate drift assessment with laying single sacrificial groyne with the geotextile tube to get the perspective functional role of the groyne field.

In certain circumstances, the geotextile tube technology was used at the eroding coastline. Geotextile tube structure placed abutting to the eroding coastline may not perform effectively and get damaged at an early age (Kudale, M.D. et.al. 2014). This was experienced at Devbag & several coastal sites in India. However, geotextile tubes placed on the eroding coast covered by rubble protection can enhance the life of the structure. Geotextile tubes can be used in the partially protected environment or away from the severe wave attack**.** Geo-bags filled with coarser materials and arranged with gentle slope can be one of the alternatives for protecting the eroding coastline.

The damaged geotextile tubes can be easily replaced. Damage to the geotextile tubes does not result in spoiling the beach, like in the case of other hard solutions. Sandy & flat bed is essential for placing of the geotextile tubes. The bed with rocky outcrops can damage the geotextile tubes.

4. Summary

The life span of geotextile tubes are limited & should be properly planned according to the requirement of the project. The placement in terms of depth and alignment plays a crucial role in the functionality and deciding the life of the tube. It is advisable to carry out proper studies regarding the sedimentation & shoreline evaluation prior to the implementation of the project. Otherwise, observation for the obstruction of drift by any protruding structures or headlands situated nearby to the proposed site is most useful.

In case of nearshore reef combined with the beach nourishment, it is observed that the performance and life span of the geotextile tubes will be enhanced by placing it at MSL or below. The greatest advantage of the geotextile tubes is the economical alternative compare to hard solution & free from adverse environmental effects. The geotextile tubes may be accommodated in the hard solutions as and when required considering the past performance. The success depends on the right design and learning from the behaviour of the geotextile tubes structures in the coastal environment.

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