INDIAN EXPERIENCE IN COASTAL AND RIVER PROTECTION WORKS WITH GEOSYNTHETICS

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Abstract: India has got a vast coastline of 5400 kms and many major rivers, to name few like Brahmputra, Ganges, Narmada, Tapi, Krishna, Godavari etc are flowing across the country. The large portions of land lost and inundated due to water is a recurring problem everywhere. While conventional solutions have existed, Geosynthetics have found a role in improving the performance of various hydraulic and marine structures. Product invention and application with geotextiles, polymer rope gabions and geotextile forms like the small bags, big bags, geotextile tubes, geotextile containers have been tried out and are being widely accepted. The polymer rope gabions and geotextile forms systems applied were found to be very effective in controlling the erosion and as well as found to be more stable in water front structures. These can be used in various applications like anti sea erosion walls, dyke, groins, guide bunds break water walls etc. These products are found to be very convenient to install in various conditions and can also be installed in underwater conditions. The sand mattresses overlaid with polymer and steel gabions are being used for bank and bed protection works and geotextile tubes were used for construction of under water dykes, open beach nourishments.

The success and the experience gained over a period of the last 7 years with these products in coastal and river bank protection work is shared in this paper.

Keywords: case study , shore erosion , coastal erosion protection, installation , geotextile containers, polymer

INTRODUCTION

In India nearly 250 million people, or around 20% of the population, living within a distance of 50 km of the shoreline, the population density of coastal areas (432 persons per square kilometer [km2]) is significantly higher than that of the country as a whole (256 persons per km2).The majority of coastal communities derive a livelihood from fisheries, agriculture, or tourism and related services. At the same time coastal areas support significant industrial and commercial activities and many urban centers. As water is dynamic, vulnerability caused by sea or river will be severe at any case. Thus proper care should be taken to protect shores and banks.

Protection work can be done through structural interventions such as seawalls, groins and nonstructural interventions like mangroves and other shelter belts, setbacks. Coastal and river protection measures adopted in India consist primarily of structural interventions. Such protections to water body come under the name hydraulic structures (Pilarcyzk, 2003), by coastal structures we imply a number of typical structures such as breakwaters, jetties, groins, seawalls, sea dikes, sea revetments, beach nourishment etc. Inland water structures includes embankments, bank revetments, groins etc.

In recent years, because of the shortage of natural rock, traditional forms of river and coastal structures have become very expensive to build and maintain .Therefore, the materials used in hydraulic and coastal structures are changing from the traditional rubble and concrete systems to the cheaper materials and systems.

Geosystems like tubes, containers, bags and sand mattress made of geotextile, and geomats are successfully implemented to protect sea shores and river banks at various locations of India. Among them some markable cases are the protection of shore between Sankarpur to Halda at West Bengal , nearby swami narayan temple at Tithal, Gujarat, and the construction submerged dike at Hoogly estuary, as well as the bank of Tapi river at Maharastra and Mula river at Pune, Maharastra also protected by polymer rope gabions.

Problem, solution provided , handling and status after installation of these projects are conferred here.

DESIGN BASICS

According to Pilarczyk the following points should be considered when designing a hydraulic or a coastal structure:

- The structure should offer the required extent of protection against flooding at an acceptable risk,
- Vents at the dike/seawall should be interpreted with a regional perspective of the coast
- It must be possible to manage and maintain the structure
- Requirements resulting from landscape, recreational and ecological viewpoints should also be met when possible
- The construction cost should be minimised to an acceptable/responsible level
- Legal restrictions.

With the above factors, client's requirement and future management control the solution selection.

COASTAL PROTECTION WORK USING GEOTEXTILE TUBES

Geotextile tube is a tube made of permeable but soil-tight woven geotextile and filled with sand or dredged material. Woven geotextile tubes are made of geotextile sheets sewn together to form a shell capable of confining pressurized slurry. It is a tubular unit with closed ends and filling ports spaced every 5 m apart. Generally woven polypropylene geotextile is used for making these tubes. The principal factors ensures its function are tensile strength of geotextile soil tightness and seam efficiency. Geotextile tubes used in most shallow water application and the maximum height of tube construction can be 10 m.

Construction of Submerged Dike at Hoogly Estuary

Kolkata Port Trust (KPT) maintains a riverline port, which consists of two dock systems i.e. Kolkata Dock System (KDS) and Haldia Dock Complex (HDC). The two dock systems share a common shipping channel from Sandheads to Saugor. The channel bifurcates at this point, one leading to HDC via Auckland & Jellingham and the other leading to KDS via Maragolia crossing, Bedford, Nayachara channel and several other bars. There are 12 bars in the navigational channel between KDS and HDC (upstream of Auckland Bar) and four estuarine bars in the shipping channel leading to HDC. In order to facilitate shipping, the bars and other locations in the shipping channels are dredged throughout the year to maintain navigable depth. The excessive littoral drift and meandering of channel makes movement ships difficult even after dredging. A flexible breakwater system requires to be constructed so as to minimize the silt carriage by sea water to the navigational channel.

Geotextile tube dike was constructed as an alternative to rock dike for constraining channel movement. One advantage is that the geotextile tubes can adjust to small variations in the ground level and minor foundation scour and do not require as extensive foundation preparation as do rock structures. Individual geotextile tubes of length 20 m are laid to build the submerged dike as shown in figure. If additional length is required the tubes can be attached end to end. The tubes laid adjacent to the excavated channel on relatively even and stable ground. In this project 110 numbers of geotextile tubes of 3m diameter and 20 m length are used

The stitched geotextile tubes were filled by dredged slurry at 30 kN/m^2 pressure with suitable pump. To prevent failure the geocontainers were filled to about 60 to 70 percent of the theoretical fill volume. The theoretical volume is defined as the cylindrical volume of the container.After filling geotextile tubes forming a system of elliptical cross section which are placed at the specific location with the help of splitting barges. Geotextile tube inside the splitting barge is shown in the Figure 1. Enclosed Polymer rope gabion provides additional confinement to the tubes, besides it serves as an anchoring unit. The main client of this project was Kolkata Port Trust. National Institute of Ocean technology, Chennai was interested with this job and it executed the task on experimental basis. Garware-Wall Ropes Ltd, Geosynthetics division supplied the necessary materials and the performance is at satisfactory level. Observations are going on after completion it could be extended to further extent.

The consultant, National Institute of Technology has observed the profile of the navigation channel after 6 months of installation. The movement of channel was restrained. The performance of geotextile tube as a submerged dike is exceptionally well.

Figure 1. Filled geotextile tube in the splitting barge

ANTI SEA EROSION WALL USING POLYMER ROPE GABIONS

Polymer rope gabions, introduced in 2001 achieved a notable place in coastal engineering. It is UV stabilized, woven, flexible foldable material which has higher breaking strength and punching shear. These are manufactured using engineering grade polypropylene/High Density Polyethylene and developed with woven joints. Hence does not corrode even in aggressive environments. These ropes made into cubical boxes of desired dimension with specified aperture size to use in anti sea erosion wall constructions. These gabions showing encouraging performance in coastal and river protection works as it has high impedance to cyclic wave loadings. Rope gabions can be tailor made to site requirements in terms of rope diameter, mesh size, gabion size etc. However generally 10 mm 3 strand Hauser laid ropes and for current projects 9 mm 4 strand ropes are being used. Higher diameter being used for higher volumes and where lifting is also required.

Protection of Swaminarayan Temple at Gujarat state of India from wave erosion

The Swaminarayan temple in Tithal - Gujarat is situated at a distance of around 200-250 m from seashore. The shore suffered extensive erosion due to strong wave action and the formation of eddies contributed by adjacent river and high velocity winds. Seabed erosion had almost reached to the walkway of the temple and posed a threat to the structure in the long run. The problem of erosion is so tremendous that roughly 6- 7 m of the shore were lost per year.

Implemented solution was construction of wall using polymer rope gabion and boulders with geotextile as a filter media below the gabion at the eroded portion of the beach profile. The design of this wall was carried out by Central Water Power Research Station which is shown in the Figure 2. For construction purpose, the polymer rope gabion is made of 10 mm rope 150 x 150 mm mesh of 6070 m^3 and time taken is May 2001 to October 2001.

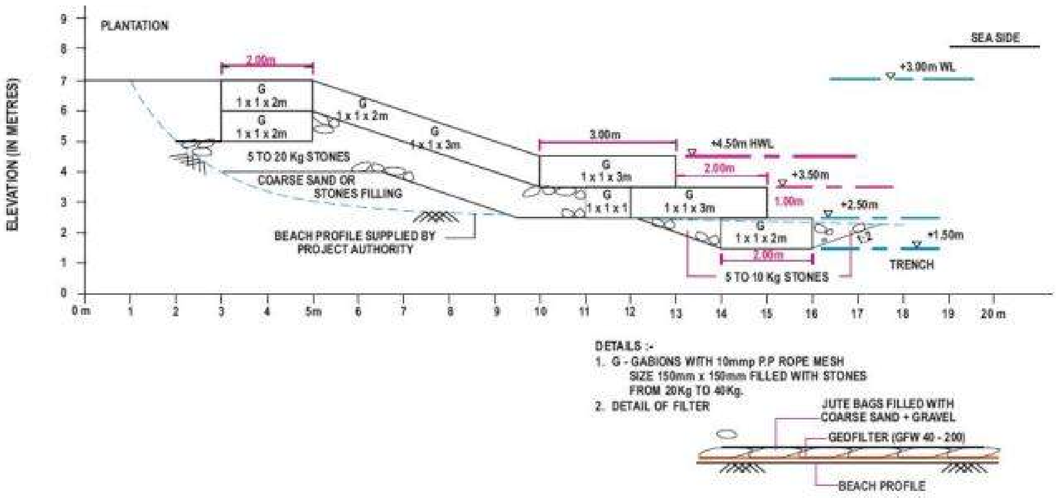

Figure 2. Design of anti-sea erosion bund at Swaminarayan temple, Tithal, Gujarat state, India

After completion of the job, washed out land of about 30 m x 330 m was reclaimed and beautified. The gabion wall is performing very well and about 3 m deep silting has taken place at the wall. The sea wall after 6 years is absolutely in sound condition even after being subjected to severe cyclonic winds and rainfall. No major maintenance cost has been incurred during the last 6 years. Curved portion of the wall and silting in front of wall can be seen in the Figure 3.

Figure 3. Sea wall at Tithal to protect Swaminarayan temple

Construction of Groynes at Varsoli – Maharastra state, India

Varsoli, a village situated on the seacoast near Alibaug, Maharastra, is a small harbour under Harbour Engineering Division , Navi Mumbai, that suffered a problem of bar formation in the entrance of the harbour . This bar formation took place because of the tidal sand movements. As a result of this ships had trouble in moving in and out of the harbour. The dredging of this bar formation would have been a costly affair. Client of this project was Central Water and Power Research Station , Pune and design work also done by this department.

After studying the problem , it was decided to construct two perpendicular groynes to the harbour entrance. Two groynes one on each side of the entrance having length of 1 km was constructed. The design if this groyne was done by Central Water Power Research Station, the design details are shown in the Figure 4. Polymer rope gabions were used in this work as it is suitable to withstand cyclic loading waves. Polymer rope Gabions of 10 mm rope and 150 x 150 mm mesh were used. The total quantity of gabion used is 9755 m^3.

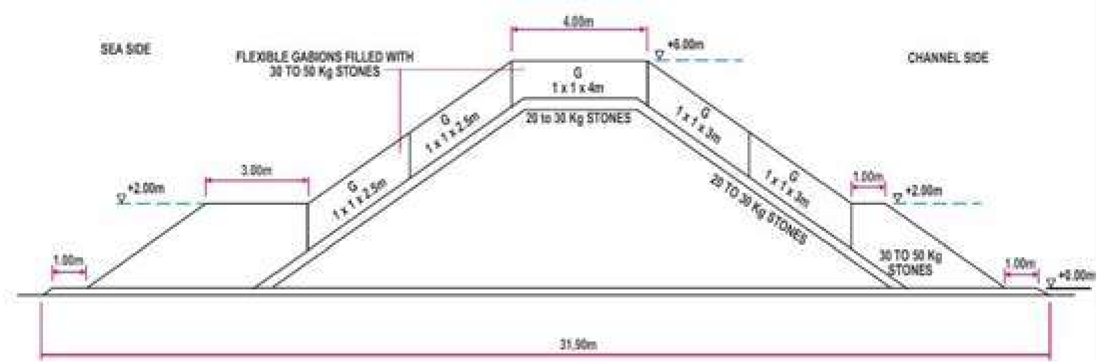

Figure 4. Design details of groyne at Alibaug, Maharastra state, India

Construction was carried out from September 2003 to September 2004. Since then the groyne controlled the bar formation near the entrance and avoided dredging.

SHORE PROTECTION USING GEOTUBES, GEOCONTAINERS, GEOBAGS AND GEOMAT

Geotubes are longer soil holding units, other forms of geosystems are Geocontainers which make box shapes and Geobags are smaller soil containers which makes pillow shapes. The Garmat (Mulch mat) is a high performance product specifically engineered for solving difficult erosion control problems. It consists of top and bottom layers of a flexible non-biodegradable net and a middle layer of biodegradable mulch material. The biodegradable mulch material provides a high level of protection during the initial period.

Shankarpur to Halda shore protection

Coastal line of Bay of Bengal between Shankarpur to Halda had a severe erosion due to waves of height 1 m and wave length of 20 m. At some locations vertical cuts of 4m were observed. It was expected to cause severe damage shoreline scenic views and public property along the coastal line. The measure to this menace should be environmental friendly and it should consider the scour potential of waves. Considering these points an effective solution was found which consist two parts.

- Toe /Scouring Apron & Geotextile-Filter Media
- Geotextile Tube

Any erosion at the toe beneath & adjacent the tube would gradually results in the undercutting of the toe and failure of the slope. Hence Geobags and Geocontainers filled polymer rope gabions are provided as toe protection and covered with Geomat which stabilize the slope surface which is provided depends upon the location. The length of apron is 2.0 m.(Vary Depending of the site conditions). Typical arrangement of 2+1 geotextile tube configuration was chosen and the arrangement of geotextile tube varied as per the site conditions and requirement. Geotextile filter media was provided beneath the total system. Design details are shown in the Figure 5.

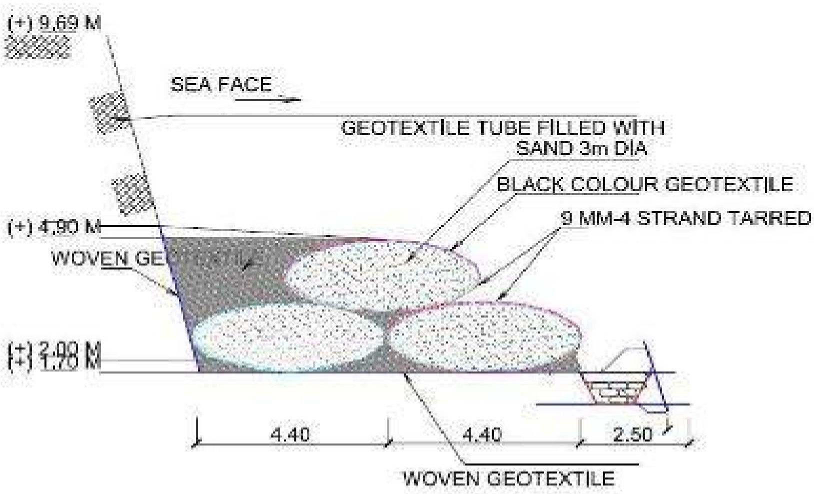

Figure 5. Laid geotextile tubes in 2+1 configuration

US Army Coastal Engineering Manual had been followed for the design purpose. The Goda's formula modified to include impulsive forces from head on breaking waves to calculate the wave force on the structure. Stability analysis had been carried out considering the cases of during construction and post construction.

The project involves the installation of 150 geotextile tubes of 20 m length and 3 m diameter. Presently installation of 100 tubes was done. The project is still in the construction phase and the completed portion of the geotube embankment is controlled the erosion to a considerable proportion. There is no loss of sand from the geotextile tube was observed as the fabric is tighter and stronger. Completed portion is shown in the Figure 6.

The total project cost for mobilization and demobilization, cost of the geotextile tubes, cost of transporting sand from 5 km and filling the tubes with sand was around 1,005,500 USD

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Figure 6. Completed protection coastal work at Shankarpur, West Bengal state, India

RIVER TRAINING

River is a water body which flows inland, can spread its hand to large area. As the requirement of more living area we are in need of restricting streams with the help of embankments. River flow is unpredictable, at any time especially during monsoon it may destroy banks and embankments. Thus it is inevitable to protect and prevent the loss. The following are the design basis

- High pore-pressures should not be allowed to develop in the bank material.
- The bank slope should not be too steep
- The slope surface should be dressed properly and any loose pockets etc. should be compacted before placing the revetment.
- Bed profile should not get silted more or should not get eroded more.

Tapi River Bank Protection Using Polymer Gabions And Geotextile

River bank protection and training works had been carried out at various places of Surat in the state of Marastra of India where the erosion due Tapi river found severe. The main clients for this project are Surat municipality corporation and Irrigation department. Rander and Barimatha, are the specific project locations.

The problem was analysed and solution provided consists of construction Gabion wall, provision of revetments and protection of bed. Polymer rope gabion is the main material used. 20 to 30 cm size stones are used as fill material. The filling work can be done manually and the filled Gabions are placed and positioned with the help of cranes. Stretch lengths at various locations are given below.

- 1050 m length at Rander
- 625 m stretch at Barimatha

Total expenditure for this protection work is around 6,032,800.USD. cost of project/structure depends upon local circumstances, type of land , availability of equipment, manpower and materials, etc.

Woven Geotextile as Filter

Traditional method of filter provision consists of 20 to 30 cm thick graded filter. This process involves construction difficulties as well as usage of various size boulders which is becoming costly now a days. An efficient replacement for this is geotextile . There are two categories as woven and non woven geotextile. Among these Woven is the best suitable one for filter as it satisfies the criteria for permeability, clogging, retention and survivability as well as it is a high tensile material.

In this project woven geotextile is used beneath Gabion walls, revetments and also under the aprons which separates the soil and structure and allows water to flow freely. The installation is shown in the Figure 7. Similarly it has been used in the rehabilitation of failed traditional seawall at Moti-danti, Gujarat state of India. This can be seen in the Figure 8.

Figure 7. Installation of geotextile under gabion wall

Figure 8. Rehabilitation of Sea wall at Moti-danti, Gujarat, India

The project of Tapi river bank protection is towards the end and the completed portion acting as good erosion protection. After completion it will provide solution to the long term problem. The Figure 9. shows construction of revetment.

Figure 9. Bank protection work for Tapi River

Mula River Bank Retention

Bank of Mula river which is running across Pune was found to be in failure stage. Near by agricultural lands were required to protect from bund falling which is of 8 m height. PVC coated, steel boulder filled gabion wall was proposed to retain the bank of Mula river. It is essential to avoid the movement of soil particles from the retained portion to the gabion wall and at the same time the flow of water should not be restricted. Woven geotextile was used in this as a filter and separator. It was provided beneath and behind the wall and proper anchorage was given which can be seen in the Figure 10. Such an arrangement was provided for a stretch of 500 m along the river. Similarly geotextile can be used in various applications.

Figure 10. Geotextile under the Gabion wall

GENERAL SPECIFICATIONS FOR POLYMER ROPE GABIONS

Table 1. Specifications for polymer rope gabions

Properties	9mm rope gabion – 4 Strand
Size of the Gabion	1m x 1m x 1m with lid & slings
Size of the body and border rope	9mm having a weight of 40gm/m with a tolerance of ±8%.
Material of the rope	PP (with adequate UV stabilizer)
Mesh opening size	150mm X 150mm
Tensile Strength	9 mm rope 1560 Kg breaking strength (min.) Rope net 10000 Kg /m width breaking strength. (c) Punching sheer 5000 kg
Structure of the rope	4 strand shroud laid
Construction of net	Woven joint at the intersection of ropes
Abrasion resistance	The rope when tested as per procedure shall have a residual B.S. of at least of 85% of the stipulated rope strength at the end of 1000 cycles.
Thermal Stability	The rope when tested as per procedure shall have a residual strength of 90%.
Resistance to UV radiation	Material shall be adequately UV stabilized.

GENERAL SPECIFICATIONS FOR GEOTEXTILE USED FOR TUBES

Table 2. Specifications for geotextiles used for tubes

S.No	***Property***		***Test Method***	***Value (MARV)***
I	**POLYMER COMPOSITION, STRUCTURE AND PHYSICAL PROPERTIES**			
1	Polymer		Polypropylene	
2	Structure		Woven with multifilament yarn in both warp and weft directions	
3	Mass per unit area		ASTM D 3776	330 g/m^2
II	*Mechanical Properties*			
1	Tensile strength	Warp	IS 1969	80 kN/m
		Weft		78 kN/m
2	Elongation at designated peak tensile load	Warp		25 %
		Weft		25 %
3	Trapezoid tearing strength	Warp	ASTM D 4533	1600 N
		Weft		1600 N
4	Puncture strength		ASTM D 4833	600 N
III	*Hydraulic Properties*			
1	Apparent opening size		ASTM D 4751	250 microns
2	Water flow rate normal to the plane		ASTM D 4491	18 l/m^2/s

ONGOING AND UPCOMING PROJECTS

Geosynthetic products are very well acknowledged by the Indian government. Now all the states willing to incorporate this new technology for protection works. Ongoing and upcoming projects are listed below.

- A portion of embankment of the river Brahmaputra fully disappeared due to river advancing. Here an embankment of 9 m stretch is going to be formed by geotextile tubes with apron length of 27m. The apron consists of sand mattress at bottom and PP rope gabions filled with geocontainers. A stitched sand mattress is shown in the Figure 11.

Figure 11. Sand mattress on the barge

- Costal protection works using polypropylene rope gabions are planned to do in the areas of Uppadia in the state of Andhra Pradesh.
- Technology-dependent quick-fix solutions using Geobags, Geocontainers and Geotubes to control the occurrence of breaching in the coming monsoon was provided to control the flood in the state of Bihar, India.

Acknowledgements: The author wish to express his gratitude to Central Water Power Research Station and National Institute of Ocean Technology, Chennai, who have helped in introducing this new technology.

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CONCLUSIONS

The use of polymer rope gabions, sand mattress, woven geotextile and woven geotextile tubes have been increasingly used in India based on their successful performance. Currently in the state of Gujarat state of India, many projects using Geosynthetics are implemented for approximately a value of 11million USD in coastal and 39 million USD in river bank protection works and the trend is same in other coastal states of India.

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