APPLICATION OF GEOSYNTHETICS AND HEXAGONAL MESH PRODUCTS IN RIVER TRAINING AND COASTAL PROTECTION WORKS

By
Ashish D. Gharpure Minimol Korulla Arun Lila
C.O.O. G.M. Design Engineer
Maccaferri Environmental Solutions Pvt. Ltd.

ABSTRACT

River training and coastal protection has assumed considerable significance in India due to huge annual recurring damage caused by the floods. The paper attempts to highlight the requirement of river training works and coastal protection systems, followed by detailing of different types of river training and coastal protection structures. These structures can be constructed using advanced engineered products, like; Mechanically woven steel wire mesh products such as Gabions and Mattresses, and Geosynthetic products such as Geotextile Tubes and Geotextile Bags, which have been successfully used globally to prevent erosion and flooding at the banks of river and shoreline. Their mechanical characteristics, eco-compatibility and self draining properties make them preferable to other types of materials in the construction of many waterfront structures.

Key Words: Coastal Protection Works, River training, Mechanically Woven Steel Wire Mesh, Gabions, Reno Mattress, Geosynthetics, Geotextile Tubes, Geotextile Bags.

INTRODUCTION:

Water flowing in natural streams and rivers is the wealth of a nation. This wealth can be effectively utilized only if rivers are properly trained and controlled. The main problems related to river are meandering, erosion and displacement of the banks, leading to loss of valuable land and property. On the other hand in the coastal region erosion is defined as change in the position of a shoreline over a period of time. As a result, river training and coastal protection usually receives the maximum attention in concern of land erosion and flooding.

The exponential increase in the population has created a huge demand for development of stable river and coastal bank fronts to effectively utilize the land. The river and coastal flooding, and rising water levels cause serious property damage, affect public safety and degrade the environment. Thus, it has become essential to effectively control the river and coastal erosion and their flooding, to sustain developments.

A number of new products and technologies are getting evolved to conquer the shortcomings of conventional methods of river and coastal protection. In this paper, the focus is given to popular and proven product families of Mechanically Woven Steel Wire Mesh Crates and Geosynthetic Products. The most widely accepted Woven Steel Wire Mesh products are Gabions and Reno Mattresses while popular Geosynthetic products include Geotextile Bags and Geotextile Tubes.

HEXAGONAL WIRE MESH PRODUCTS

Mechanically Woven Steel Wire Mesh products (Refer Fig. 1) were first used on the banks of River Reno near Bologna Italy in 1879. For the past 130 years, steel Gabions and Mattresses have been widely used by Government Agencies and Private Developers for Coastal and River Bank Protections, Retaining Walls and Slope Stabilization Works.

Gabions and Mattresses as per ASTM 975 and other accepted international standards are rectangular in shape and are made of Mechanically Woven Hexagonal Shaped Double Twisted Steel Wire Mesh. The hexagonal shape of the mesh provides a better distribution of the working tensions along the wires that form the mesh. Double twist avoids unraveling of the mesh in case of accidental breakage of any wire. The mesh wires as per the above mentioned codes are of 2.2mm-2.7mm diameter with galvanized and PVC coated to provide adequate protection against corrosion.
Gabions: Modern Gabions are rectangular crates (Figure 3), available in different sizes to suite the requirements at site. The inner space of the crate is partitioned with diaphragms placed at 1 meter center to center. The edge wires of each panel are higher diameter wires than the mesh wires to impart stiffness and retain shape. Each Gabion block is joined with the adjacent Gabion with lacing wire.

Reno Mattress: Reno Mattress is similar to Gabion (Figure 4) unit with large dimensions in plan and of smaller thickness.

Sack gabions: Sack gabion is a cylindrical double twisted steel wire mesh unit (Figure 5) with a lateral opening for the stone filling on site.
GEOSYNTHETIC PRODUCTS

Geosynthetics are construction materials made from polymers. These materials are manufactured as textiles, grids, nets, solid membranes or as a combination of one or more of the above. The type of geosynthetic selected for a particular project depends on the intended application, which can include drainage, separation of different materials filtration of soil particles from draining water, reinforcement, confinement and containment. Attempts are being made to use efficient geosynthetic system increasingly in coastal engineering projects. High strength fabrics are utilized as a form for casting large units by filling them with water, sand or mortar and they are referred as Geotextile tubes and Geotextile bags. Today geotextile system ranging in diameter from 1.0m to 5.5m are used in many coastal applications the world over. Oh (2006) and Shin (2007) presented various issues related to the geotextile tube construction for shore protection at Young-Jin Beach on the east-coast of Korea. A new approach for the stability analysis of geotextile tubes by 2 dimensional limit equilibrium theories is highlighted.

Types of Geosynthetic Products for Coastal Protection

Getexile bags: These are small volume containers that are filled on land or above water and then placed either near water or below water level. Use of geotextile bag is illustrated in Figure 6.
Geotextile tubes: Geotextile tube is a tube made of permeable but soil-tight geotextile and is generally filled with sand or dredged material. Figure 7 illustrate Geotextile Tube.

The most popular form of Geosynthetics containers are geotextile tubes and this paper focuses more on the features, installation, design consideration and application of the same.

Features of Geotextile tubes:

Woven Geotextile tube is manufactured from high strength polymer yarns, specially designed for good soil tightness and high seam efficiency. Its diameter and length are specific for each project and are limited by installation possibilities and site conditions only. Inlet and outlets are regularly spaced along the length of the tube. The tube is filled with dredged material, which is pumped as a water-soil mixture (commonly a slurry of 1 part of solid on 4 parts of water) using an inlet port. The choice of geotextile mainly depends on the characteristics properties of fill material. Geotextile tubes are generally used for coastal protection and also for the dewatering of environment wastes. It is described in terms of circumference rather than diameter due to elliptical shape it takes when filled. While tubes are fabricated to any circumferences, the most cost effective sizes are 15, 30, 45 and 60 feet. Tubes are considered stable when the ratio between the height (H) and width (W) is smaller than 0.5. Filling the tube more than this ratio can lead to excessive circumferential stress resulting in failure (Figure 8).

Specification of Geotextile tubes:

The fabric forming the container shall be of high strength. As a general guideline, Tensile strength corresponding to 18% elongation should not be less than 70 kN/m in machine direction, and 100 kN/m in Cross Machine Direction, when tested as per ASTM D 4595. The main hydraulic parameters, which are to be considered, are same as that of a
Geosynthetic filter. The apparent opening size (O95) as well as flow rate (in l/m²/min) is to be considered in the selection. Apparent opening size (O95) should be less than 0.5mm for retaining the soil particles as per ASTM D 4751 and flow rate should be more than 900 liters/m²/min, when tested as per ASTM D 4491. The fabric should show 80% strength retention after 500 hours of outdoor weathering when tested for UV stabilization - tensile strength retention test as per ASTM D 4355.

Design consideration:

To perform under severe conditions it is necessary to design the Geotextile Tube properly. The major design considerations include sufficient geotextile and seam strength in order to resist pressures during filling and during impact of geocontainer on the bottom, and compatibility between soil and fabric. Long term UV resistance, resistance to abrasion, tearing and puncturing and tube flattening resulting from consolidation of sediments within the tube are additional design considerations. Final elevation of the tube is the most important factor since tubes are to increase the height of berms or provide protection from waves and floods. The Geotextile Tube design depends on the pump discharge pressure, capacity and characteristics of fill material, including grain size distributions and specific weight. Types of geotechnical stability analyses for a Geotextile tube are the followings:
- Global stability - The stability of the whole structure: this is particularly important to stack or terrace the tubes
- Overturning - The possibility that the tube overturns
- Sliding (lateral movement) - The possibility for back pressure or surcharge to slide the structure.
- Bearing (rotation of the base) - The possibility of the foundation to give way under the load of the structure: this is particularly important for soft soils.

Installation of Geotextile tubes:

**General:** Geotextile tubes used in coastal applications are most often filled hydraulically with slurry of sand and water.

**Scour Apron:** A scour apron may be necessary to provide with the geotextile tube to prevent the undermining effects of scour. Scour apron is an apron made of high strength woven geotextile designed to protect the foundation of the main geotextile tube from undermining effects of scour. Scour aprons are typically anchored by small tubes at the water’s edge called scour tubes.

**Site Preparation for Tube foundation:** The foundation for the placement of the geotextile tube and its scour aprons shall be smooth and free of protrusions which could damage the geotextile.

**Filling Material:** Suitable material for filling the tubes should contain not more than 15% fines (percent by weight by passing the No 200 sieve) to minimize subsidence of the tubes after filling.

**Fill Gradation:** Gradation testing of hydraulic fill materials shall be conducted at a minimum, one gradation test shall be performed for each 1000 linear feet (300 m) of fill tube.

**Fill Port:** Fill ports are sleeves sewn into the top of the Geotextile tube into which the discharge pipe is inserted.

**Tube Alignment:** The geotextile tubes require an alignment within ± 600mm of the base line. The filled tubes shall have an effective height of ± 0.5 feet (150 mm) of the specified elevation.
**Tube Anchorage:** The main geotextile tube and the scour apron shall be deployed along the alignment and secured in place as necessary to assure proper alignment after filling. No portion of the tube shall be filled until the entire tube segment has been fully anchored to the foundation along the correct alignment.

**Tube Overlaps:** The ends of tubes can be overlapped or butted together as shown in Figure 9. An overlap of 1.5 to 3.0 m is recommended to ensure proper terminal connection. Beneath the geotextile tube, the ends of each geotextile scour apron shall be overlapped a minimum of 5 feet (1.5 m). The effective height of the tube structure at the overlap is typically 80% of the specified height. (Figure 9)

**Underwater Alignment:** The underwater alignment of tube can be achieved by placing temporary guides on either side of the geotextile tube. Before filling the tube with the sand slurry mix, the alignment correction should be carried out by filling the tube with water. In case there are scour tubes along with the main tube, the scour tubes should be filled prior to the main tube.

**Tube Filling:** After completing the deployment and anchorage of the geotextile tube, the filling with sand water mixture should be started (Figure 10). The mixture shall contain 5 – 15% of sand. The inlet port pressure should be limited to 35 kPa.

![Figure 9: Overlaying of Geotextile tube](image1.png)
![Figure 10: Filling of Geotextile tube](image2.png)

**Fill port closure:** After filling the tube, the port sleeves shall be closed and attached to the main tube. Closing of the fill ports can be done by sewing or knotting by rope or nylon cables.

**Important longevity and environmental considerations of geotextile tube**

Ultraviolet (UV) degradation of an exposed synthetic material is a valid concern since this may affect the lifespan of the geotextile tube. UV degradation is a superficial phenomenon which breaks down the polymers. Anything blocking the UV radiation process (sand, water, algae) will retard the degradation. Polypropylene (PP) and Polyester (PET) are very different materials that undergo different processes when degrading. Both are considered inert and do not combine with anything in the environment. Polyolefin break down by oxygen degradation, resulting in smaller olefins, retaining all the original chemical characteristics. The result of degradation to the tube is the same regardless of the material; that is the tensile strength of the fabric is reduced.

**COASTAL PROTECTION STRUCTURE**

Coastal protection structures, when properly placed, provide protection to the shoreline by minimizing the impact of natural and human made forces. In general, the structures adopted for coastal protection works can be classified as:

**Breakwater:** Breakwaters are usually placed at a short distance offshore. By breaking the full force of incoming waves, they promote the accumulation of sediment between the structure and the eroding beach.

**Groynes:** They are narrow, elongated coastal-engineering structures built perpendicular to the length of the beach.

**Jetty:** These are built perpendicular to the shoreline at confluence of the navigation channel to stabilize the position and to shield vessels from wave forces.

**Seawall:** These are vertical, coastal-engineering structures built parallel to the beach or dune line and usually located at the back of beach or seaward edge of dune.

**Revetment:** Coastal Revetments may be defined as structures placed on the beach profile or along the base of coastal cliff to absorb the energy of incoming waves.
RIVER TRAINING STRUCTURES

With mechanically woven steel wire mesh products it is possible to construct flexible structures that effectively sustain the vagaries of river and also preserve their natural look thus providing eco compatible solutions. An attempt has been made herein to elaborate the utilization of mechanically woven steel wire mesh products to provide solution to river training works.

**Longitudinal Structures (Lining of bed and banks and Retaining structures at banks)-:** Longitudinal structures are built parallel to the river flow. The longitudinal structures aim at erosion protection of banks, control of meandering, and flood protection. The longitudinal structures can be further classified as retaining systems, lining systems or combined structures (Figure 13 & 14). Where the protective structure has to be provided to correct geotechnical instability and there is a space constraint to provide stable slopes, it is desirable to use structure with wide cross section.

**Transverse Structures (Weirs or Check dams)-:** In mountainous terrains the control of erosion in torrent and streams is checked by reducing the velocity of water to a value at which it ceases to move the soil particles forming the bed and banks. This is achieved by reducing the gradient to obtain a stable velocity and hence the equilibrium. Such conditions are attained by the construction of a series of weirs or check dams. Gabion weirs offer numerous advantages over conventional ones. The height and size of Gabion weir can be changed simply by building up or removing courses of gabions on the existing structure. This can be very convenient when control works are required urgently on river on which the collected hydrological information is meager. The vertical weir (Figure 15) is certainly the simplest type, and is often used for small weirs in a system controlling a reach of a stream. The stepped weir (Figure 15) is essentially the same as the vertical type, but the water flowing over the weir dissipates as part of its energy at each step. For large weirs where the height of the structure ranges from 10 to 15m, the requirements of greater stability and improved hydraulic behaviour dictate use of weirs with sloping downstream face (Figure 15).
Deflectors – Groynes: Groynes protrudes into the river bed, with the aim of moving the flow away from the banks of the river on which the groynes are built. The most important function of the groynes is to train the main flow of the water away from the bank; they can be oriented upstream or downstream. Gabion Groynes can be either straight, T shaped or hockey shaped (Figure-16) to cater to the hydraulic requirement.

RESEARCH DONE FOR THE USE OF MATTRESSES

The Colorado State University, Fort Collins, had carried out some years back (1982-83), certain hydraulic tests to develop design criteria for the use of Reno Mattresses. These tests were carried at the behest of MACCAFERRI. Accordingly the indicative Reno Mattress and Gabion thickness in relation to the stream velocities, as derived from the tests on the models carried on at the Colorado State University Fort Collins are presented in Table-1 below. The studies carried out, a comparison of rip-rap and mattress has been shown in Fig 17.

Fig.17. Comparison between rip-rap and mattress thickness
Table- 1 Indicative Reno Mattress and Gabion thickness in relation to water velocities

<table>
<thead>
<tr>
<th>Type</th>
<th>Thickness(m)</th>
<th>Filling stones</th>
<th>Critical velocity (m/s)</th>
<th>Limit Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Stone size(mm)</td>
<td>d50 (mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>70-100</td>
<td>85</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70-150</td>
<td>110</td>
<td>4.2</td>
</tr>
<tr>
<td>Reno</td>
<td>0.15-0.17</td>
<td>70-100</td>
<td>85</td>
<td>3.5</td>
</tr>
<tr>
<td>mattress</td>
<td></td>
<td>70-150</td>
<td>110</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>0.23-0.25</td>
<td>70-100</td>
<td>85</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70-150</td>
<td>120</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>0.30</td>
<td>70-120</td>
<td>100</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100-150</td>
<td>125</td>
<td>5.0</td>
</tr>
<tr>
<td>Gabions</td>
<td>0.50</td>
<td>100-120</td>
<td>150</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120-250</td>
<td>190</td>
<td>6.4</td>
</tr>
</tbody>
</table>

The Water Research Laboratory at the University of New South Wales had carried out some hydraulic tests (C.T. Brown, 1979) for the use of Maccaferri gabion and reno-mattress for coastal revetments. Accordingly the research it was found that for all practical slopes the failure mode is one of sliding rather than uplift, although the sliding is most probably triggered by incipient uplift. Also their study shows the use of thin mattress less then 0.3 m showed a buckling mode of behaviors, which is absent in thicker units. The laboratory work conducted for especially where mattress and gabion work is to be frequently exposed to wave action. It is recommended that under these conditions thick section and heavy stones along the shores be used, where maintenance and consequential cost must be minimized. This report (C.T. Brown, 1979) supports, the use of any type of gabion structure for waves of height 2m or less and a maximum of 3m for frequent occurrence using selected stone and probable ultimate design limit for gabion/mattress of 3 to 4 m.

CASE REFERENCES –

*Devi Nadi and Mahanadi Orissa (Near Paradeep):-*The Gabion Mattress Protection has been provided at the embankment and bed of Devi river, which was severely eroded in October 1999 cyclone. It has been noted that some temporary protection works (rip-rap and bamboo piling) were observed to be dislodged. Devi river sites being close to Bay of Bengal, small tidal waves (in the range of 0.2 m - 0.5 m) are present throughout the year. These waves, combined with the velocity of water (2-3 m/sec) have dislodged the existing protection works. The project was a World Bank aided project. The project involved under water placement of Gabion mattress. The prefilled mattresses were placed on the bed of river with crane. The mattresses were placed at a depth of 15 - 18 meters under water. Cost effectiveness, flexibility of mattress to adapt to the bank profile, durability were major factors for adopting mattress for protection work.

*Fig.18. Gabion mattress Placement and mattress protected banks at river Mahanadi*

*Tulear flood protection, Tulear, Madagascar:*- Tulear is located on the south-western coast of Madagascar and has one of the major ports in the country which is subjected to periodic flooding during the fierce cyclonic season. This
is largely due to the overflowing of the River Fiherenana, which runs for approximately 150km and hence, presents a threat to the residents of Tulear and to the adjacent agricultural land. The catchment area is some 6000m² and pluviometric records in January 1999 indicated a daily precipitation from 105mm to 163mm in 24hrs, which corresponded to a flood return period of more than 50 years. The design parameters for the protection works of Tulear included a discharge of 6000m³/s for a 1 in 100 return period and river bed width of 772m which, resulted in a design average water velocity of 3.61m/s and water depth of 20.13m. In 2001 for the rehabilitation measures they were constructed 12 straight gabion groyes each 27m to 114m long and 5m to 10 wide, 3 bayonet gabion groyes each 55m to 73m long and 5m wide and the lining of a 9.4km long of 4m high dyke with a 300mm thick flexible Reno mattress apron. (Figure 19) In 2004, Construction World magazine awarded Maccaferri a special commendation for Best Project - Tulear Flood Protection

Cap Malheureux cemetery sea wall (Cap Malheureux, Mauritius):- Wave action was eroding the sand dune bordering the Cap Malheureux Cemetery. A retaining system was needed which could withstand the occasional cyclonic conditions, and also retain the sand to a maximum height of 5.8m. A gabion revetment was constructed using 2x1x0.5 PVC coated gabions. (Figure 20)

Norfolk golf club [United Kingdom] : Offshore Flood Protection:- Offshore flooding protection work has been carried out at Royal North West Norfolk Golf Club in United Kingdom by the use of Geotextile Tube made from woven polypropylene Geosynthetic Material. The Geotextile Tube has been manufactured by TenCate Geosynthetic Netherlands, where as Maccaferri UK acted as distributor and technology provider. (Figure 21)

Sg Pahang – Pekan – Malaysia: Shorer Protection work: - Scour Protection work has carried out using Geotextile Bags at Pehang Malaysia. The work included under water placement of Geotextile Bags as illustrated in Figure 22.
**Geotextile Tube and Geotextile Bag Application at Fano near Metaura River Mounth, Italy:** Pipe line instability was encountered at Metaura River Mounth at Fano in Italy. The design was to use Geotextile Tubes and Special size Geotextile Bags to protect the pipeline. The Construction was started in April 2008 (Figure 23)

![Geotextile Bag Installation at Pahang](Image)

![Geotextile Tube Installation (Italy)](Image)

**SUMMARY AND CONCLUSIONS:**

1. Among the different types of structures for river and coastal bank protection, flexible structures like gabions and Reno mattresses have many advantages which make them popular worldwide.
2. With the broad range of Double Twisted wire mesh products, effective, long lasting, eco friendly structures can be economically build for river-training works.
3. River improvement and Coastal protection works always need careful consideration and a scientific as well as practical approach.
4. The products described above are specially designed for environmental friendliness and flexibility. Their use assures minimal disturbance to the coastal environment or aquatic life.
5. Construction of structures using these advanced products involves less work volume and execution time which will contribute to overall economy compared to conventional solutions.
6. Future scope for the experimental and practical study of these advanced engineered products for hydraulically severe conditions i.e. High Velocities, High wave height, Corrosive Environment, Severe Water Quality etc. shall be explored.

**REFERENCES**