GEOTEXTILE TUBE AND GABION ARMOURED SEAWALL FOR COASTAL PROTECTION AN ALTERNATIVE

by

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ABSTRACT

The present study deals with a site-specific innovative solution executed in the northeast coastline of Odisha in India. The retarded embankment which had been maintained yearly by traditional means of ‘bullah piling’ and sandbags, proved ineffective and got washed away for a stretch of 350 meters in 2011. About the site condition, it is required to design an efficient coastal protection system prevailing to a low soil bearing capacity and continuously exposed to tides and waves. The erosion of existing embankment at Pentha (Odisha) has necessitated the construction of a retarded embankment. Conventional hard engineered materials for coastal protection are more expensive since they are not readily available near to the site. Moreover, they have not been found suitable for prevailing in in-situ marine environment and soil condition. Geosynthetics are innovative solutions for coastal erosion and protection are cheap, quickly installable when compared to other materials and methods. Therefore, a geotextile tube seawall was designed and built for a length of 505 m as soft coastal protection structure. A scaled model (1:10) study of geotextile tube configurations with and without gabion box structure is examined for the better understanding of hydrodynamic characteristics for such configurations. The scaled model in the mentioned configuration was constructed using woven geotextile fabric as geo tubes. The gabion box was made up of eco-friendly polypropylene tar-coated rope and consists of small rubble stones which increase the porosity when compared to the conventional monolithic rubble mound. In such a configuration, multi-tiered geotextile tube seawall was constructed with four layers of 10 hydraulically filled geotextile tube as the core, while stone filled polypropylene tar coated rope gabion boxes acted as armour layer for the structure. This scaled model examined for emerged water conditions of 0.5 m design water depth for different wave heights and different wave periods. The geotextile tube with gabion showed good wave energy dissipation characteristics. Furthermore, reflection characteristics of this model were also quantified. After that, the design was implemented and constructed as a pilot project on Pentha coast. This case study establishes geotextile tube seawall as an alternative to the conventional method of coastal protection.

Keywords: Seawall, Geotextile tube, Coastal Protection, Gabion, Embankment.

1 INTRODUCTION

The coastal state of Odisha is almost protected with saline embankment for a length of 475 km along the shoreline, which constructed with locally sourced soil. A particular stretch of saline embankment has been observed to regularly eroded during the storm surge, tides, waves, and flood. Pentha (20°32.5’N 86°47.5’E) is a coastal village in Kendrapara District of Odisha State at about a distance of 8.6 km from Rajnagar Town, in India. The damage to the saline embankment was posing a significant threat to the lives and livelihood of the coastal communities. In addition to this, As per the past 25 years, metrological data pertain to the coastline was also affected by two cyclones, viz. Phailin (2013) and Hud Hud (2014). Therefore, a retarded embankment built which is also likely to erode if not protected. The Government of India intends to construct a suitable geotextile tube embankment on the seaside of the retarded embankment. Hence a new geotextile tube embankment was proposed which lies between the two points of (20°32’23.10″ N – 86°47.18.01” E) and (20°32’23.10” N – 86°47’18.01” E) for 505 m length (Figure 1). The site was continuously affected by cyclones and storm surge, associated with a low pressure weather system, whereas the tidal ingression is around 500 meter into the land since 1999, that causes the water to pile up higher than the ordinary sea level and tends to increase the wave height which is a predominant reason for erosion of beach berms and dunes, since storm surge waves are non-breaking waves. The region was connected with Hexa Rivers Brahmani, Baitarani, Chinchiri, Pathsala, Maipura, Kharasrota, Barunei and Dhamara. The coastal tracts with those rivers are interconnected with fault lineament. The general topography is irregular with many drain cuts, rivers, lakes, ponds, swamps, estuaries and lagoons.

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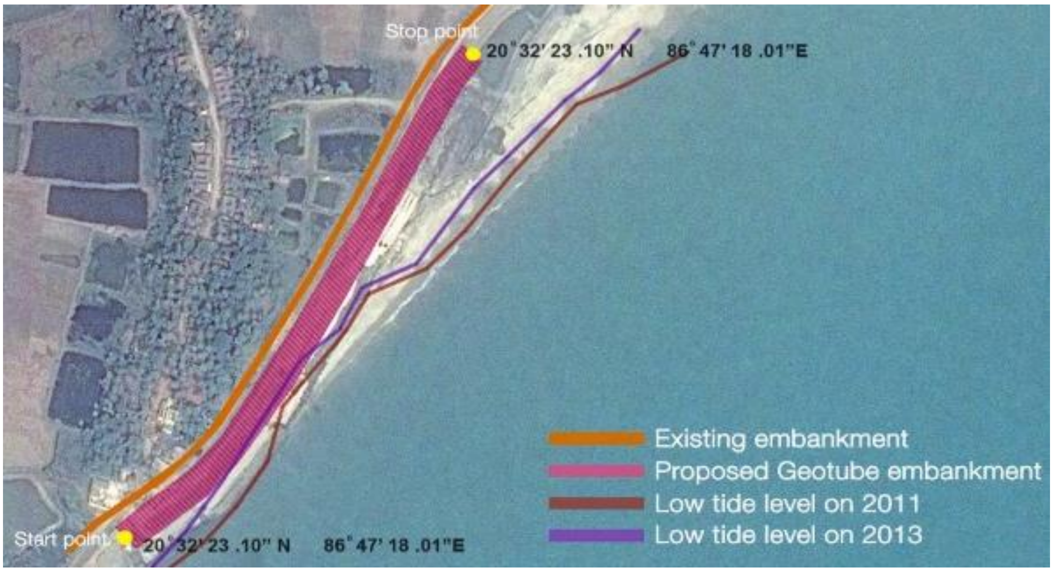

Fig. 1 Google image of geotextile seawall of 50m scale (accessed on July 2017)

1.1 Process of erosion

Coast near the Pentha is a village subjected to severe erosion for the past 25 years. Initially, the sea was 500 m away from the existing saline embankment. Since this original saline embankment eroded, a retarded embankment has been constructed 60 m behind. The shore was at 50 m from the retarded embankment on 21st Nov 2009 and on 23rd Oct 2011 and coastline was at 33 m from retarded embankment eroded at a rate of 8.5 m/annum. Hence the erosion rate is about 8.5 m per annum. Storm waves from 2009 encroached around 300 m stretch of the retarded embankment. Since the retarded embankment proven ineffective a new standalone geotextile tube embankment has designed with 30 m base width and a height of 7.4 m, aligned about 5 m to 10 m away from the retarded embankment for a length of 700 m during 2011; The standalone geotextile tube cross-section detailed in Figure 2. However, due to the subsequent erosion of coast, the base was integrated, and the width of geotextile tube embankment had altered to 24 m from 30 m.

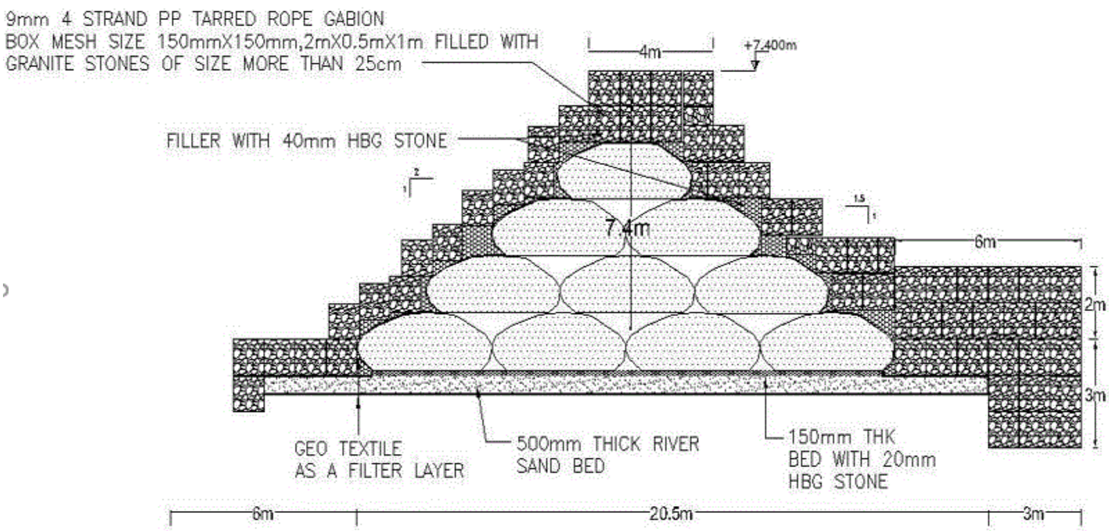

Fig. 2 Typical cross-sections of geotextile tube embankment (All dimensions are in m)

Hydrostatic pressure occurs due to groundwater seepage and development of pore water pressure mobilises sufficient stress in the soil. The foundation soil over the site is highly plastic, and the soil characteristics are poor. Hence this low bearing and undrained material behaviour can offer less resistance to the structural loads when exposed to dynamic wave loading. Apart from foundation soil, wave characteristics must adequately assess through model study, which needed for understanding structural stability well in advance. A brief literature study of geotextile tube seawall with and without gabion protection as a coastal structure conducted along with the practical experience gained on the construction grounds.

2 Factors influencing the stability of geotextile tube and gabion boxes

There are two major factors for the failures of geotextile tube structure: the hydrodynamic factors (such as inertia and drag) and geotechnical factors. The wave-induced lateral forces must counterbalance in addition to horizontal and vertical loads by the geotechnical characteristics of soil bed profile. Inadequate handling of these loads can lead to various types of failures of the geotextile tube embankment system. The factors influencing the stability of geotextile tubes are detailed in following sub-sections.

2.1 Hydrodynamic failure mechanism

Hydrodynamic loads can alter the shape and geometry-related characteristics of the geotextile tube configuration, locally as well as globally. This effect set up various mechanisms of failures as reported by (Jackson *et al.* 2006) and (Lawson 2008). These studies show that sand loss or sand migration is due to the aggressive action of waves and currents which passes through the geotextile pores. This cause the failure of the geotextile tube containment system. These losses can detect a loss of sand fineness within the geotextile tube cross-section. The rate of sediment loss from the geotextile tube structure will initially influence the structure geometry, and in due time it will fail. To prevent the sand loss, the particle size of fill soil should be higher than the geotextile aperture size. Another reason for sediment loss (although not directly related to hydrodynamical loads) can be due to the damage of geotextile such as vandalism, bursting, and puncturing. The different types of hydrodynamic failure mechanism of geotextile tube due to sand loss are as follows.

2.2 Geotechnical failure mechanism

Geotechnical failures refer to the failure of the base or sub-base layer underneath the geotextile tube. Hence, such failures depended upon engineering characteristics and physical composition of soil which will vary concerning location, environment and influence of load acting upon them. Usually, engineering properties which modified during soil deformation are the shear strength, stiffness, and permeability. Coastal structures exposed to wind, waves and currents; hence these environment characteristics also influence the foundation soil properties and its stability. Such scenarios explained in detail in following sections.

2.3 Need for the geotextile tube embankment

Geotextile tube made of woven geotextile sheets which are flexible and perforated, hence allows water to exit. Thus the development of pore water pressure will be avoided. If any differential settlement occurs, the geotextile tube will adjust with soil bed profile because of the flexibility and porous nature of geotextile tube. These tubes will act as a solid core in the embankment and will serve as an impervious medium. However, these geotextile tube elements continuously subjected to various static and dynamic forces such as gravity, surcharge, and wave loads. In addition to the lateral forces, they support overburden pressure. A combination of these applied forces and loading may contribute to potential problems. Therefore, to counterbalance these forces gabion boxes are used to dissipate the large kinetic wave forces. Another significant advantage of the gabion boxes is that they shield the geotextile fabric from solar Ultra-Violet (UV) radiation and hence increase their durability.

3 Results and discussions

The variation of K_R, K_T, $K_{L,}$ are studied for design water depth of 0.5 m. The former water-depth used for assessing the effect of high tides, whereas the latter one includes the high tide and storm surge. Results of the various hydrodynamic coefficients compared with non-dimensional parameter (D/L) for different wave steepness ranges H_{m0}/L, where, H_{m0} is the significant wave height obtained from the wave spectrum and D/L denotes the relative water depth. D is usually the water depth it crosses the structure from toe and L is the respective wavelength of the corresponding period of the regular wave were tested. In general, the present study confirms that the geotextile tube configurations structures have better hydrodynamic performance than the conventional rubble mound structures concerning reflection and dissipation coefficients. These results are discussed separately and compared for geotextile tube structure (GTS) and geotextile tube with gabion structure (GGTS). The variation of K_R, K_T, K_L with D/L for various wave steepness ratios are filtered and separated on three different wave steepness range, The results for K_R, K_T, and K_L are discussed for three different wave steepness range (H_{m0}/L) viz. Lowest wave steepness (0.001 to 0.01), Moderate wave steepness (0.01 to 0.02), and Highest wave steepness (0.02 to 0.038). Comparisons are discussed in the in the following sections.

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