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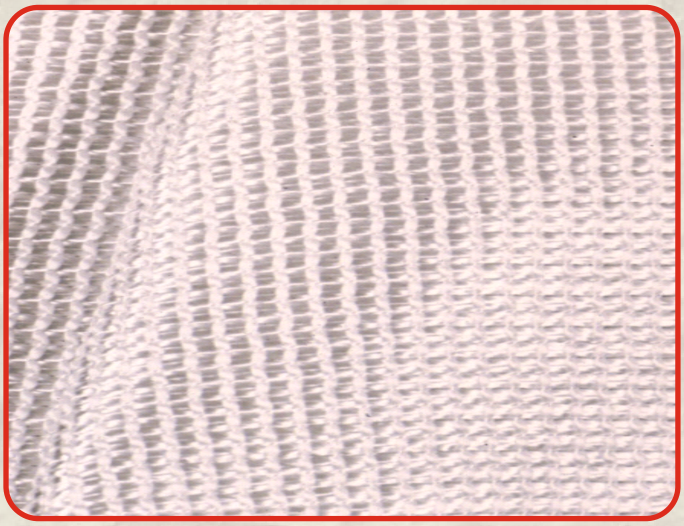

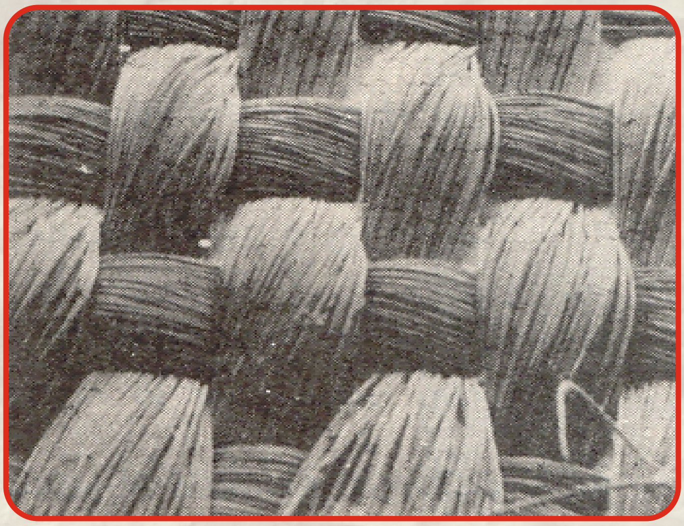

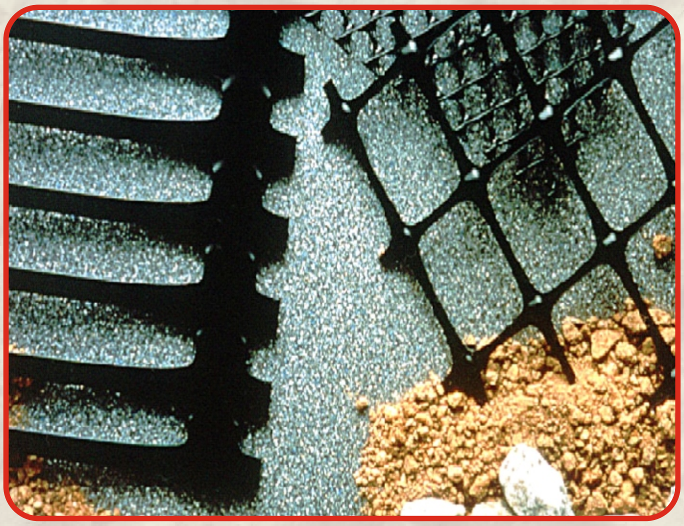

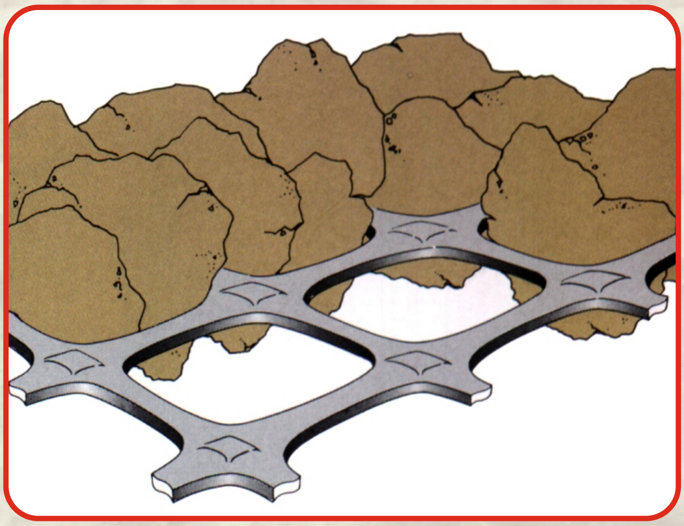

INDIAN CHAPTER OF INTERNATIONAL GEOSYNTHETICS SOCIETY

INDIAN JOURNAL OF GEOSYNTHETICS AND GROUND IMPROVEMENT

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FROM THE PRESIDENT DESK

Protection of river banks and sea shores has become extremely important these days owing to cost of land and existing infrastructure. Geo-synthetics have re-galvanized the techniques for such protection works. Main advantage of geo-synthetics is in the form of longevity of the solution. Avoiding repetitive expenditure drastically decimates the life cycle cost besides saving of large quantity of natural material as an added advantage which serves the cause of environment. Ease of applying them under water makes them a preferred option.

Roads in embankments require stable banks. Either due to non-cohesive materials or due to ground movements that road failures have become a concern which is more pronounced in the hilly terrains. Geo-synthetics help to attain an effective solution of all such challenges.

This issue of the journal focusses on the case studies on bank protections and road embankment stability. Authors of papers have shared their first-hand experiences to encourage wider acceptance of innovative solutions that would be longevous and still more economical than the conventional ones.

The objective of this journal is to disseminate the knowledge and experiences of technocrats such that India can walk a long along the pathway towards environmental safety by way of adopting geo-synthetics and natural textiles wherever possible. It is a matter of immense pleasure for me as the President of the I.G.S., India and Vice President of the Central Board of Irrigation and Power on eve of the publication of this volume which I hope, would be providing a very useful information and learning for those who are in the field of design and execution of challenging engineering projects.

V. P. Kapadia

Vivek P. Kapadia
President
Indian Chapter of
International Geosynthetics Society

FROM THE EDITOR'S DESK

Dear IGS India Members,

Geo-synthetics are one of the most important materials in infrastructure construction today. This covers everything from natural fibres to polymer geomembranes. Internationally these materials play a major role in **soil stabilisation, landfill construction and landslide prevention, rock protection and soil erosion.**

Geosynthetics engineering has made phenomenal advances during the last decade in areas of manufacturing as well as practical applications. As a result, geosynthetics have become essential and regular construction materials that can be used to facilitate construction, ensure better performance of the structures and reduce the long-term maintenance in routine civil engineering works. The creative use of geosynthetics in geo-engineering practice is expected to continuously expand as innovative materials and products are becoming available.

Geosynthetics are now being recognized as fundamentals to sustainable infrastructures development as they can satisfy sustainable development goals, such as economic development, social development and environmental protection. In order to take full advantage of this momentum, we, the members of IGS, must be more proactive in collaborating with relevant parties such as planners, developers, and even construction engineers to raise awareness of geosynthetics and to further discuss how geosynthetics can bring sustainability into the infrastructure developments for future generations. We are confident that these efforts not only add significant value to the IGS membership but also enable us to lead our society to the next level.

IGS India is grateful to authors of the various papers for their contributions included in this issue. Through this journal our attempt is to provide useful information to our readers on geosynthetic which would help them in better understanding and update their knowledge on the State of the art technology and material in this field. We are sure these papers will be of interest to the readers.

We request all the readers for contributing technical papers, case studies, and technical news, etc., which would be of interest to others, for publishing in the subsequent issues of the journal

A.K. Dinkar
Member Secretary
Indian Chapter of
International Geosynthetics Society

USE OF GEO-TUBULAR MATTRESS IN FLOOD MITIGATION AND BANK EROSION PROBLEM - CASE STUDIES

Suresh Maurya[1], Dr. Manish Gupta[2] and Dr. R. Chitra[3]

ABSTRACT

Over the years, significant progress in the use of geosynthetics as a short term and localized flood mitigation has been witnessed. Numbers of geosynthetics polymeric products like geotextiles, geotubes, geocells, geocomposites etc., are helping us to conserve resources and protect the environment. The geotubular mattress filled with sand is another versatile solution increasingly used as revetment along riverbanks, channel slopes, waterway sections and impoundment slopes for erosion protection. Geotubular mattress is manufactured with special integrated composite on the exposed surface to provide a green fleece texture and moisture retention that encourages the rapid establishment of vegetation and shielding UV attack. It replaces the conventional method of using rock, boulders, cement, concrete, steel etc., thereby reduces the emission of the greenhouse-gas from the construction process.

This paper is based on some of the key advances over the past years in using geotubular mattress as environmental friendly solution for flood mitigation and river bank erosion control. Various case studies illustrating the use of geotubular mattress at different vulnerable reaches has been discussed (i.e. Left & right bank embankment along the Ranganadi River, strengthening of Biswanath-Panpur embankment along the Brahmaputra River and construction of geo-dyke in breach portion of Matmara, North Lakhimpur). Geotubular mattress is designed for high strength, pore size, abrasion resistance, UV resistance etc., for protecting the vulnerable reaches.

Through the case studies an attempt is made to disseminate the solutions which may be rapidly deployed on field to achieve maximum benefit to the community, typically through the use of on-site river bed material, innovative geotubular mattress and construction techniques. It is a challenge for the professionals to build stable structures within constrained time against natural disasters like recurring floods.

***Keywords** : geotubular mattress, embankment, flood, erosion, control*

1. INTRODUCTION

Due to increase in number of flood cases in the recent years, protection works and raising of embankment has become a paramount environmental importance. Strong water forces due to flood, migration of fines due to seepage flows as well as erosion and sedimentation effects have continuously threaten, alter and damaged river bank structures. The classic use of geotextile is their application in revetment as bank protection and launching apron as bed protection. These construction are dislocated in water if filter layer is absent, which prevent the passage of fine soil to prevent erosion and simultaneously allows passage of water from a soil to release pore pressure. Revetment with geotextile filters are far more resistance to water forces than conventional materials thereby providing a stable environment for the soil slope. Generally, revetment can be divided into hard revetment or soft revetments depending on the types of material used for their construction. Hard revetment use armour units consisting of rock, boulders, cement, concrete etc., for the protection layers while soft revetments uses geotextile sand filled containers, or vegetation in conjunction with a geomat for the protection layer. Hence a properly designed protection work is to be provided with bank revetment, toe-portion and apron area as per IS 14262:1995 [1]. Interest in the use of soft revetment solutions has increased due to their technical, economic and environmental advantages as compared to conventional materials. Miller et al. 2015 [2], has documented lower impact on environment when geosynthetics material is used in construction. The cumulative greenhouse gas emissions amounted to 10.9 kg CO_2-eq. for gravel layer and 3.6 kg CO_2-eq. for geosynthetics composite drain. The overall cost

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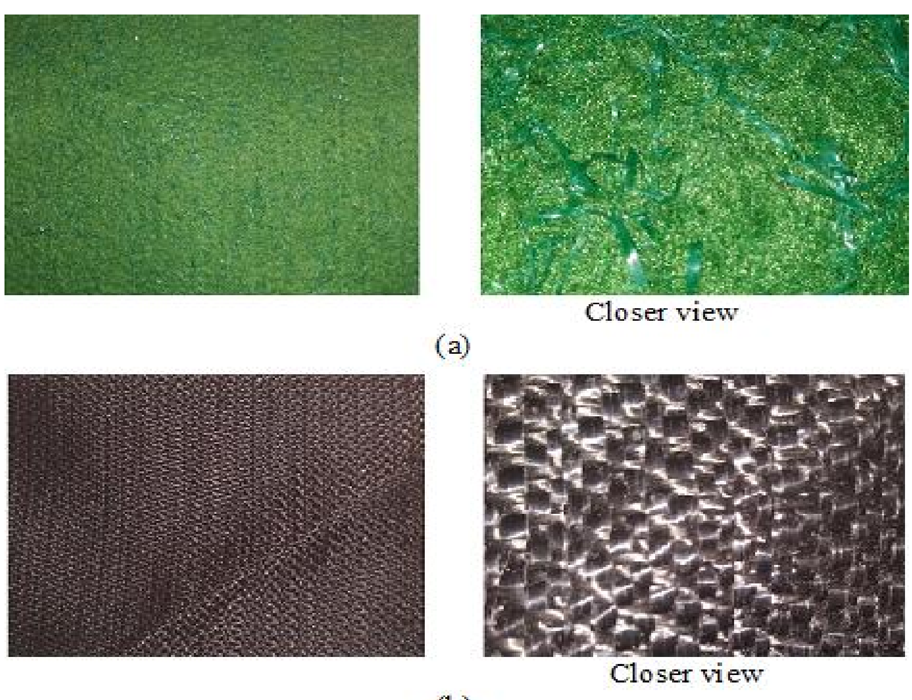
reduction was 30% and construction time was saved when geosynthetics was used. The non-renewable cumulative energy demand of the construction and the disposal of one square meter of drainage layer measured 194 megajoule for gravel layer and 86 megajoule for geosynthetics composite drain. Transport and handling of geosynthetic products strongly reduces the carbon footprint as compared to conventional construction products.

Geotextiles are applied in the form of composite construction elements, which are composed of a geotextile container, filled with locally available sand to bring economy and complete the construction within constraint time period. The products are also used as filter fabric layers [3] in embankment dykes, bank revetments as well as scour protection, separation and filter layers at the foundation level of groynes and breakwaters, structural elements in the form of sand-filled tubes for coastal protection and so on. Due to strong water force during flood, sand filled geotextile bags sometimes get displaced which disturbs the integrity of structure. Geotubular mattress can effectively replace the use of former geobags on embankment slope and bank revetment portions. The applications of geotubular mattress are illustrated with case studies. In addition, geotubular mattress design benefits, its specification, general installation procedure and benefit related to the use of geotubular mattress are discussed.

2. MATERIAL DESIGN

The geotubular mattress is a double layered composite geotextile fabricated to form a tubular mattress when filled with sand and used at design slope of affected reach. Two layers of engineered fabrics are stitched together at regular intervals. The upper layer of the mattress is directly exposed to sunlight, temperature, abrasion etc., where ultraviolet (UV) degradation could be the greatest. The upper layer is therefore made from heavy-duty polypropylene (PP) woven geotextile, needle-punched with a formulated mixture of UV stabilized green fleece and cut tape yarns forming an engineered composite geotextile fabric. This layer provides excellent durability in terms of abrasion and UV resistance. Green fleece, as a special substrate when integrated to the exposed upper surface give instant green effect and provide a textured surface that encourages the rapid establishment of vegetation and shielding UV attack. The lower layer of the mattress is also made up of heavy-duty UV stabilized polypropylene woven geotextile fabric without any substrate. Special pore size and high strength of woven fabrics give good drape properties to achieve the profile of sloping ground surface. Sewing thread is made of high tenacity polyester. The continuous parallel stitches are positioned 350 mm apart with a stitch length not exceeding 40 mm. Geotubular mattress is delivered in rolls of width size 3.8 to 5.2 m which can be easily transported to site. Closer view of upper and lower layer of geotubular mattress is shown in Figure. 1.



Closer view

(a)

Closer view

(b)

Fig. 1 : (a) Upper layer and (b) lower layer of geotubular mattress

Thus a double layered geotubular mattress is a containment product designed in such a way that local available sand can be pumped to form a three dimensional structure of tubular shape for use under different site conditions. Geotubular mattress when filled with sand, typically range in thickness from 0.15 m to 0.3 m. The net result is a completely flexible revetment and can replace concrete slabs, block, rip-rap revetments etc.

3. MATERIAL SPECIFICATION

Geotubular mattresses are designed for high strength, robustness, special pore size, excellent abrasion resistance and UV resistance etc., for the vulnerable reaches to be protected. An evaluation of such specialized product for a specific application needs proper selection of testing program and conduct of the various tests as per test procedures. The specifications of geotubular mattress are presented in Table 1 [4].

Site seaming of adjacent mattress is done at right angles to the sloping directions with a double locking chain stitch, at not less than 3 stitches per inch to achieve a maximum seam strength of 25 kN/m. Geotubular mattress is a factory made products, therefore its engineering requirement can be customized to suit site condition in terms of mechanical strength, pore size small enough to prevent migration of fines and high permeability to ensure quick dissipation of pore pressure.

Such type of composite material replaces conventional materials like rock, boulders, cement, steel etc., therefore there is a huge requirement in the near future and role of quality control and assurance should therefore be emphasized to ensure that the materials being used meet the minimum qualifying criteria.

4. GENERAL INSTALLATION PROCEDURE

Geotubular mattress is designed to provide high strength, drapability, excellent durability and soil tightness to survive the stresses during installation and operational life. Following general procedure is adopted in the installation of geotubular mattress, but not limited to any modification which may improve its efficiency. Installation of geotubular mattress is shown in Figure 2 [5].

Table 1 : Specification of geotubular mattress & stitching thread (North Lakhimpur, W.R. Division, Assam, 2015)

Properties	Test Method	Unit	Minimum values	
			Upper layer	Lower layer
Mass per unit area	ASTM D 5261	g/m^2	≥ 650	≥ 400
Tensile Strength	ASTM D 4595	kN/m	> 42	>76
Apparent Opening Size, O_{95}	ASTM D 4751	mm	< 0.35	< 0.35
Abrasion resistance (Retain tensile strength)	ASTM D 4886	kN/m	> 35	
UV stability (Strength retained)	ASTM D 4355 @ 500 hrs	%	≥ 80	≥ 80
Resistance to oxidation (Strength retained)	ISO/TR 13438 @ 100^{O} C for 28 days	%	≥ 80	
Sewing thread: High tenacity polyester (tensile strength of 200 N and elongation at break is ≥ 20 %				

Fig. 2 : Geotubular mattress laid over prepared slope (North Lakhimpur, W.R. Division, Assam)

1. Geo-tubular mattress delivered in rolls is laid with parallel tubular section running down the prepared slope.
2. Each tube of the mattress is filled hydraulically with sand on-site through the top openings.
3. The sand is introduced through a small hopper and washed down with water pumped from the waterway.
4. While water is drained through the permeable skin of the tubular units. This results in a compact sand filled mattress.
5. Adjacent rolls of sand filled mattresses are joined by seaming on site at right angles to the sloping directions with a double locking chain stitch.
6. Opening of sand filled mattress is closed and anchored by bending it into the trench filled with earth materials at the top of the slope. The size of trench excavated is usually 1.5 m x 1.0 m.

5. ADVANTAGES OF USING GEOTUBULAR MATTRESS

(i) Geo-tubular mattress is delivered in rolls which can be easily transported to site.

(ii) A Geo-tubular mattress systems utilizes locally available sand for the construction of structure. They are more economical and often have lower carbon footprint than the conventional materials.

(iii) Installation is quick and uses simple equipment. They can be rapidly mobilized if necessary for emergency works.

(iv) Geo-tubular mattress system is economical and easy to install without the requirement of skilled labour. They are ideal solutions for areas with poor accessibility and handling of precast concrete units and rip-rap.

(v) Material give good drape properties to achieve the profile of sloping ground surface which makes it easy to install.

(vi) These fabrics can be engineered to suit most site condition in terms of mechanical strength, pore size small enough to prevent migration of fines and high permeability to ensure quick dissipation of pore pressure.

(vii) It is an effective erosion protection solution for the long run with high robustness and durability of the composite geotextile fabric with excellent abrasion and UV resistance properties.

Geotubular mattress is a good choice for the environment as:

(viii) They are less resource intensive as they are lightweight, and easy to install with simple equipment. They are helping us to conserve resources and protect the environment.

(ix) It reduces or completely replaces the conventional method of using rock, boulders, cement, concrete etc., thereby reduces the emission of the greenhouse-gas from the whole construction process.

(x) A special substrate integrated to the upper surface of the sand filled mattress provides a surface texture that encourages the rapid establishment of vegetation for a long term vegetation cover to be in place.

(xi) Increasing environmental concerns regarding the flood and bank protection have led to a massive awareness of available range of geosynthetics types that can provide secure mitigation of harmful human activities and natural calamities.

(xii) They also offer the most energy efficient and cost effective way of constructing protection works while concurrently creating systems which help to protect the environment.

6. CASE STUDIES

After having discussed the relevance of the specific material and its benefits, various case studies on the use of geotubular mattress are presented on flood protection and erosion control works, which is intimately related to environmental problems.

6.1 Left and Right Bank Embankment along the Ranganadi River

Ranganadi River is one of the tributary of Brahmaputra River which originates from Dafla hills of Arunachal Pradesh. Out of the total length of 150 km, the river traverses a distance of 90 km in the hills of Arunachal Pradesh and about 60 km in the plains of Assam. The total catchment area of the river basin is about 2941 Sq km. Out of total 57.53 km of Ranganadi embankment 28.17 km is in L/Bank and 29.84 km is in the R/Bank. Figure 3 shows the location of Ranganadi River and Ranganadi Dam [5].

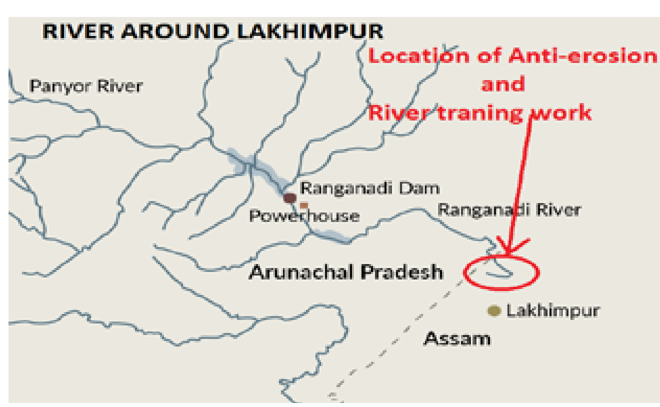


Fig. 3 : Location of Ranganadi River and Ranganadi Dam

6.1.1 *Flood and Bank Erosion Problem*

Gradual rise of silt load in river bed over decades and due to increase in the inflow of water from the upper catchment areas, the surplus/excess discharge have to be allowed to spill over the Ranganadi Dam of the NEEPCO Hydel Power Project which ultimately increases the discharge at the downstream reaches. Increase in the discharge during the monsoon period suddenly leads to flood-lift within a very short period and threatens both left and right bank embankment system of Ranganadi River. Every year flood-lift decreases the free board and causes overtopping. For the safety against the anticipated flood lift, both the banks of River Ranganadi were required to be strengthened.

6.1.2 *Solution Implementation*

The work of anti-erosion and river training works was executed by North Lakhimpur Water Resources Division, Assam under the flood management scheme. It consist of two main construction component i.e., bank revetment and launching apron. It benefitted an area of 18,850 hectares of land comprising of vast area of thickly populated homestead and fertile cultivable land in the North Lakhimpur district of Assam including township and various Government and private assets. Geotubular mattress, Geotextile bags and gabions used in the above scheme were evaluated for their quality at CSMRS, New Delhi [4].

A. Bank Revetment-

The work has been carried out for left and right bank embankment of Ranganadi river for a total length of 7200 m where the river bank is dressed to an inclination of 1V: 2H and over this a layer of geotubular mattress of 0.3 m fill height is laid and anchored at the top and toe of bank slope by bending the mat into key trench of size 1.0 m x 0.75 m. Figure 4 shows installation of geotubular mattress at various stages [5].

B. Launching Apron-

Launching of apron of size 9 m width and thickness 0.9 m all along the left and right bank is carried out with six layers of sand filled non-woven geotextile bags which include two sets of three layers of sand filled geotextile bags of Type A (size 1.03 m × 0.70 m) in one layer of gabion box (size 2m × 1m × 0.45 m). At the junction of the bank and apron, toe-key is formed from two layers of strips of zinc coated wire mesh gabion box (2 m × 1 m × 0.45 m) filled with a sets of three layers of sand filled non-woven geotextile bags of Type A all along the length of apron. Here, the revetment is a part of bank protection work, while launching apron & toe-key are part of bed protection work. Figure 5 shows the cross section of bank revetment and launching apron [5].

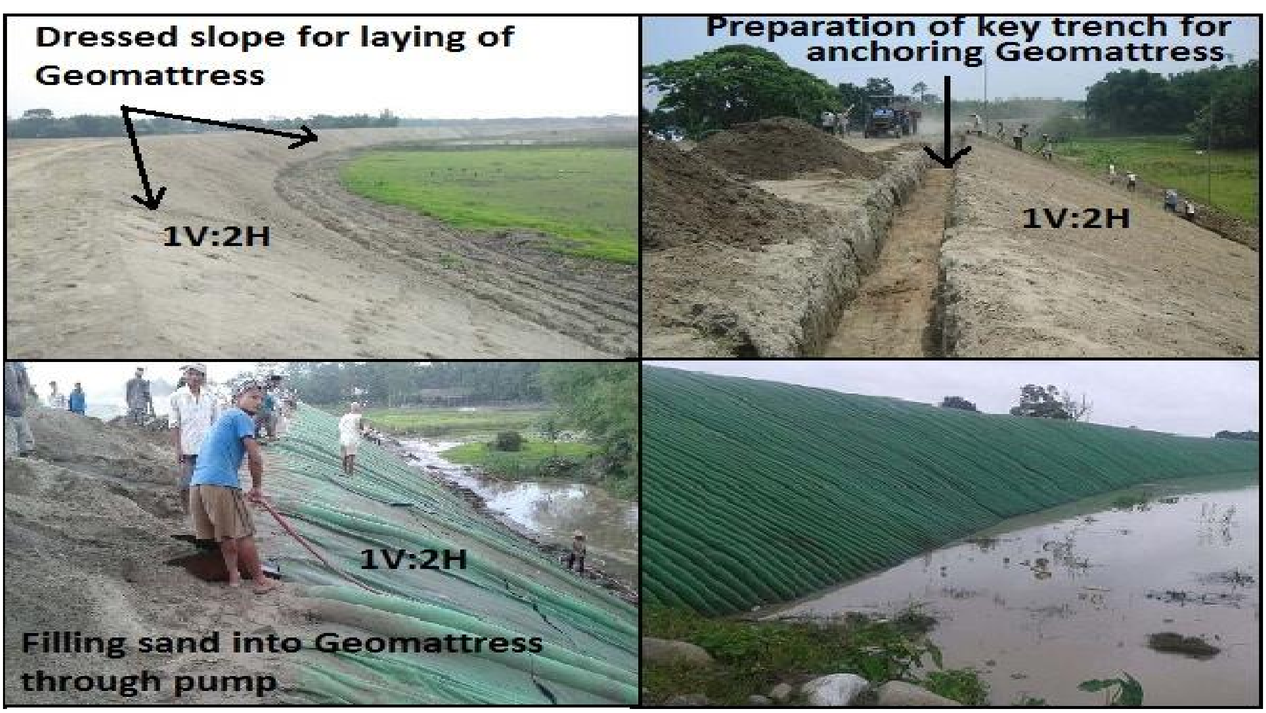


Fig. 4 : Installation of geotubular mattress at various stages (North Lakhimpur, W.R. Division, Assam)

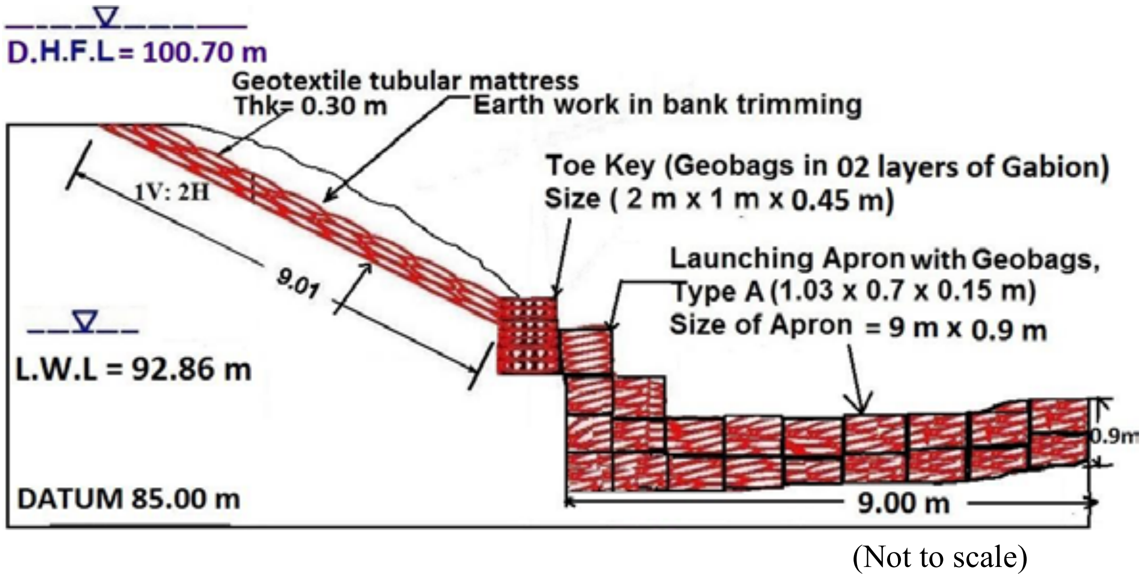


Fig. 5 : Typical cross section of bank revetment and launching apron (North Lakhimpur, W.R. Division, Assam, 2015)

6.2 Strengthening of Biswanath-Panpur Embankment along the Brahmaputra River

6.2.1 *Erosion Problem of the Area*

There was a severe erosion problem from Brahmaputra CH: 282 km (Silamari) to 373 km (Borgaon) in the Sonitpur District of Assam. The erosion in above said reach was so severe that the river bank line migrates 300 to 400 m each year. The difference between the dyke and the river at Bisawnath–Panpur reach was only 35 m at some locations. In case the erosion problem continued, the lakhs of country side population would be flood affected; the huge private and public properties along with the agricultural crops would have been damaged. To prevent this development, the erosion affected bank reaches were stabilized with sustainable strengthening and anti-erosion measures [6].

6.2.2 *Solution Implementation*

The protection work was carried out by Tezpur Water Resources Division, Assam under the flood management scheme. It consists of bank revetment with launching apron and strengthening of the embankment with geotubular mattress. Figure 6 shows the protection work and benefitted area [6]. Geotubular mattress, geotextile bags and gabions used in the above scheme were evaluated for their quality at CSMRS, New Delhi [7].

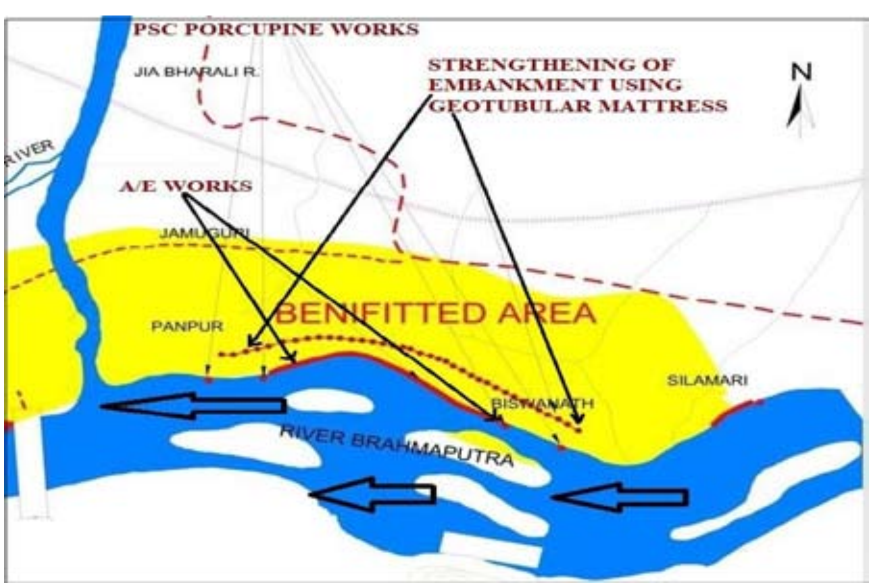


Fig. 6 : Protection work and benefitted area (Tezpur W.R. Division, Assam, 2015)

A. Raising and Strengthening of Embankment

Raising and strengthening of embankment is carried out for the total length of 8758 m. Crest width is kept 7.50 m and top height is maintained at RL 74.30 m with respect to HFL of 72.50 m with freeboard of 1.80 m. Filling of earthwork is done in uniform layers not exceeding 22.50 cm thick with profiling to achieve a slope of 1V:3H. Country side slope is protected by turfing with grass sods and river side slope is protected by a sand filled geotubular mattress. Geotubular mattress is anchored at upper and lower ends of embankment slope by bending the mat into the trench filled with sand filled geotextile bags. Figure 7 shows strengthening of embankment using geotubular mattress [6].

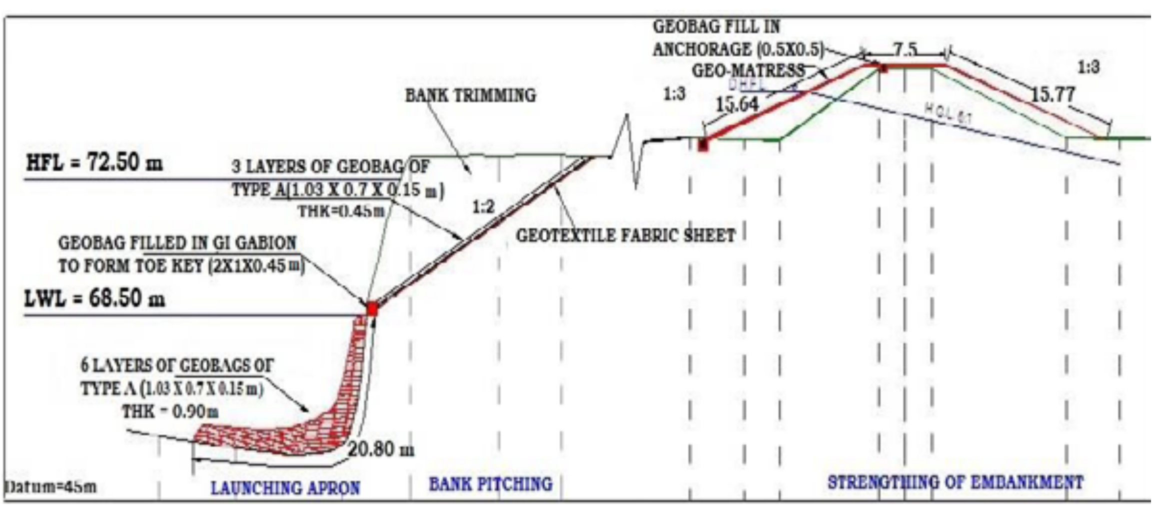
B. Bank Revetment with Launching Apron

Pitching of Geotextile bags and launching of apron is carried out for a total length of 15600 m including Biswanath–Panpur reach of 8758 m length. The river bank is dressed to the inclination of 1V: 2H and over this a layer of non-woven geotextile of 400 gsm is laid as filter media, anchored at top and bottom of bank slope. After placement of geotextile filter on bank slope, sand filled geotextile bags of Type-A (size 1.03 x 0.70 m) made of non-woven geotextile are placed all along the length of bank. Thickness of pitching on bank slope is 0.45 m (3 layers) and top height of bank is maintained with respect to HFL of 72.50 m. Launching of apron is carried out with multiple layers of geotextile bags (6 layers) having thickness 0.90 m and width 20.80 m. At the junction of bank and apron, toe-key is formed from strips of zinc coated wire mesh gabion box (size 2 x 1 x 0.45 m) filled with three layer of sand filled geotextile bags of Type A (size 1.03 x 0.70 m) all along the length of apron. Figure 8 shows typical cross section of launching apron, bank pitching and embankment work [6].

6.3 Construction of Geo-Dyke at Matmara in North Lakhimpur

During the flood of 2007, matmara area was devastated due to major breach on the flood embankment of River Brahmaputra causing enormous damages in

Fig. 7 : Strengthening of embankment using geotubular mattress (Tezpur W.R. Division, Assam)



(Not to scale)

Fig. 8 : Typical cross section of launching apron, bank pitching and embankment work (Tezpur W.R. Division, Assam)

Dhakuakhana division in North Lakhimpur District. The entire stretch of landmass was formed by river sand & silt and construction of retirement bund of 5 km length was not sustainable. Basically the materials available for earthen embankment especially on the northern bank of the Brahmaputra River are sandy & silty soil, which often do not possess required cohesion and stability. However, these materials form an excellent filler material for use in geotubular mattress, geotubes containers and geotextile bags. Geotubular mattress, Geotubes and Geobags made of geotextile materials with sufficient tensile strength were used for construction of embankments and anti-erosion works during the 11th five year plan in Matmara of Dhakuakhana [8].

6.3.1 *Construction of Embankments*

Good quality of soil for embankment construction was not available in the vicinity of the project. Hence geotextile in the form of geotube mega containers was used in the core of the embankment, with adequate soil cover to provide a trapezoidal shape.

6.3.2 *Anti-Erosion Measures with Slope Protection and Apron*

On the river side of the embankment, geotubular mattress filled with sand (200 mm thickness) was laid on the slope to protect the slope from getting damaged due to the rain cuts etc., and due to flood water. It also served the dual purpose of preventing bank erosion and bank sloughing due to seepage of country side water, as it is filtered out by the sand filled mattress. Geotubular mattress was anchored on the top and the bottom at low water level of embankment slope by bending the mat into the trench of size 1.5 m x 1.0 m and filled with earth materials. Trench at the bottom slope also acts as toe-key for the revetment and apron. Geotubes filled with sand were also laid on the river side ground from toe-key for a length of 12 to 16 m as scour apron to prevent scouring in the river bank. Figure 9 shows the geotubular mattress with scour apron at Matmara geo-dyke [9]. Here, the revetment is a part of slope protection work while launching apron & toe key is a part of bed protection work. Slope protection followed by a suitable bed protection can be considered as the key success for any anti-erosion work. This is regarded as a first project of its kind in the country in the year 2010.

Dhakuakhana W.R. Division implemented similar works in the year 2015-16 under flood management scheme with nomenclature “Protection of B/dyke from Sissikalghar to Tekeliphuta at different reaches from Lotasur to tekeliphuta using geotubular mattress and geotube mega containers”. Geosynthetics materials for above scheme were evaluated for their quality at CSMRS, New Delhi[10].

7. CONCLUSION

Geosynthetics are used to fulfill various functions in geoenvironmental engineering and are of ever growing importance in the construction industry. Interest in the use of geotubular mattress in the revetment portion has increased due to their technical, economic and environmental advantages compared to conventional materials.

The case studies briefly presented the problems and the remedial works carried out along the vulnerable reaches (i.e. Left & right bank embankment along the Ranganadi River, strengthening of Biswanath-Panpur embankment along the Brahmaputra River and construction of geo-dyke at Matmara in North Lakhimpur). To enable this system perform in the long run, it is necessary to prevent the erosion from bed and subsequent sliding of revetment and for that formation of toe-key and launching apron is a must. Sand filled geotextile bags assembled in zinc coated gabion box and then placed in a toe-key & apron portion is an ideal option.

Having discussed the environmental benefits, possible negative effect of the product should not be neglected. The geosynthetics material will become brittle due

Fig. 9 : Geotubular mattress with scour apron at Matmara geo-dyke (www.waterresources.assam.gov.in)

to aging at some time. The product will rupture and disaggregate leading to failure of whole construction. Negative effect refers to the accumulation of plastic debris in the environment after their service life. This can be reduced by adopting a process based model for early detection of ageing effect and retrieval of synthetic components to become a part of reconstruction. Emission of additives due to ageing effect can be of environmental concern if the emissions are of eco-toxic nature. Both the problems of plastic accumulation and eco-toxic emission can be avoided by an appropriate choice of the basic polymeric materials in the manufacturing stage.

To make the best use of geosynthetics product in geo-environmental engineering, due care has to be taken (1) for selecting the polymers and their additives for their long term behavior, (2) for proper design of the product to meet expected function and (3) that the product is realized by an experienced engineer and contractors who install the system.

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NOVEL NATURAL FIBRE-BASED COMPOSITE-STRUCTURED GEOTEXTILES FOR PROTECTION OF RIVER-BANK – A CASE STUDY

G. Basu[1], A.N. Roy[1], L. Mishra[1], R. Chakraborty[1] and Md SK J Abbas[1]

ABSTRACT

Bank erosion causes inconceivable damage to the human habitation and property every year. Looking into the perennial problem and non-availability of indigenously produced geotextiles for specific use, a set of novel geotextile fabrics using jute and jute-coconut fibre blended yarn separately (in cross direction) and polyolefin tape yarn (in machine direction) has been developed. Some composite structured/layered-structured geotextiles have also been developed. The fabric samples contain more than 70% (wt/wt) natural fibre. The production viability of the developed geotextiles has been tested through continuous production of the geotextile fabrics using commercial-scale machines at NIRJAFT laboratory. The performance of the fabric samples were evaluated following ASTM standard test methods. The composite structured geotextiles having much balanced property parameters are durable, more effective than both 100% natural and 100% synthetic fabrics and much cheaper than 100% imported synthetic geotextile fabrics. In addition, the developed geotextiles offers excellent drapability and anti-slip property. At the same time it helps to maintain the flora and fauna of the soil, which is not achieved when 100% synthetic geotextiles are used. A successful field trial was conducted for protection of a part of the bank of Mayurakshi River (rain-fed river) at West Bengal using the developed geotextiles based on the principle of using geotextiles as reinforcing material for stable grass-turfing. The vertical height and angle of gradient of the bank were approximately 9.0 m and 60º respectively. All the materials used for execution of laying-work of geotextiles were procured from adjacent locality. The work-force was also appointed from the nearby villages. A total shower (till laying of geotextiles) during monsoon was recorded as nearly 140 cm and then at the end of full monsoon period, even after release of stored water from Massanjore dam through Tilpara barrage @ 1,25,000 cusec (plus additional 35,000 cusec from local catchments due to a spell of spear-headed shower for continuously three days during the same period), no change (deformation), and zero erosion of the part of the river-bank under trial was observed. Vegetation had been established. While, on the rest of the part (where geotextile was not been used), signs of major soil erosion including rain-cuts (Number of rain-cut – 64/100 m length of river-bank) were clearly visible. In case of all-PP geotextiles, patchy grass vegetation, slipped/washed-out soil cover and torn-off places due to cow hooves were observed.

INTRODUCTION

Presently, bank erosion has become a serious problem in many rivers. Generally occurring in the monsoon season, when the rivers are in spate, bank erosion causes inconceivable damage to the human habitation and property. Usually, masonry structures are constructed and boulders are laid on the eroding banks to stop caving. In case of rain-fed river, most of the river-banks are made with sandy soil taken from river-bed, so banks are highly porous and unstable. All these measures are generally of temporary help only. Erosion and caving recur, often in higher magnitude after each monsoon. Since the monsoon mechanism dominates the Indian climate, and as tropical depression in late monsoon causes heavy down pours, the dams and barrages become nearly brim-full and thus the huge quantity of water has to be released from the dams and barrages within a very short span of time, which ultimately results in flood-like situation in every year.

The major benefit of using geosynthetic/geotextile products is that the desired properties of the material can be engineered and manufactured. These "engineered" properties are essential to the product providing the desired results. To assure that these desired properties are achieved in the field condition, it is necessary to properly specify the correct geosynthetic material for the job, as well as, to correctly install the product. If not, chances are the geosynthetic material will not produce the desired results. If the geosynthetic/geotextiles is properly designed, manufactured and installed, it should provide the long-term performance that is expected.

1. National Institute of Research on Jute & Allied Fibre Technology and Indian Council Agricultural Research, Kolkata
Source : Geosynthetics India 2011, 23-24 September 2011, Chennai, India

It may be mentioned-worthy that out of total geotextiles used in India; about 90% are being imported from outsides, mainly due to lack of detail knowledge to produce, and use of appropriate geotextile materials. So, cost of geotextiles is very high in this country and consequently, use of geotextiles for improvement of geotechnical parameters for civil engineering work is negligible in India compared to developed countries.

The prime objective of the present work is to (i) explore the possibility of producing standard geotextile materials using natural fibre (jute or other natural fibres) as the major element(s) in conjunction with synthetic materials having improved property performance suitable for river-bank construction, and (ii) to lay down a range of specifications of jute-based geotextiles which can easily be produced indigenously in most economic way.

MATERIALS AND METHODS

Materials

Jute fibres (Corcorus olitorius) of TD 4 grade and coconut fibre of white variety were used for preparation of 100% jute and jute-coconut blended yarns. 111 tex high density polyethylene (HDPE) flat-tape (slit-film of 2.5 mm width, made from polyethylene having a density 0.94 g/cm^3 maintaining a draw-ratio, 1:7) used for this work was procured from Lohia Starlinger Ltd., Kanpur, India.

Methods

Preparation of yarn and fabric samples

Conventional jute spinning system with slip-draft two-legged flyer spinning machine was used to prepare 100% jute and jute (75%) – coconut fibre (25%) blended yarns. Machines used for fabric production: (i) plain-weave circular weaving, (ii) leno-weave circular weaving, (iii) plain-weave flat-bed (42 inch reed-space) jute weaving, and (iv) needle – punched nonwoven machines were used to prepare fabric samples.

Field-trial of jute-synthetic union fabric for construction of rain-fed river-bank

Field trial of developed geotextiles for protection of river-bank was undertaken on a part of bank of Mayurakshi River at Satpalsa Gram Panchayet under Mayureswar –II Block Development Area in the month of June, 2006, just on the eve of monsoon in collaboration with the Birbhum Zilla Parishad.

The embankment was reconstructed only three months back was built with the soil dug out from the river-bed during summer season. Type of soil of the newly constructed embankment was sandy-silt. So, soil was very soft and unstable. The height of the bank was about 9.5 m. The main economy of the river-side villages entirely depends upon agricultural activities. The agricultural fields are very fertile. The local farmers usually maintain the average cropping intensity at around 3.2 on an average.

Problem of washing-off the river-bank is a perennial problem due to the release of water every year. The Mayurakshi River is coming down from Chhotnagpur plateau. So, it is a rain-fed river, and susceptible to flash flood every year. The part of the river, under trial, is situated at its middle course and the area comes under the Gangetic plain. As the part of the bank (under field trial) is at a sharp bend, facing a huge mass of deflected water with rolling wave, it is usually washed away more or less every year due to occurrence of flash floods during emergency release of stored water from Massanjorh Dam and Tilpara Barrage at end of the pick monsoon season. Due to the flood, population of approximately 55,000 residing at three Gram (Village) Panchayet area (Shhat-palsha, Dekaha, and Ulkunda Gram Panchayet) (38 villages) covering approximately 260 km^2 of land, is badly affected. In addition, a thick layer of sand covers the agricultural fields making the land fallow.

In the present work, seven different types/combinations of geotextiles have been placed on the river bank with the scheme detailed in Table 1.

Table 1 : Type of geotextiles placed during construction of river-bank

Treatment No.	Type of geotextiles fabric used
1	Jute-polyolefin plain woven union fabric
2	Jute-coconut fibre-polyolefin blended fabric
3	Polyolefin leno-weave fabric (47 g/m^2) (Fig 5) backed with 350 g/m^2 jute nonwoven fabric
4	Polyolefin leno-weave fabric (26 g/m^2) backed with 250 g/m^2 jute hessian fabric (Fig 6)
5	Polyolefin leno-weave fabric (26 g/m^2) backed with 350 g/m^2 jute nonwoven fabric (Fig 7 & 8)
6	100% polypropylene (61 tex) leno-weave fabric of 26 g/m^2, mesh 20 X 20 end/dm
7	100% polypropylene (139 tex) plain weave fabric mesh 25 X 25 end/dm, UV-stabilised.

- Average slant-length – 15 m; Average cut-length of fabric – 17 m, Fabric width – 1.5 m.
- Total area covered with geotextiles – 5560 m^2.
- Jute-polyolefin plain woven union fabrics, and Jute-coconut fibre-polyolefin blended fabrics were developed and produced by NIRJAFT.

- 100% PP-tape plain-weave and leno-weave fabrics were supplied by M/s Haldia Petrochemicals Ltd., Kolkata.
- PP leno-weave fabric, 100% jute nonwovens, Jute Hessian fabrics, and 100% PP-tape plain woven fabrics are already being produced by the different organizations for other purposes.

Method of Placing of Geotextiles and Related Information

The part of the bank, under trial was dressed to get a regular slant-surface. The continuous length of the fabric was maintained as 16 – 18 m depending upon the contour of the bank-slant. Before placing, 4 – 5 numbers of 48” wide fabric was stitched (overhead-loop stitch with a plain hemming as safety stitch on 3-fold, 1.5” width seam) manually to make the fabric panes. Fabric was laid manually by unrolling it from the top. The Minimum side-wise overlapping of the fabric has been kept as 0.3 m, if not stitched. The U – hook and/or clamp and with spear-headed bamboo pegs/nail has been used to fix the fabric with the soil at an interval of 1 m (at least) with sufficient anchoring strength depending on water wave force. The fabrics were also fixed to the soil by placing 2-3 long (15 – 20’) bamboos (parallel to top line of the bank) horizontally on the fabric panel on the slant-face. The fabrics were anchored/nailed with some tension so that there should not be any wrinkle, fold, waviness, etc., on the fabric after nailing. Size of spear-headed bamboo pegs was approximately 3’ (long) x 1.5” (wide). Long bamboos collected from the nearby villages, were fixed with a number of U-shaped iron hooks of 24” long and 4” wide made from 6-8 mm diameter tor-rod. Top end of the fabric was wrapped round a long bamboo and nailed with U-hook. The bottom end of the geotextiles was anchored at the base of the slant by wrap-around method. In case of leno-weave polyolefin tape fabrics, initially a light-weight jute Hessian cloth or jute non-woven fabric (250 g/m^2) was laid on the slant (as a filtering medium), before placing and fixing the leno cloth by the above mentioned method. On the one end of the total stretch of geotextile fabric pane, a geotextile tube, christened as ‘Geotextube’ (having diameter 0.4 m approximately) filled with moistened sand, was laid longitudinally, stretching full length of bank contour (approximately 16 – 18 m), and on the other end where the bank first receives the thrust of water, two such geotextubes were laid side by side. The geotextube was laid to hold the cloth against the rolling water current during release of water from the dam/barrage. When laying (of fabric) work was completed, the geotextile fabrics and sand-bags were covered with thick grass-sods, cut out from the nearby field-surface (Fig 1 to 18).

Average 35 unskilled and 4 semi-skilled labour worked from the nearby villages for 12 days to complete the laying work of a 220 m stretch (including dressing of the soil surface). Cost of incurred towards laying of geotextiles including the anchoring and fabrication geotextile materials has been estimated as Rs. 75.00 per m^2.

Performance Evaluation and Monitoring

1. At the end of the monsoon period, a spell of wide-spread rain started on 20th September, 2007 (due to deep depression created over Bay of Bengal and China Sea) and continued up to 26th night over entire Southern Bengal, Jharkhand and Bihar plateau.
2. Total rain-fall at Mayureswar from June, 2007 to September, 2007 has been recorded as 114 mm (approximately). Rainfall at Mayureswar during the period, 24th – 26th September, 2007 was recorded

Fig. 1 : laying of fabric

Fig. 2 : Geotextube

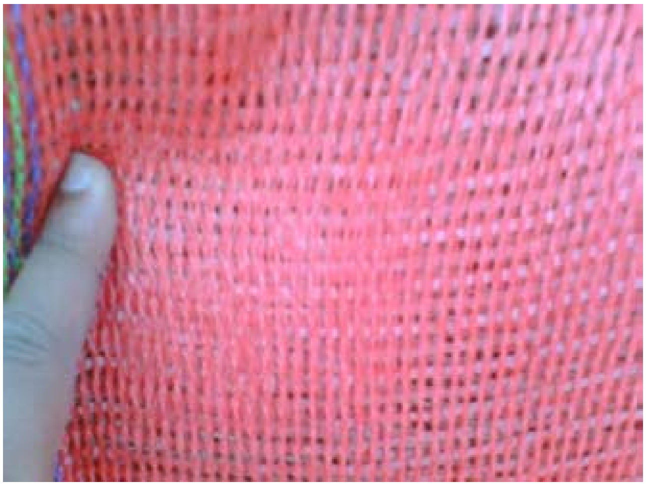


Fig. 3 : pp leno-weave fabric

Fig. 4 : Open-weave light jute hessian fabric

Fig. 5 : pp leno-weave fabric backed by jute nonwoven fabric

Fig. 6 : Trench at the base of the slope for anchoring of geotextiles by wrap-over method

Fig. 7 : Geotextile-tubes being filled in for anchoring

Fig. 8 : Covering geotextiles with grass-sods

Fig. 9 : New vegetation growth within 4 months

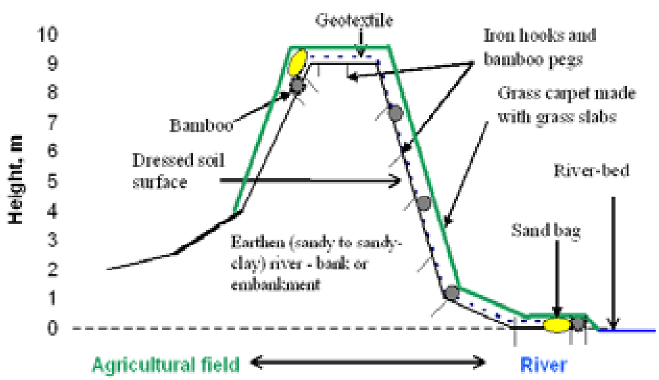


Fig. 11 : Sectional diagram showing method of placing jute-polyolefin union blended geotextile fabrics for the construction of the part of the Mayurakshi river-bank at Mayureswar

as 340 mm (Table 2) resulted to a water flow from the local sub-catchments to an extent of 35,000 cusec approximately.

3. Release of excess-water from Tilpara barrage was started from 8:00 A.M. on 25th September at the of 20,000 cusec reaches the peak-flow at 1,24,000 cusec within 12 h, the peak-flow level was maintained for approximately 4 h and then reduced slowly to the base-flow level for further period of 18 h.

Fig. 10 : Condition of 100% pp geotextiles

Table 2 : Rainfall at Mayureswar gauge station (8.00 A.M.)

Date	Rainfall, mm
24.09.07	70.00
25.09.07	251.30
26.09.07	18.15
Total	**339.45**

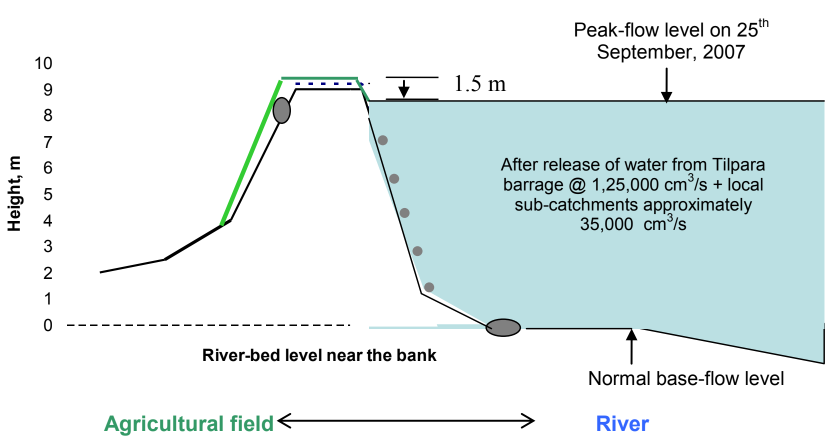


Fig. 12

Table 3 : Comparative results related to the condition of geotextile-laid river-bank vis-a-vis river-bank constructed without geotextiles after four months of construction

	No. of rain-cut due to rain/100 m length of river-bank	Depth of channel of rain-cuts, cm		Width of channel of rain-cuts, cm	
		Maximum	Minimum	Maximum	Minimum
Geotextile-laid river-bank	Nil	Not applicable	Not applicable	Not applicable	Not applicable
River-bank constructed without geotextiles	64	750	100	700	450

In the geotextiles-laid (of seven different types/ combinations of geotextiles) embankment, no sign of slope collapse or rain cuts were observed (Table 3) even after release of water from Tilpara barrage at the rate of up to 1,25,000 cusec in addition to the approximately 35,000 cusec water flowed through the river from local catchments due to the rain-fall. Where as, the condition of adjacent part of the bank made without geotextiles has been badly damaged due to heavy rain and discharge of water. Few portions of embankment slope have been collapsed and at the same time several rain cuts (depth, 100 – 750 cm) were observed having width of cuts ranges from 450-700 cm. The pictures (Fig 17 -20) show the condition of geotextile-laid river-bank after full monsoon season and water discharge from Tilpara barrage. Permanent vegetative growth (Fig 19) and effective reinforcement and filtration through the geotextiles are the main reasons of improvement of the river-bank condition. Jute yarn was decomposed leaving a mesh of synthetic element allowed penetration for intertwining of grass roots with the soil and synthetic yarn. However, some small portions of geotextile pane and geotextube have been exposed due to large lateral force of water current which was again covered by grass slab (minor repairing). Otherwise, no notable deformation/defects of the fabric have been observed. While in case of 100% PP geotextiles, it was observed that vegetation growth was much scattered even after two years. Grass-sod slips down repeatedly and some parts have been torn-off due to cattle hooves (Fig 13). In this year, even after torrential rain during two phases in June and August, 2011, and release of water from Tilpara barrage @ 50,000 to 55,000 cusec for several days, the experimental site did not show any deformation.

Fig. 13 : Pictures showing the extent of erosion due to rain, and release of water from dam

Fig. 14 : Stable grass cover on the geotextile laid bank

Fig. 15 : Contour of erosion

Fig. 16 : Vegetation on geotextile-laid bank

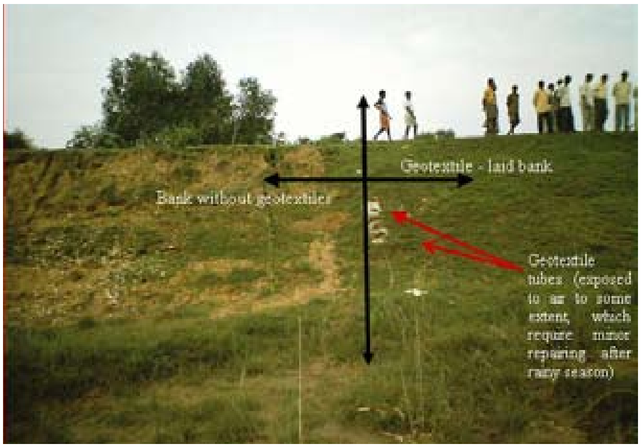


Fig. 17 : Photograph showing the difference between the parts of the river-bank constructed with geotextile and without geotextiles

Fig. 18(a) : Plain weave fabric (HDPE in machine direction and jute- yarn in cross-direction)

Fig. 18(b) : Jute-synthetic leno-weave fabric

Fig. 18(c) : Jute-coir-synthetic blended fabric

(Blending with coir increases the durability of the geotextiles. The structure of the fabric increases the anti-slip property.)

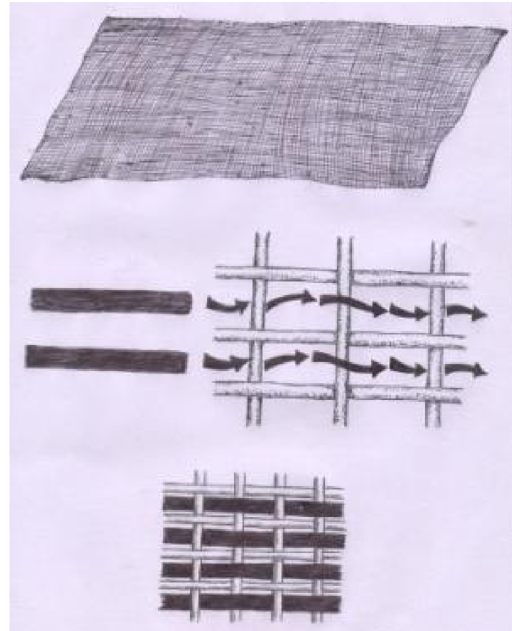


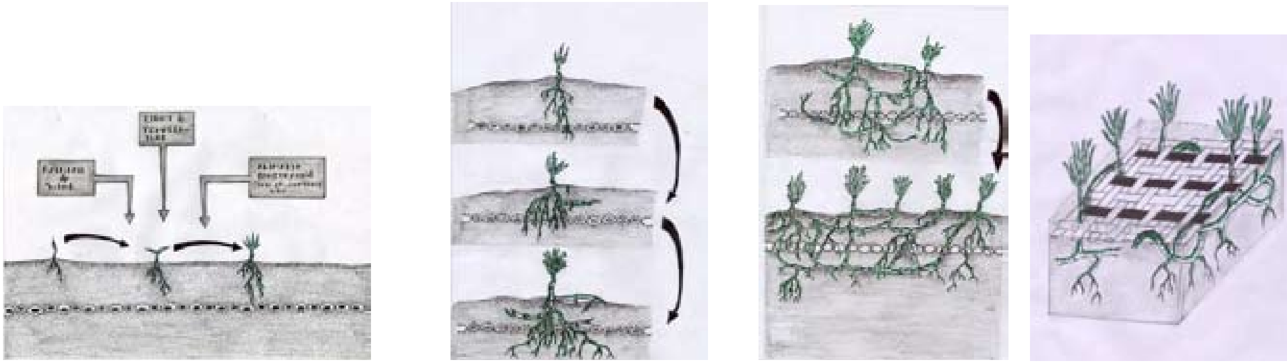
Fig. 19 : Structure of union blended geotextiles

Maintenance Requirements

Minor repairing work of the geotextiles laid-slants may be required after monsoon season for one or two years. Recovering (with grass-slab) is essential when thickness of the cover is reduced and/or erosion occurs. Inspection of geotextile-laid areas is needed within 24 hours after each rainfall or periods of heavy winds or daily during periods of prolonged rainfall. Inspections and consequent action should be continued until vegetative cover is established.

Principle of Reinforcement with Jute-synthetic Composite Geotextiles for Grass Turfing

Initially, the close-structured fabric acts as a fine-strainer (filtrating layer, preventing the soil particles (of very small sizes) to wash away with seepage /run-off water. The finer particles deposited at the back-face of the fabric and form a harder layer of soil. In the mean time, the new grass seedlings grow with time and penetrate their roots though the fine perforation of the fabric. After decomposition of jute, the fabric provides more space for easy access to roots of matured grass/plants maintaining a net structure of the geotextiles – thus provide a nearly permanent reinforcement to the base layer of soil. In addition, surface grass gives a cushioning effect to reduce the impact of large rain-drops as well as huge impact of released (from dam/barrage) water. Fig. – 20 - 21 show that jute yarn was decomposed gradually within a certain period leaving a mesh of the synthetic element allowing penetration for intertwining of grass roots with the soil and synthetic mesh.



(a) (b) (c) (d)

Fig. 20 : (a-d) Sketches showing style of intertwining of root grass with soil and geotextiles during its growth as well as gradual decay of natural fibre

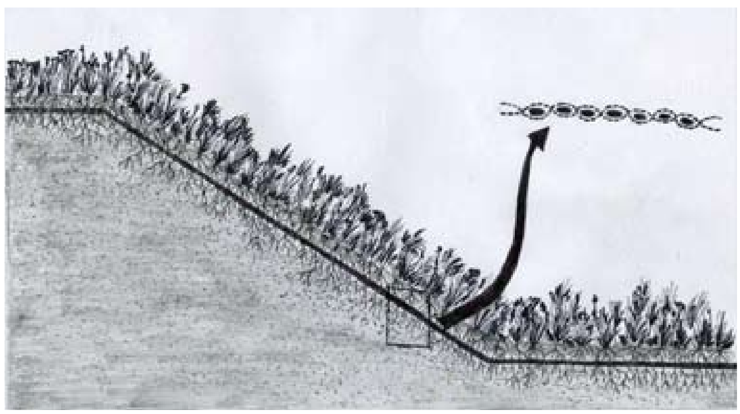


Fig. 21 : River bank after establishment of vegetation

CONCLUSION

1. Jute -synthetic geotextile fabric (suitable for river-bank protection) is possible to produce at indigenously available high productive weaving machines on commercial basis. The 100% jute and jute-coir blended (75:25) yarn of required quality can easily be produced in conventional jute spinning system using suitable eco-friendly spinning additives.

2. As a field-trial, a part of the Mayurakshi river-bank has been constructed using our developed jute-based geotextiles of seven different types/combinations of geotextiles for protection of river-bank. It was observed that even after release of storm-water from Tilpara barrage @ 1,25,000 cusec (plus additional 35,000 cusec), and a spell of spear-headed shower for three days (at the end of full monsoon period) no change (deformation), zero erosion of the part of the river-bank under trial was observed. While, on the rest of the part (where geotextile has not been used), signs of major soil erosion including rain-cuts (Number of rain-cut – 64/100 m length of river-bank) were clearly visible.

3. Minor repairing work of the geotextiles laid-slants is required after monsoon season for 1st two years.

4. Natural-synthetic mixed geotextiles showed much better performance than 100% PP geotextiles in terms of vegetative growth, durability, and maintenance of site condition after placing geotextiles.

5. Laid down a range of specifications (six different types) of jute-based geotextiles which can easily be produced indigenously in most economic way. Type(s) of geotextiles can be selected depending on site condition, availability of geotextile materials and availability of fund, etc.

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APPLICATION OF GEOTUBE AS ENVIRONMENTAL FRIENDLY SOLUTION

Suresh Maurya[1]

ABSTRACT

Rising water levels, higher waves and more frequent storms and heavy rainfalls are increasingly impacting shorelines along coastal areas and inland waterways, river banks and embankments. Many of these areas are experiencing serious erosion and loss of land that is threatening life, property, infrastructure and natural environments. Geotextile tube (geotube) systems are a proven alternative to conventional management approaches and are used worldwide to provide reliable and resilient remediation of contaminated sites, water resource engineering, wastewater treatment, waste handling and storage, pollution control, coastal reconstruction, protection and preservation, flood control, etc. This technology is cost-effective, easy to install, highly versatile and help us to conserve resources and protect the environment. The use of geotube as sludge dewatering application can readily meet the need of a growing wastewater treatment plants. This paper is based on some of the key application of geotubes as environmental friendly solution.

***Keywords** : geotube, sand, water, coastal, flood, erosion*

1. INTRODUCTION

As global warming has caused the sea level to rise in recent years, the river or coastal related disasters such as tsunami and flood have become higher in frequency and stronger in intensity. Conventional structural measures can directly reduce the magnitude of erosion to some extent, but are not always efficient or cost effective. To quarry, transport, stack and construct a structure with large amount of rockfill material, precast concrete units, cement etc., increases the emission of the greenhouse gas (GHG) from the whole construction process. However, there is a growing interest both in developed and in developing countries in low cost or adopting novel methods that has minimum impact on the environment. This is where geoenvironmental engineering plays a vital role in remediation of environmental problems [1]. Geosystems (geotubes, geocontainers, geomattress, geobags, geocurtains etc.) have gained popularity in recent years because of their simplicity in placement and constructability, cost effectiveness and their minimum impact on the environment. However, all these systems have some advantages and disadvantages, which have to be recognized before application.

Geosystems utilize a high-strength synthetic fabric as a form for casting large units by filling with sand slurry or mortar. Within these geosystems a distinction can be made between bags, mattresses, tubes, containers and inclined curtains [2]. All of which can be filled with sand or mortar. Mattresses are mainly applied to slope and bed protection. Bags are also suitable for slope protection, launching apron, retaining walls or toe protection. The tubes and containers are mainly applicable for construction of groynes, offshore breakwaters, protection of coastal and flood prone areas, and as bunds for reclamation works. Geotubes can also be used to store and isolate contaminated materials from dredging etc., and use these units for reclamation works. Geotube dewatering application is discussed in section 4.9. Geotubes are normally formed by inflating the tubes with pumping water along with sand or waste sludge. The advantages of this method are, that the tube is lightweight, easy to transport, reusable in future and can be constructed in any site location. The on-site required is just a portable pump and locally available fill materials.

The ability to develop more sustainably will determine the speed and degree of climate change experienced. While some climate change is inevitable due to past GHG emissions [3]. We need to reduce our future GHG emissions to better manage the future impacts of climate change on the environment, economy, and society.

2. INSTALLATION AND STABILITY OF GEOTUBES

Geotextile tube (geotube) is defined as “a large tube (greater than 2.3 m in circumference) fabricated from high strength, woven geotextile, in lengths greater than 6.1 m)”, according to GRI Test Method GT11, 2012: Standard Practice for “Installation of Geotextile Tubes used as Coastal and Riverine Structures” [4].

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2.1 Installation

Geotextile tubes used in coastal and riverine applications are most often filled hydraulically with slurry of sand and water. Also, filling ports are geotextile sleeves sewn into the top of the geotextile tube into which the discharge pipe is inserted (see Figure 1). They are typically laid at the final intended location prior to filling. Initially, the filling ports at the extreme ends of the geotextile tube are utilized while those in-between are temporarily closed. One end is for the pumping of sand slurry while the other end is for water pressure relief and discharge. In this way, the sand slurry will flow from one end to the other of the geotextile tube gradually depositing sand along the way. It may be necessary to move the filling point in order to achieve more even filling of the geotextile tube. After completion of filling, the port sleeves are closed and attached to the geotextile tube in a manner sufficient to prevent sand loss and movement of sleeve by wave action.

2.2 Stability of Geotube

From a technical standpoint the geotextile tube needs to fulfil the following:

1. Internal stability
    - The geotextile used to fabricate the tube, including seams and closure, need to withstand the stresses encountered during placement and filling process (commonly referred to as the tensile strength requirement).
    - The geotextile should prevent loss of fines during installation and under in-service wave and flow attacks (commonly referred to as the sand tightness requirement).
2. External stability
    - The sand filled geotextile tube structure should be stable against wave and current attacks (commonly referred to as the hydraulic stability requirements).
    - The sand filled geotextile tube structure should be stable against sliding, overturning, bearing and global slip failures (commonly referred to as the geotechnical stability requirements (see Figure 2).
3. Durability and robustness
    - The geotextile should withstand installation stresses and perform as required over the lifespan of the design (commonly referred to as the survivability requirement).

For the selection of the strength of the geotextile and calculation of a required number of tubes for a given height of structure, knowledge of the real shape of the tube after filling and placing is necessary. Depending on this static head of the (sand) slurry, it is possible that the cross-sectional shape of the filled tube will vary from a very flat hump to a nearly fully circular cross-section.

When applying geotubes the major design considerations/problems are related to the integrity of the units during filling, release and placement impact (impact resistance, seam strength, burst, abrasion, durability), the accuracy of placement on the bottom (especially at large depths), and the stability under current and wave attack. If the stability under current and wave attack does not fulfill the functional requirement a new larger size of geotube can be taken into account to obtain the proper shape (i.e., width and height of the tube crest level).

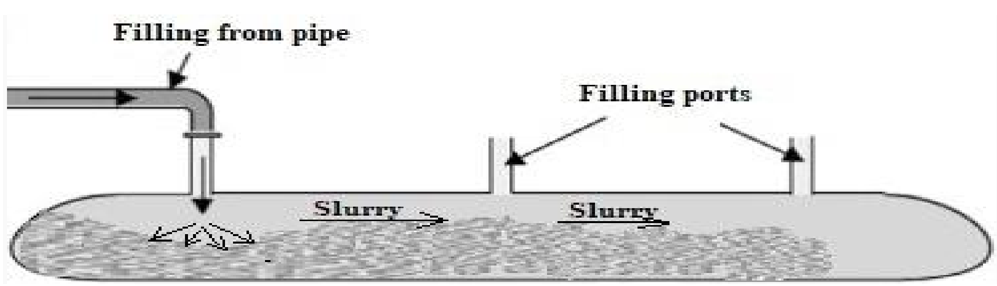


Fig. 1 : Filling of geotextile tube with sand slurry [6]

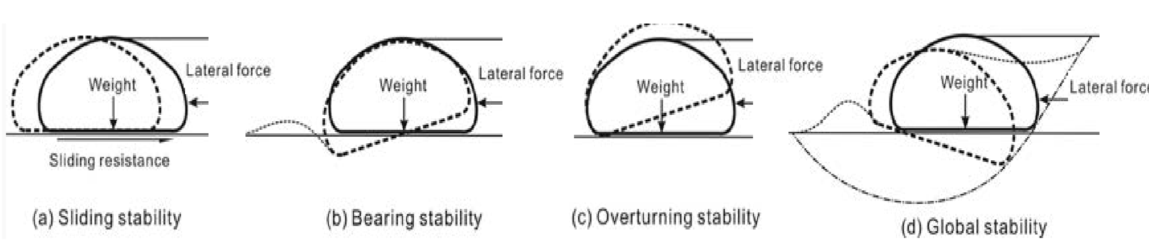


Fig. 2 : Stability of geotubes [7]

3. TECHNICAL ASPECTS AND PROPERTIES OF GEOTUBES

Specification of geotube depends upon the site conditions and stresses they are going to encountered during their performance. They should have high tensile strength to receive high pumping pressure during tube filling process. Typically, the geotextile tube can have a tensile strengths ranging between 50 to 250 kN/m with elongation at break ≤ 23 % (Test method: ASTM D 4595) depending upon the requirement. Seam strength is generally kept > 70 % of the material tensile strength (Test method: ASTM D 4884). In addition, the geotextile material also have a suitable apparent opening size to retain sand fill material from flowing out during pumping (Test method: ASTM D 4751). Additional details on the specifications like tensile strength & elongation, trapezoidal tear strength, puncture strength, water permeability, apparent opening size etc can be found in Yee et al. 2007, 2010, 2015 [5-7], ICZMP Odisha, 2017 [9].

Durability : There is no problem with durability of the geosystems when they are submerged or covered by armour layers. However, in case of exposed geosystems the UV radiation and vandalism are the factors, which must be considered during the design. All synthetics are vulnerable to UV. The speed of UV degradation, resulting in the loss of strength, depends on the polymer used and type of additives. Polyesters (PET) are by nature more light stable than, for example, polyamide (PA) and polypropylene (PP). The strength retention after 500 hours of exposure in the Xenon Arc accelerated UV testing chamber(Test method: ASTM D 4355), is usually not less than 80% [10], this retained percentage can be kept even high due to fully exposed condition of geotextile tube. To provide additional UV protection to the exposed sections of tubes, a coating of elastomeric polyurethane is often used. This coating, however, has a tendency to peel after about a number of months and therefore, has to be re-applied.

4. DIFFERENT APPLICATION OF GEOTUBES AS ENVIRONMENTAL FRIENDLY SOLUTION

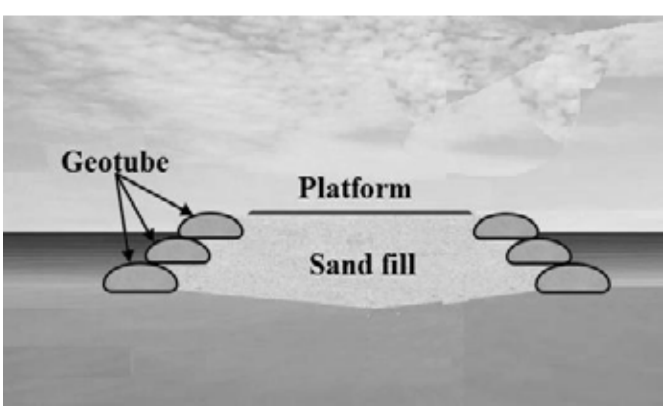
Geotubes, is an engineered containment systems, designed for use in hydraulic and marine application, and dewatering applications. Because of their simplicity in placement and constructability they can be used in number of applications as described below.

4.1 Use of Geotubes for the Construction of Platform in Sea Water

Sand is readily available in sea water and is dredged for the construction of the work platform. Dredging is carried out using a suction dredger and sand is stored in a temporary storage yard for use in reclamation fill to construct platforms. As sand is readily available, the geotextile tube solution became an economical alternative to the rock fill solution. The geotubes used in such type of construction comprised of circumferences ranging from 4.6 m to 11 m with lengths ranging from 15 to 75m. Geotubes are segmentally stacked in two to three layer high for the construction of work platform (see Figure 3).Working platform in many cases facilitates further installation of foundation piles, construction of bridge piers, use of heavy machineries etc. Additional details on these types of platform construction can be found in Yee et al., 2007, 2010, 2015 [5-7].

4.2 Use of Geotube as Breakwaters for Shoreline Erosion Protection Measures

Breakwater is effective in reducing the wave energy approaching the shoreline while intercepting the movement of sediments. Conventionally, breakwaters are constructed using rock armour or concrete. With the increasing cost of rock armour due to scarce resources and the rising concerns for the environment, alternative methods are explored including geotubes systems (see Fig. 4.)



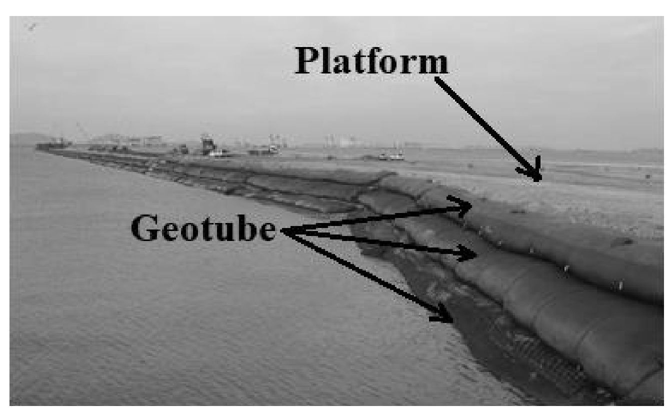
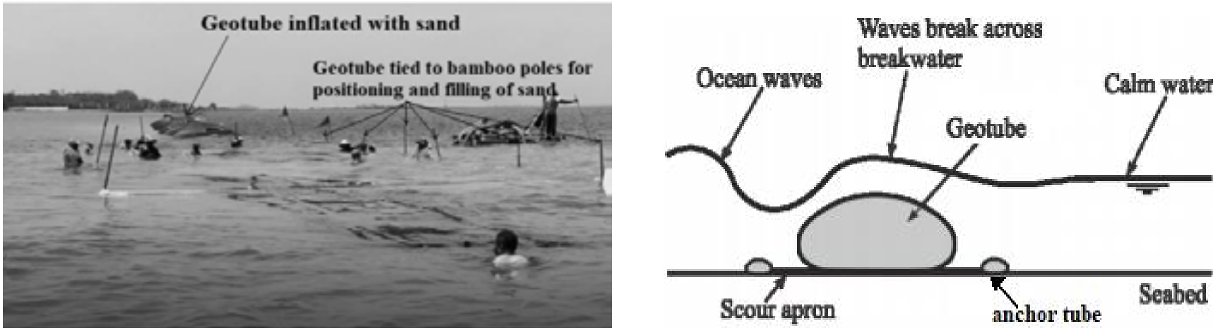


Fig. 3 : Geotubes in construction of work platform [6]



Sigandu Beach, North Java [8]

Fig. 4 : Geotubes in construction of breakwaters

The length of tube is generally in the range from 15 to 25 m with a design filled height of 1.5 m. With a non-woven inner liner prefabricated inside the tube, finer materials can be used to fill tube. To prevent the scouring of foundation which result in the instability of the main geotube, scour aprons-anchor geotube are installed at the base of the main geotube. The scour apron consists of a geotextile filter that passes beneath the main geotube and anchored by two small geotubes located at both ends. A breakwater must have a sufficient height in order to reduce the wave energy optimally. The height must consider water level, wave height, and run-up height caused by wave propagation.

Table 1 : Steps in laying geotubes as breakwaters

(i) It is ensured that seabed surface is flat prior to the installation of the geotubes and any protruding or sharp objects are removed to prevent damage to the geotextile tube.

(ii) Bamboo poles are installed at the predetermined locations spaced at ± 5 m alongside the tube to serve as a guide and for restraining the tube location during pumping as shown in Figure 4.

(iii) Once the location is set, the scour apron is positioned with the help of rope tied to bamboo.

(iv) Sand slurry pump is used to hydraulically pump sand (15 % - 20 % sand ratio) into the anchor tubes of the scour apron through the inlet ports.

(v) Once the anchor tubes have reached the designed inflated height (generally 0.20m), pumping is stopped and the inlet sleeve is tied to prevent the outflow of sand.

(vi) The main geotextile tube is then unrolled and floated above the installed scour apron and tied to bamboo poles for the positioning.

(vii) The filling pipe is then connected to the first inlet port of the tube with all other inlet ports closed except for the last one to allow the overflow of water. Once the tube has reached its designed inflated height, the filling pipe is then relocated to other inlet ports to achieve a more even filling throughout the tube.Once the whole tube is fully inflated, all inlet port sleeves are closed & secured.

4.3 Use of Geotubes in River Bank Protection

When rock is not readily available nearby and site access is difficult. Geotubes and geomattress can be well designed to protect riverbank is a sustainable manner. Sometime vegetation can take a long time to be established naturally and turfing will not sustain these brackish water environments. The geotextle fabric used for the fabrication of the geotube and geomattress units is extremely robust and can also withstand weathering and sunlight exposures over the long term.Scour apron and anchor geotube are installed in front of the geotube units to protect scouring below the geotubes. After the geotubes units are installed, the riverbank is gently slopped back. Sand filled Geomattress are then installed above the geotube units for river bank protection (see Fig. 5.).

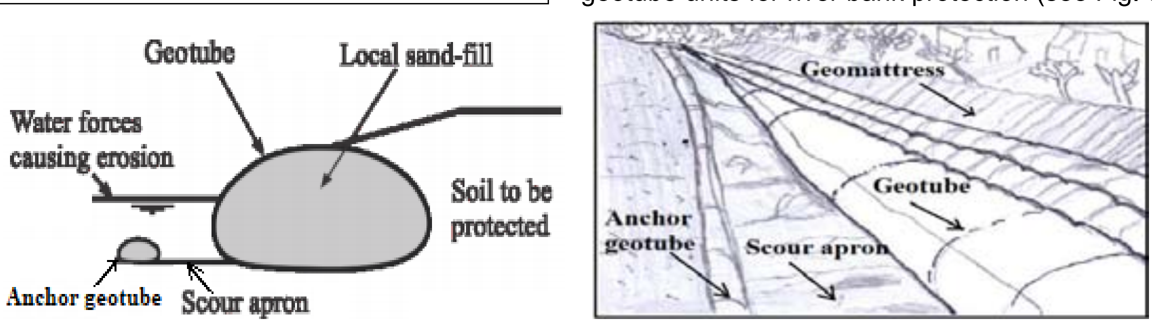


Fig. 5 : Geotubes in river bank protection

4.4 Geotubes as Check Dam

When there is lack of rock nearby and site access is difficult. On-site materials if found suitable can be used to fill the custom fabricated geotube which fit into narrow area. Culvert systems can also place underneath to limit the water table behind the stacked geotube structure to increase stability. Geotube as check dam may help to reduce the flow in downstresm while intercepting the movement of sediments as shown in Figure 6.

4.5 Use of Geotubes in Embankment as Core

If good quality of soil for construction of embankment is not available in the vicinity of the project, geotubes can also be used as core of the embankment. Use of Geotubes in coastal protection [9] with rock armour and rope gabion box is shown in Figure 7. In Figure 8 adequate soil cover is provided on sides of the geotube to form a trapezoidal shape as constructed in Matmara geo-dyke in Lakhimpur district, Assam [10]. In Matmara area construction was carried out on the breach portion for a length of 5 km. The length of geotubes used were 25 m long with fill height of 2.5 m having tensile strength more than 200 kN/m and UV resistance more than 80 %. On the river side of the embankment, geotubular mattress filled with sand (200 mm thickness) is laid on the slope to protect the slope from getting damaged due to the rain cuts etc., and due to flood water. It also served the dual purpose of preventing bank erosion and bank sloughing due to seepage of country side water, as it is filtered out by the sand filled mattress.

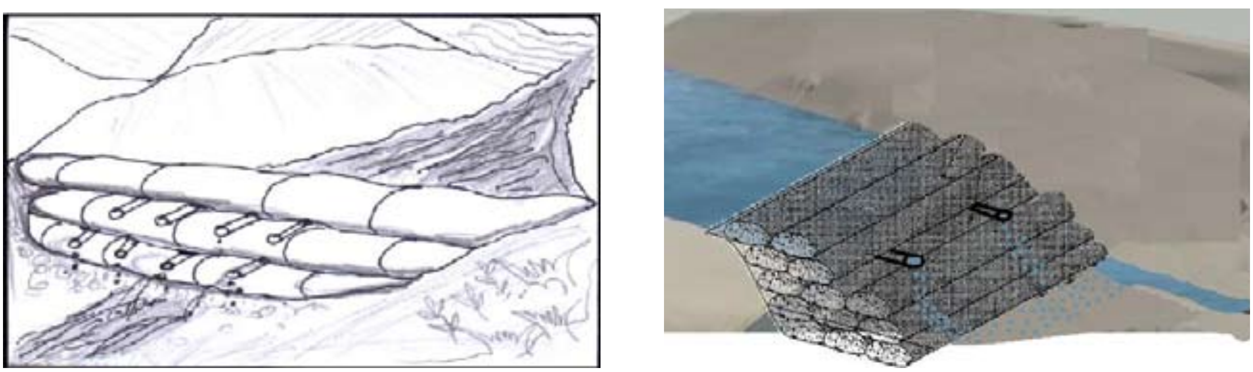


Fig. 6 : Geotube can be used in check dam to reduce the flow in downstresm

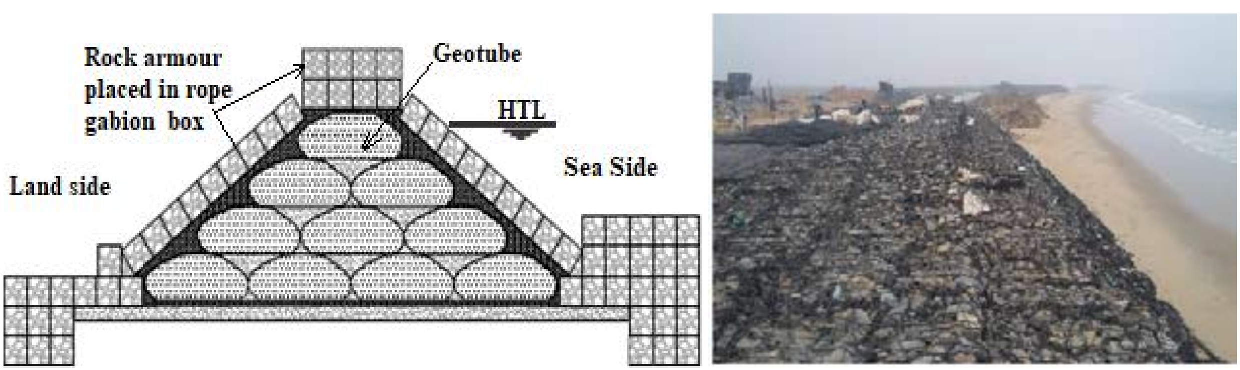


Fig. 7 : Use of geotube as core of embankment in coastal protection [9]

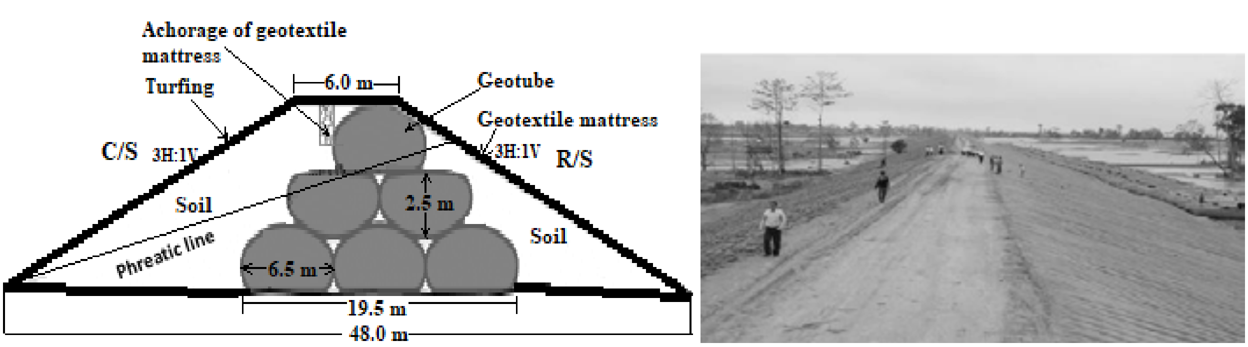


Fig. 8 : Use of geotubes as core of embankment in bank protection [10]

4.6 Use of Geotubes as Groynes

Conventionally, groynes consist of rock mounds. With the increasing cost of rock armour due to scarce resources and the rising concerns for the environment, alternative methods are explored including geotubes systems. Groynes are structures, constructed transverse to the river flow. It extends from the bank into the river upto a limit. It gives protection to the banks by dampening the velocity of flow towards erosion prone bank and inducing siltation at the required place. Groynes control lateral movement of sand along the beach, reducing erosion and retaining sand in specific locations. Groynes interrupt wave action and protect the beach from being washed away by long shore drift. Long shore drift is the wave action that slowly erodes the beach. Groynes can be used single (see Figure 9) or in series, depending upon the reach of length to be protected. The spacing, orientation and length of groynes may be decided by the model study of the flow.

4.7 Use of Geotubes as Coffer Dam to Provide Solution to H.E. Projects

Use of Geotube as a cofferdam can be of immense help in diverting or reducing the level of water flow so that the other permanent component of main dam can be completed. Geotube technology system can be installed in water depths that fluctuate from 4 to 5 m deep with turbulent conditions. Such technology becomes useful when cofferdam had to be installed quickly and it had to be removed without the use of heavy construction machinery. Looking at the requirement to maintain the water level, geotube can be installed in a 3-2-1 or 4-3-2-1 pyramid structure. Geotube cofferdam was installed to complete the work of Central Angostura 350MW hydroelectric dam [11] in Santiago, Chile (see Figure 10). It consisted of 4-3-2-1 pyramid structure (8 m height) in 4 to 5 m deep water, each geobag units were 10 m in circumference and 25 m in length, properly secured within the steel positioning frame at the underwater working platform. Geobags units were filled in-place underwater with sand-water slurry, allowing the tubes to fit the countour of uneven bottom and rock sides. The high-strength woven engineered textile that formed the tube containers allowed the water to permeate through the surface, retaining the sand inside the structure. The results were geotextile tube containers having fill volume of 165 m3 with an in-place mass of more than 300 tons. Experienced diver's plays an important role in underwater in assisting the positioning of the frame, riser poles, geotubes and connecting sand slurry line. After four weeks of work, the geotextile tube coffer dam installation was completed at a height of 8m. For additional safety against overtopping, two layers of steel rebar cages lined with a nonwoven geotextile were placed on top of the structure and filled with sand, achieving a total structure height of 9.5m. For removal process of the coffer dam, workers were lowered in a steel safety cage to cut open the geotextile tubes, and the flow from the river washed the sand downstream.

4.8 Use of Geotubes as Geocontainers to Create Underwater Structure

Geocontainer units are specially designed to be filled before being placed in the water. Special split bottom barges are used to fill the geocontainers with sand. After filling and sealing the geocontainer units, the barge moves to the proper position and the bottom opens, the container slides through the split-bottom barge and settles on the seabed forming into semi-oval shape (see Figure 11). Geocontainer units are custom designed to fit the size of the barge. The containers can be placed in position with a high degree of accuracy to create underwater structures such as dykes and breakwaters. Thus the containers are ideal for coastal protection and infrastructures of ports and harbors. Geocontainer units before fill are envelope or tubular shaped and can range in volume upto 1000 m^3 after the fill [2]. Geocontainer units are manufactured from

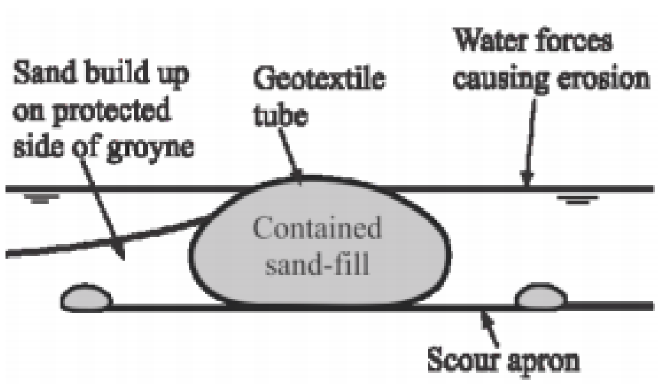


Fig. 9 : Geotubes as groynes

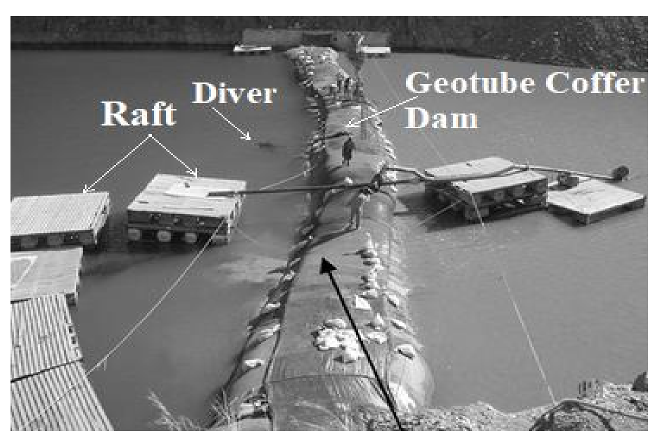


Fig. 10 : Use of geotube in construction of emergent coffer dam [12]

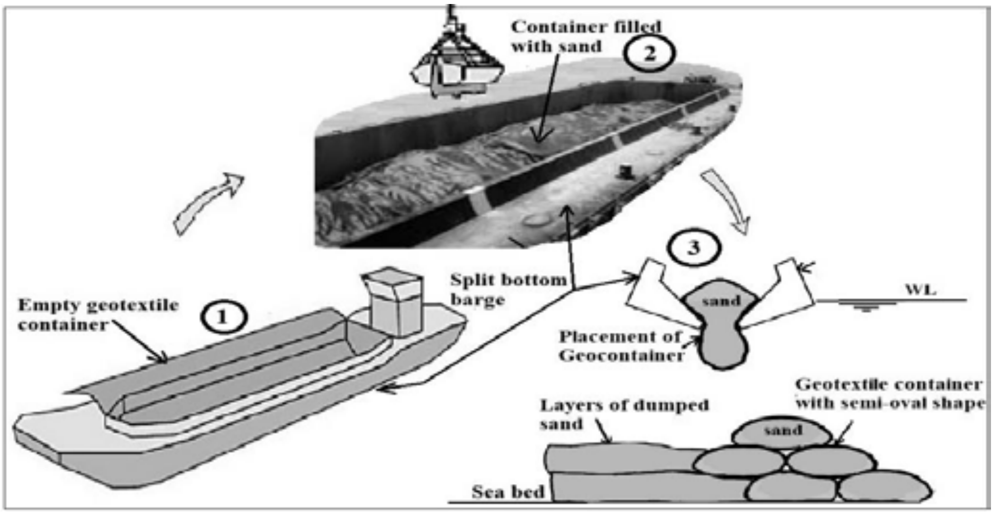


Fig. 11 : Placement of geocontainer through split bottom barge

woven polypropylene engineered fabrics combined with high capacity seams to produce mass-gravity containers with ensured integrity during installation and during operational life.

The advantages of this large barge placed geocontainers include:

1. Containers can be filled with locally available soil, which may be available from simultaneously dredging activities.
2. Containers can be relatively accurately placed regardless of weather conditions, current velocities, tides, or water depths.
3. Contained material is not subject to erosion after placing. Containers can provide a relatively quick system build-up.Containers are very cost competitive for larger works.

4.9 Geotube Dewatering Applications

Geotube dewatering containers are prefabricated using high strength engineered textile and quality seaming techniques into tubular forms with filling ports for site filling. They are fabricated into permeable containers to optimize solids retention, high effluent discharge rate and filtrate quality (see Figure 12). The containers are custom sized to save land space and are ideal for areas where space is a constraint. Capacity of Getube dewatering units can be scaled upto 1000 m^3 bio-solid storage if needed. Geotube dewatering containers offers environmental friendly solution for various sludge dewatering applications. It can be applied in environmental dredging, industrial wastewater processing, mining and mineral processing, agriculture waste reduction and municipal applications. Getube dewatering units can readily meet the need of a growing wastewater treatment plant including future upgrades. In many cases, dewatered tailings contained inside the geotube units can be used as a structure within the pond or placed on top of the perimeter of the berm to provide additional capacity. Geotube performance will also be influenced by factors like the percentage of water content in the media, particle size, the shrinkage when dry, and the soil composition.

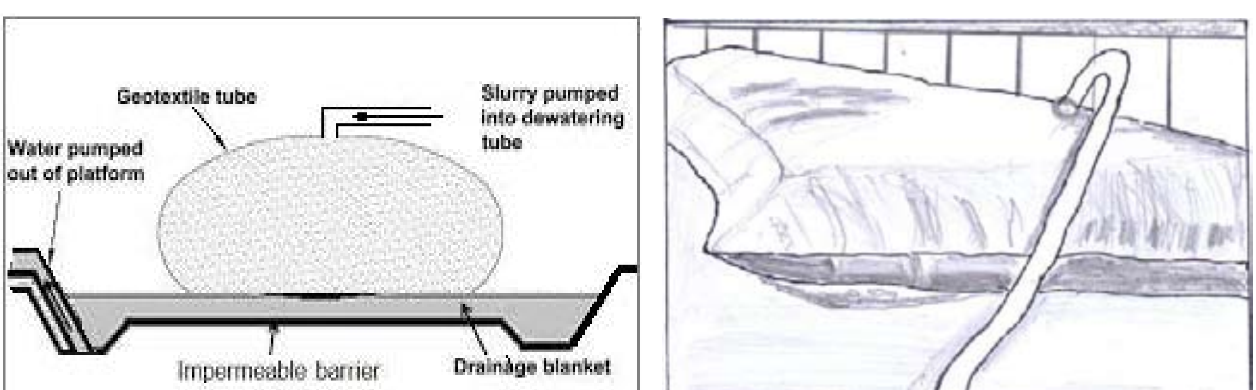


Fig. 12 : Geotube in dewatering application

4.9.1 *Steps in Geotube Dewatering Technology*

Geotube dewatering operation is simple and does not require special and heavy equipment. It can be completed in following steps given in Table 2.

Table 2 : Steps in geotube dewatering technology

Steps	Details
Step 1: Filling	Sludge (slurry material) is pumped into the geotube container. Environmentally safe polymers (flocculants) are added to the sludge, which makes the solids bind together and water separate which seeps through the pores of the geotube. The geotube container's unique fabric confines the fine grains of the material.
Step 2: Dewatering	The clear effluent water simply drains from the geotube container through the small pores of a specially engineered textile, leaving the solids within the container. This results in effective dewatering and efficient volume reduction of the contained materials. The volume reduction allows for repeated filling of the geotube container until it reaches its solids containment capacity. With this over 99% of solids are captured, and clear filtrate can be collected and re-circulated through the system. The decanted water is often of a quality that can be reused/returned for processing or returned to native waterways without additional treatment.
Step 3: Consolidation	After the final cycle of filling and dewatering, the solids remain in the bag and continue to densify due to desiccation as residual water vapor escapes through the fabric. Over time, allows further drying of biosolids to take place. Volume reduction can be as high as 90 percent.
Step 4 : Disposal	When the bag is full, the geotube container and its contents can be deposited at a landfill site, left on-site, or the solids can be removed and land-applied when appropriate as shown in Figure 13.

Fig. 13 : Disposal of solids from geotube container [12]

4.9.2 *Benefits of Geotube Dewatering Technology*

(i) Process does not require special and heavy equipment and therefore less carbon footprint.

(ii) Geotube dewatering containers can provide dewatering, containment and consolidation in one operation, with 85% to 90% reduction of BOD in the effluent.

(iii) Over 98% of solids/contaminants are captured and clear filtrate is collected. This reduces odour problem in the environment. Unlike mechanical system, it operates relatively noise-free.

(iv) The technology has distinct advantages over drying bed, centrifuge, and belt filter press systems in the areas of cost, maintenance and risk in waste water treatment.

(v) The utilisation of large land areas, the cost of constructing the holding ponds and the requirement for eventual capping of the holding ponds make the 'mechanical desludging' solution more costly.

(vi) Geotube dewatering units can be customized to various sizes, depending on volume and space requirements. It can even be mounted on mobile roll-off containers that can be transported to safe places. It can also be used in emergent cases when conventional system exceeds discharge limits.

(vii) It replaces the need for a traditional embankment tailing storage facility. Such embankment is under severe risk in areas of seismic activity and during high rainfall. It offer greater flexibility for placement of contained tailings to required location.

(viii) It significantly reduces the potential for an environmental disaster in case of natural calamities.

(ix) Easy removal and disposal of solids which will allow the production unit to work uninterruptedly. Reliable in all weather conditions and reduces risks in operational safety.

(x) It is cost effective, less maintenance and save time. Local labour can be engaged in the process.

5. CONCLUSION

Geotubes have been used for many hydraulic and marine engineering projects for erosion control, stabilization and habitat enhancement. Some examples of applications have been illustrated in this paper. It should be noted that different methods are suitable only to different site conditions faced with serious erosion. The full scale trial installation is important to test out the proposed installation methodology as well as suitability of selected materials and equipment. Trial will not only help in understanding the stability of inflated geotube but also construction team to gain experience of site conditions.

Use of geosynthetic tubes over conventional method offers a number of advantages. Firstly, it is cost-effective. The use of a layer of geosynthetic to form a tube with sand as fill materials is often more economical than the use of concrete or rocks. Secondly, the construction process can be made simpler and faster. Thirdly, it enables local soils and even slurry materials to be used as fill materials for construction. The high tensile strength of geosynthetic materials offers the best combination with any kinds of soil. Geotextile tube solutions can save money, construction time and carbon footprint, when compared with rockfill options. Yee et al. 2013 [13] reported a saving of more than 230,000 tons of CO_2 eq. (i.e., 52 % reduction in carbon footprint when compared to rockfill options) for the construction of a 4 km polder dyke using geotube in Korea. The installation and placement of a geotextile tube is a more gentle process and results in less loss of construction structure when applied on soft marine bed.

Regular maintenance and more intensive monitoring of the existing structure will help in the verification of its design. Geotubes in protection works normally extend longitudinally over a long distance, a small improvement in the design could result in a significant amount of saving. Therefore, it will have a great benefit if more cost-effective method could be established while at the same time bringing about a positive contribution to the reduction of greenhouse gas emissions during the construction process itself.

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RIVER BANK EROSION CONTROL WITH JUTE GEOTEXTILE -A CASE STUDY

Tapobrata Sanyal[1]

ABSTRACT

The paper highlights the development of Jute Geotextile (JGT) as a remedial concept for controlling river bank erosion, specially, for the high erosion prone Ganga-Brahmaputra delta. A specific case study of the successful use of JGT in the River Subarnarekha at Sonakoria is described in detail.

INTRODUCTION

Conventionally, eroded river banks are protected by arraying graded granular stones or similar materials. Use of gcosynthetics in lieu of the granular filter is gradually gaining ground in developing countries because of case in execution, durability and competitive cost. Jute Geotextile (JGT) is a fabric made of jute yarns is a comparatively new entrant in the fraternity of geosynthetics. Jute grows in abundance in the eastern part of India for ages. Its inherent properties like high initial strength, low extensibility at break, eco-concordance, high drapability and competitive cost have made JGT a suitable material for various geotechnical applications. Functionally JGT is no different from its man-made counterpart and can meet the requirements of separation, filtration and drainage effectively. Design principles related to its use in river bank protection are identical to what is followed in case of man-made geosynthetics though it is felt that empirical relations formulated in the western countries have not seemingly considered some of the important factors causing river bank erosion.

In this paper an attempt has been made to highlight the overlooked causes of river bank erosion along with the remedial concept. It also presents a case study in the river Subarnarekha in the western part of West Bengal, India where JGT was put to use for bank protection.

MECHANISM OF BANK EROSION IN RIVERS

The basic causes contributing to river bank erosion are several. These are :

- river geometry
- lithology of the river banks, i.e., characteristics of bank soil and geology of the water shed
- bed profile of the river, especially its transverse gradient
- proximity of the main flow to a bank and formation of eddies close to the toe of a bank
- extent of draw down, i.e., difference between the maximum and minimum water levels

The Ganga-Brahmaputra delta has formed as a result of unabated alluvial deposits over ages. The landform is still somewhat fragile prompting the rivers in this region to re-orient their courses frequently. The right bank of rivers in the south of West Bengal is more stable as the land on that side is of older geological formation. Understandably this part of the land is less prone to erosion. Rivers take tortuous courses to find the path of least resistance developing meanders, Concave banks of meanders are vulnerable to erosive forces of rivers.

But the most overlooked reason behind riverbank erosion is transverse gradient of riverbed. Transverse gradient is a prominent feature in river bends. Straight reaches also may develop cross gradients to a good degree as a result of which the bulk of the flux follows the gradient and hugs the bank at a lower level. The drag force of current unsettles the bank soil and dislodges it. There could also be situations when eddies or rotary currents caused by principally due to density and temperature gradients develop close to the toe of a bank causing bank erosion.

Patently, the principal agents of bank erosion are draw down, i.e., the drop in water level of a river after the monsoon on the one hand and fragility of bank soil on the other. Rising water during the rains finds its way into the bank soil and forces its way back in the river to release the pore water pressure when the water level drops after the rains. The pressure balance when a river is full to the brim or overflowing prevents release of differential pore water pressure so developed.

In tidal rivers the situation is more complex. Banks are subjected to alternate drying and wetting to varying degrees with changing volume of entry and exit of flood-waters every day. The ebb flux does not also remain uniform, but changes almost every day. Waves induced

1. Jute Manufactures Development Council

Source : Geosynthetics in India - Present and Future (Two Decades Celebrations), November 2006, New Delhi by wind and ships, especially in the esluarine reach, also contribute to bank erosion. In a river estuary, ingress of saline water with the floods creates density gradients. Diffusion and dispersion characteristics determine the type of flow - layered or otherwise – as a result. The-phenomenon influences sediment deposition pattern in the river. In coasts, there are additional erosive forces like down rush of water, wave run up, storm surges, uplift pressure, direct wave impact.

REMEDIAL CONCEPT

The empirical relations so far established for designing a geosynthetic presumably have not taken into account all the factors as aforesaid. The basic design principle for remedying the problem of bank erosion should be to induce siltation on the eroded bank. The first step in this direction should aim at repelling the flow away from the eroded bank by suitably guiding the flow. This is essentially a preventive measure. Flow guidance can be achieved by construction of guide wall and repelling spurs projecting out of the eroded stretch of Ihc bank. In difficult situations both flow guidance and bank protective measures should go hand in hand.

Vegetation grown on riverbanks helps retain its shape. It can attenuate forces of flow as well as of waves. The present growing trend is to protect riverbanks naturally. Studies are on in some of the developed countries to ascertain the extent of attenuation of the said forces by different kinds of vegetative covers over riverbanks. This is also an environmental need.

This is exactly where JGT can fit in. JGT can withstand installation and hydraulic stresses till such time the bank soil is consolidated naturally. JGT is capable of functioning as a separator, filter and drainage medium as effectively as its man-made counterpart. Field trials have substantiated that it does not take more than one to two years for natural consolidation of bank soil. Durability of JGT can be ensured for the period by smearing it with textile-friendly additives. On biodegradation JGT acts as mulch and add nutrients to soil at micro levels. Growth of vegetation is thus accelerated if the species are carefully chosen. The roots cling to the soil restraining its migration, besides reducing the direct impact of current and waves,

It is necessary to explain the often-asked question of low durability of JGT in this context. The role of any geosynthetic in helping natural consolidation of soil is that of a change agent that requires to perform for a limited initial period. Laboratory studies and field trials have substantiated that not more than two season cycles are needed to maximize natural consolidation of the soil overlain by appropriate geosynthetics. This holds good for JGT as well. Normally untreated JGT loses its strength by a year or so (depending on the type of yarns used in the fabric and the soil quality). Its durability can be prolonged by at least three years by coating it with special textile-friendly additives. In bank protective works, water-repellant additives, usually bitumen, are used. But certainly there is need to explore alternatives that do not affect the drapability of JGT and aids growth of vegetation at the same time.

CHOICE OF JGT

Geosynthetics for strengthening any soil arc chosen usually with an eye to effectiveness in filtration. Filtration, as already explained, implies fulfillment of two criteria viz. retention of soil in place and dissipation of pore water pressure that develops within the soil. For retention of soil particles, the basic relation is ;

O_n (usually O_{90} or O_{95}) < K d_n (usually d_{50} or d_{90}) ...(1)

For permitivity or cross permeability of JGT, the basic relation is :

$$k_g > k_s \qquad ...(2)$$

where kg stands for co-efficient of permeability of JGT and k_s for co-efficient of permeability of the base soil.

In a reversing flow, the constant K in relation (1) is recommended to be 100 while that in a unidirectional flow, K. is taken as 10. (ref; SVG 1995—Schweizerischer Verband der Geotextile Fachleute).

The constant in relation (I) is supposed to have considered the factors influencing river bank erosion. Rationally speaking, the constant should be decided on river-specific parameters. Sweeping application of the constant may prove to be ineffective. In fact, there is no unanimity in respect of the value of the constant in the said relation. For instance, PIANC (1987) recommends different relations in respect of (1) and (2) above. For the relation in (1), it has taken into consideration of Uniformity Co-efficient (d60 / d10) and hydraulic gradient of soil for the relation in (2). This is a pointer to develop site-specific relations for choice of gcosynthelics with the right AOS.

CASE STUDY AT SONAKONIA IN THE RIVER SUBARNAREKHA

The Subamarekha originates from Bihar plateau with its outfall in the Bay of Bengal. It flows through Jharkhand, Orissa and West Bengal. Out of its total length of 477 km., 71 % is in Jharkhand, 11% in Orissa and the rest in West Bengal. Unlike the usual trend of any river that widens as it approaches the sea, die width of the Subamarekha exhibits an irregular trend. Its bed till Dantan in West Bengal has gradually widened, has suddenly narrowed after that point and has taken several turns before converging with the sea (Fig. 1). Several river projects have constructed in river for irrigation and generation of hydel power.

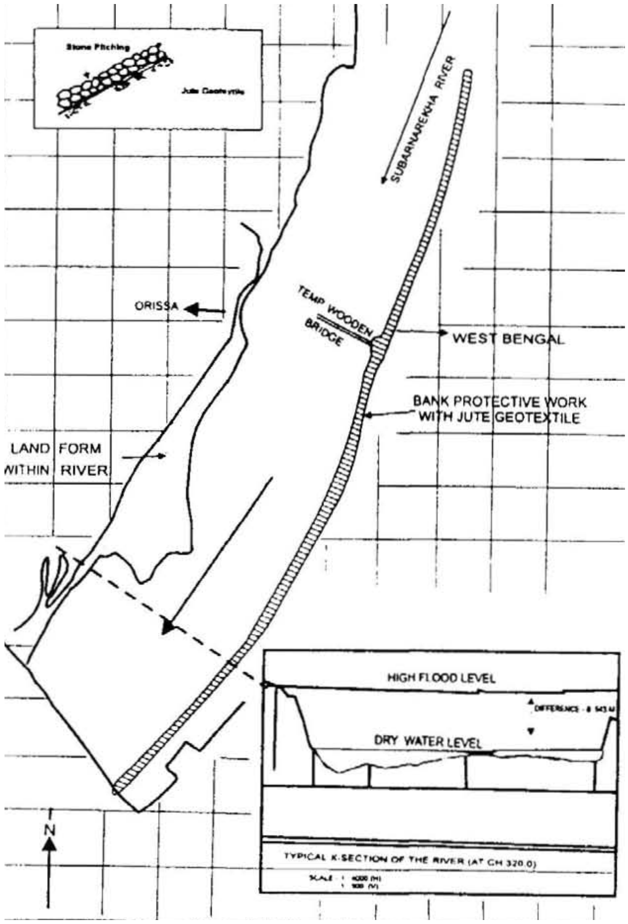

Fig. 1 : Bank protective work with jute geotcxtile at Sonakonia, West Bengal on the river Subamarekha

The maximum flux in the river is 17,000 cumec and the minimum is as low as only 3 cumec. This shows the large difference in water level of the river between wet and dry seasons. Drawdown is of the order of 7.5 m in its lower reach. The velocity of flow reaches 1.5 m per second and above during the monsoon.

The stretch where bank protective measures were undertaken by the Irrigation department of the Government of West Bengal is in the concave side of a bend and has been under threat of erosion for the last 20 years or so as per records. The bank line has receded by around 50 m due to erosion during this period.

The riverbank soil is dominantly silly clay mixed with moorum and sand Table 1. The other features of the bank soil are indicated in Table 2. The ground water table is 6 to 7 m below the top of the river bank. In the affected stretch the river is 500 m in width. The dressed length of the slope (1: 1.8) is 21 m.

The remedial measures comprised :

- re-shaping the bank slope to a gcotechnically stable profile
- laying of JGT (woven, bituminized) (Table 3 for specs, of JGT used)
- placement of an armour layer with laterite boulders of suitable specific weight

The work was done in the dry season of 2002 (Fig. 2). The first assessment was made in November 2003 after the treated bank weathered two monsoons. Sprouting of vegetation through the interspaces of the armour layer was clearly visible. There was no sign of distress or settlement in the treated stretch, as evident from Fig.3.

Fig. 2 : Stone pitching at in River Subamarekha

Fig. 3 : Vegetation growth at Sonakonia in river Subamarekha after 2 Years of treatment

Table 1 : Soil Characteristics at Sonakonia

	Stratum	Description	Properties
I	(0.0-12.00 m)	Medium / stiff brownish grey silty clay with moo rum and sand	NMC = 27% LL = 55% PL = 20% Cu = 75 kN/m^2 C'=50 kN/m^2: φ =120°
II		Stiff / very stiff yellowish brown / brownish yellow silty clay with traces of sand and kankar and grey patches	NMC=28% LL = 50% PL = 18% Cu =120 kN/ m^1 C' = 7OkN/m^2: φ = 15°

[Ground water table is at a depth of 6.0-7,0m below riverbank]

Table 2 : Soil test results

Location (m)	S. No.	Description	N.M.C. (%)	γ kN/m³	Permeability (cm/sec)	LL (%)	PL (%)	PI (%)	% Gravel	% Sand	% Sill	% Clay
10	1	Sandy clayey silt	24.5	17,9	$1.2 x10^{-5}$	43	18	25	-	17	59	24
135	2	"	26.8	18.6	$1.6 x l0^{-5}$	42	IS	27	-	19	61	20
260	3	"	25.7	18.6	0.97×10^{-5}	51	20	31	2	10	58	30
450	4	"	29.1	18.5	1.14×10^{-5}	42	17	25	-	13	60	27
BOO	5	"	23.7	16.6	$I.75 \times 10^{-5}$	39	18	21	4	21	55	20
1000	6	"	21.6	16.8	2.05×10^{-5}	38	20	18	8	18	52	22
1200	7	"	28.4	18.1	1.89×10^{-5}	40	18	22	7	19	64	10
1450	8	"	31.6	18.4	1.43×10^{-5}	41	19	22	3	22	50	25

From the data it appears that the soil on the river embankment is mostly clayey silt with average permeahility 1.5×10^{-5} cm/sec.

Table 3 : Specifications of Bitumen treated Jute Geutcxlilcs used

(a)	Weight (grey) - 760 gsm
(b)	Weight (bitumen treated) - 1512 gsm
(c)	Tensile strength - 22.4 kN/m (MD) X 25.6 kN/m (CD)
(d)	Cross Permeability (under load 2 kPa) - 8 layers at 100 mm water head – 1 x 10^{-3} cm/sec
(c)	AOS - (after treatment) - 150 micron
(f)	Elongation at break - 8% - 9%
(g)	Puncture Resistance (cm^2) around 400

DISCUSSION

JGT-treated bank slope performed satisfactorily corroborating the expressed view that its role was that of a change agent and that biodegradability of geosynthctics after an initial period of maximum two years would not affect the bank soil once naturally consolidated. Had the perennial discharge been substantial, the measure would not have been sufficient to check erosion of the bank located at the concave end of a bend. Regulatory measures like construction of repelling spurs might have been necessary in that event.

Cost-wise, JGT with the armour layer stands on a par with the conventional granular filler—Rs. 60,00 per m^2 – prevailing at the time of construction. But advantages of case and quickness in execution should be taken into account. Quick growth of vegetation and facility in quality control are other advantages. Quality control over installation of graded granular filter is understandably far more difficult. To these, we may consider the indirect environmental costs accruing out of indiscriminate mining of boulders.

The case study substantiates the efficacy of the earlier field application, using bitumen-treated JGT for control of erosion, undertaken by Calcutta Port Trust in the 1990s al Nayaehara island in the Hugh estuary opposite Haldia docks, with the author as the leader of the team (Sanyal 1992, Sanyal and Chakravarty 1993).

Acknowledgement

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ROAD STABILISATION THROUGH GEOSYNTHETICS IN SLIDE PRONE AREAS OF TALA HYDROELECTRIC PROJECT IN BHUTAN, HIMALAYAS

J. Kharbanda[1], R.K. Misra[1], D.P. Goyal[1] and R.N. Khazanchi[1]

ABSTRACT

This paper highlights the geosynthetic techniques applied for road stabilisation through the slide areas in eastern Himalayas for implementation of 1020 MW capacity Tala Hydroelectric Project in south-west Bhutan. About 115 km of hill roads had to be freshly cut to approach various components of the project. These formation cuts in the fragile Himalayan geologic formations underwent numerous occurrences of bench settlements, slides, slips, damages to retaining structures and failures of subgrades/road surfaces. Stabilisation solutions were evolved quickly by supplementing the age-old tested methods with the "geosynthetic techniques". The paper focuses on tackling major problems encountered on the vital 26 km long road connection to the powerhouse area of the project and dwells in detail on the application of geosynthetics in the form of nets, meshes and mats for immediate as well as long-term protection measures.

1. THE TALA PROJECT

The need to exploit vast hydropower potential of Bhutan of more than 20,000 MW in it's five river basins, is a vision the Royal Government of Bhutan shares with the Government of India. Exploitation of this resource will result in development of this tiny country in Himalayas in a substantial manner. The 1020 MW Tala Hydroelectric Project, in the Wangchu basin is presently coming-up downstream of the existing 336 MW Chukha Power House. This symbol of Indo-Bhutan friendship is scheduled to be commissioned by September 2005 and requisite progress is being made on all fronts to meet this schedule.

2. THE ROAD NETWORK

Implementation of the Tala HEP necessitated cutting of about 115 km of hill roads through fragile Himalayan geologic formations in order to approach various components of the project from the Phuentsholing-Thimphu National Highway (Fig. 1). The important approach roads include the connection to dam and the Thiyomachu HRT adit (10.5 km from the take-off point at km 80 of the National Highway); connection to the Padechu HRT adit (11.5 km from the takeoff point at km 58 of the National Highway); connection to the Geduchu HRT adit (14.5 km from the take-off point at km 47 of the National Highway) and the all important connection to the powerhouse location (33 km from the take-off point at km 44 of the National Highway).

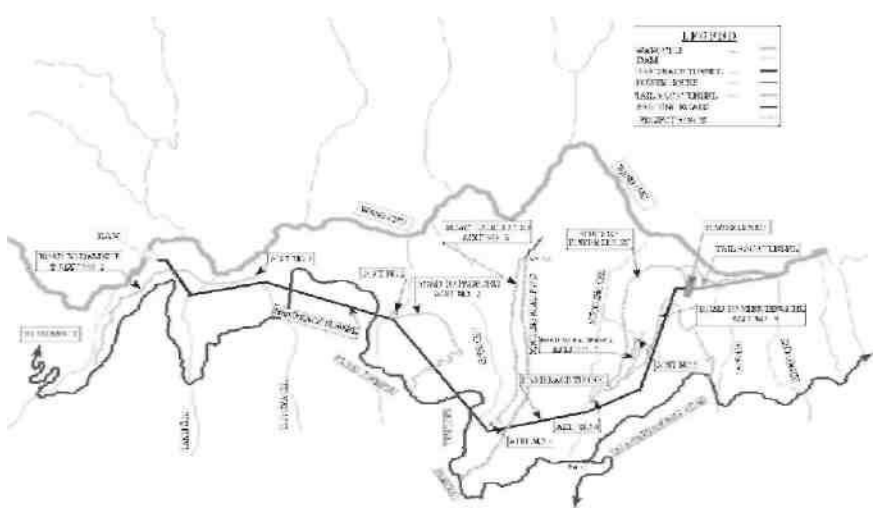

Fig. 1 : Road net work of Tala Hydroelectric Project

1. Tala Hydroelectric Project Authority, Bhutan

Source : *Case Histories of Geosynthetics in Infrastructure Projects, Publication No. 289 (2003)*

3. THE STUDY AREAS

Present case study is in respect of tackling major problems encountered on the 26 km long road connection to the powerhouse area of the project which, interalia, provide access to the surge shaft top, surge shaft bottom, penstock adits, HRT adits, powerhouse caverns and the tailrace tunnel. Due to it's obvious importance, the said road connection had to be provided with all the necessary stabilisation measures through the application of age-old tested methods and the use of geosynthetic techniques.

The Tala HEP is being executed in a fast track 'concurrent model'. The fresh formation cuts in delicate Himalayan geology could not, by and large, be afforded sufficient time to stabilise before the heavy construction equipment started traversing the freshly created riding benches. The construction of 26 km long road to the powerhouse was taken up in 1997. It had its own share of problems-difficulty in cutting-through, bench settlements, failure of sub-grades, major slides and resultant damages to the retaining structures. Like in most of the north-eastern region of India and the adjoining project area in Bhutan, the road construction work was impeded due to the high incidence of land-slides primarily attributable to immature topography, deep weathering profile, young mountains with soft rock mass further aggravated by relatively high rainfall of up to 5000 mm annually in the Tala Project area. Wide spread surface draining pattern of the river and deep nallahs criss-crossing the selected road alignment, coupled with sustained blasting activities for bench development further aggravated the situation by accelerating the process of erosion and toe-cutting.

3.1 The Trouble Spots

Road alignment to the powerhouse passed through particularly trouble prone areas between km 20 and km 24.5. While the executing agency, Border Roads Organisation of India, was having difficulty in cutting through a major subsidence zone near km 22, the road stretch near km 20 continued to display signs of instability during the years 1998,1999 and 2000.

The above bottlenecks portended delay to the start of work on important fronts of the powerhouse and the tailrace tunnel. Effective alternatives and stabilisation solutions were, therefore, evolved and applied quickly by supplementing the conventional methods with modern geosynthetic techniques to ensure round the year access to the work areas.

The first highly successful alternative implemented was the construction and stabilisation of a 5 zig bye-pass link road fondly called 'Pango link' (Photo 1) because of its proximity to a place called Pango. It is 1 km long road which connects the upper leg of powerhouse main alignment at km 19.5 to it's lower leg at km 21.

Photo 1 : Pango link (after geosynthetic treatment)

The 2nd effective measure has been the construction and stabilisation of a 1.56 km long link road having 21 zigs for connecting the main alignment upper leg at km 20.2 to it's lower leg at km 24.5. This engineering marvel is popularly called '21 zigs'. The road bench leading to the '21 zigs' (Photo 2) could not, however, be stabilised by the conventional methods of road construction. It displayed signs of upheaval of sub-grade resembling the back of a camel before the entire bench failed completely. This area has, thus, been nick-named 'Camel back' (Fig. 2).

Photo 2 : The 21 zigs

4. SPECIFIC PROBLEM

The '21 zigs' and the 'Camel back' area lies on a hill inclined at an average slope of 45°. The adverse conditions, caused by the presence of slope wash material, which used to get highly charged with surface/ sub-surface water during the initial months of rains in the area, viz., March and April, worsened during the following monsoons loosing soil properties rapidly before failure. Surface geology also did not suggest presence of competent rock anywhere near the sub-grade. The hill slope, spanning between El 500m near to the river Wangchu at bottom to El 1530 m near the top of the hill,

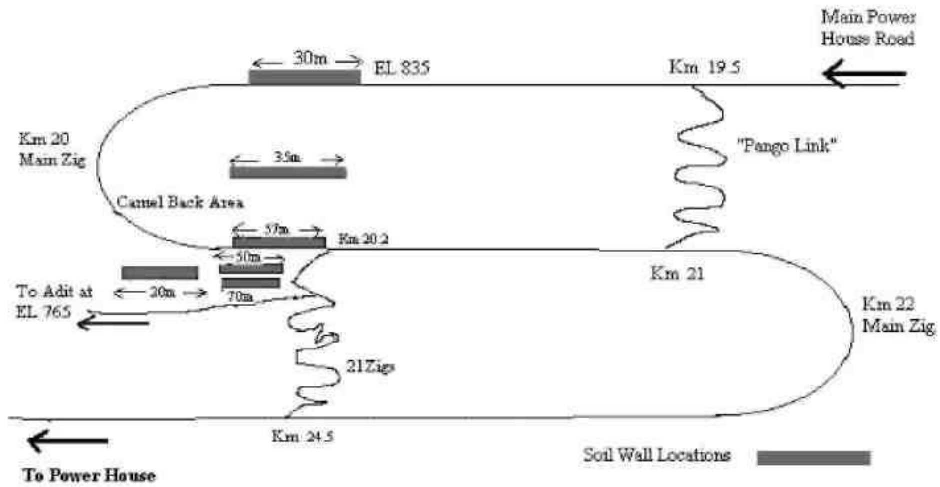

Fig. 2 : Arrangements at 'Camel back'

cuts across several project road benches at El 1430 m, El 1250 m, El 1010 m, El 830 m, El 765 m and finally El 520 m. Peculiarly, the slope poses no problems during the non-monsoon months.

As observed over the period, the whole hill, especially above El 1010 m, gets charged with water. The slope used to support sparse vegetation till it got washed-out completely during the unprecedented floods in August, 2000 which saw very heavy precipitation (record 1700 mm in 3 days from August 1" to 3"). The rains resulted in land slides and devastated most of the project roads. Two rivulets originating somewhere near El 980 m cross through the 200 m long vulnerable stretch of 'Camel back' further affecting the stability of the slope. The area showed signs of instability during the 1998 and 1999 monsoons and in the early part of the year 2000. The provision of conventional RRM breast walls, toe walls, surface drains and water chutes were supplemented with sub-surface inverted filter drains but all these measures were not generating enough confidence about the sustained performance of the road bench. This prompted the construction of 'Pango link' in April 2000 to completely bye-pass, if necessary, the "Camel back" area for accessing the power-house area through the 21 zigs. Proving the fears right, the "Camel back" area became totally unliable after the heavy down pours on 12th, 20th and 21st June 2000. The sustained rainfall (900 mm in just 48 hours on 20th and 21st June) took it's toll; persistent ingress of water and massive surface flows resulted in mass subsidence of the slopes by up to 9 m in some places.

The timely completion of 'Pango link' a little earlier, thus, proved precious by becoming the only available link to the power-house fronts. It also convinced the project authorities that a lasting solution, preferably using geosynthetics, had to be tried for stabilising the 'Camel back' area at the earliest opportunity.

Another heavy down pour from August 1st to 3rd, in the year 2000, devastated most of the communication network of the project. Fortunately the 'Camel back' area; by then provided with underground filter drains, water-chutes and concentrated plantation of fast growing species of felido, bushes, bamboos and trees; did not immediately emit any serious alarm signals. But a more immediate worry seized the Project Authorities. The by-far stable 'Pango link', started displaying large scale subsidence and slushy conditions making it un-trafficable. Stabilising this important link, therefore, became the first priority for the project as in the event of 'Camel back' area becoming un-pliable during any further heavy rainfall, the project could be faced with an unpleasant situation of not having any access to the powerhouse area at all. An elaborate plan using a combination of geosynthetics and the conventional methods was immediately devised and successfully implemented during the period October 2000 to February 2001. The 'Pango link' has ever since been an 'all season' important link road to the powerhouse areas.

Pursuing a vision of un-interrupted traffic flow through the 'Camel back' area, well thought of geosynthetic solutions, using sub-surface drainage galleries and reinforced earth walls, have been implemented during the working seasons of years 2001, 2002 and 2003. All the measures so taken have proved very beneficial and there have been no significant traffic interruptions in this area during the monsoons of these years.

4.1 Geology of Slide Areas

The area around the 'Camel back' and 'Pango link' consists mainly of highly weathered and slumped gneisses and schists belonging to Thimphu formation of Pre-Cambrian Age. The road network in this area has been constructed mainly within the loose and semi-consolidated over-burden comprising angular rock fragments of various sizes enmeshed in a silty sandy matrix. The localized slips and landslides have mostly developed along valleyward dipping joints. The subsidence patches noticed in the area are apparently due to the above landslides and the loosely packed over-burden with relatively high permeability. The frequent instability is caused by the seasonal run-off through the topographical depressions existing within the slumped and weathered rock mass.

5. THE SEARCH FOR SOLUTION

We understand that intense construction activity can and does bring about lasting changes in the groundwater, stress and soil properties. If the natural ground or topography is viewed as an engineering material input, many of the likely problems can be anticipated. Engineering geology, soil mechanics and cost considerations play their individual roles in the ultimate solutions applied to a particular situation/site. In most cases, atleast in the developing world, the cost considerations, the past failures and success rates experienced by the engineers concerned and the available time end up in selection of the final solutions.

Consultations with various agencies like the Kvaerner Cementation India Ltd., Dupont India Ltd., and Z-Tech India Ltd., proved very helpful in devising suitable short-term as well as long-term solutions. Substantial product information regarding major functions of geosynthetics, viz., separation, filteration, drainage and reinforcement, was gathered from these entities. The choice of a partner-in-implementation, however, finally ended in the selection of M/s. Z-Tech (India) Ltd., New Delhi, who not only assured arrangement and supply of the selected geosynthetics but also showed keen interest in associating during the implementation stage on ground. Project engineers visited Mongpoo, Mirik Road and Dudhia Bridge locations in the Darjeeling district of West Bengal, India, to acquire first hand information regarding installation of mechanically stabilised earth walls and river bank erosion control measures.

5.1 Solutions and their Implementation

The construction of power-house road has been entrusted to the premium road construction agency of India, the Border Roads Organisation. Any long-term solution for the stability of this road, therefore, required co-operation from that organisation. The initial doubts and hesitation about the efficacy of geosynthetics vis-a-vis the conventional breast walls and surface drain solutions soon gave way to enthusiastic participation. The following description covers the details of actual plans devised and implemented at various locations described earlier.

5.1.1 *Pengo Link*

The situations and the problems described in the foregoing paragraphs required the treatment of ‘Pango link” to provide :

(a) Subsurface and cross-drainage to arrest seepage water,

(b) Protection of the slopes against erosion, and

(c) Stabilisation of the sub-grade to provide proper riding surface.

Border Roads Organisation of India, had constructed the ‘Pangolink’ and they were also actively Involved In the Implementation of the following geosynthetlc solutions:

(a) *Arresting Seepage*

A permeable textile, non-woven in nature, had to be selected due to the dominant site requirement for a filtering, radially draining media rather than a woven geotextiles having higher strength properties. Ingress of seepage water being the main cause of slope and pavement distress, a drainage gallery was devised to carry the seepage water away without allowing the migration of soil particles. A non-woven geotextile product. MIRAFI-160N, produced by M/s. T.G. MIRAFI, having a high permeability of 220 L/m^2/S was selected for the purpose and was installed in the manner shown in Fig. 3.

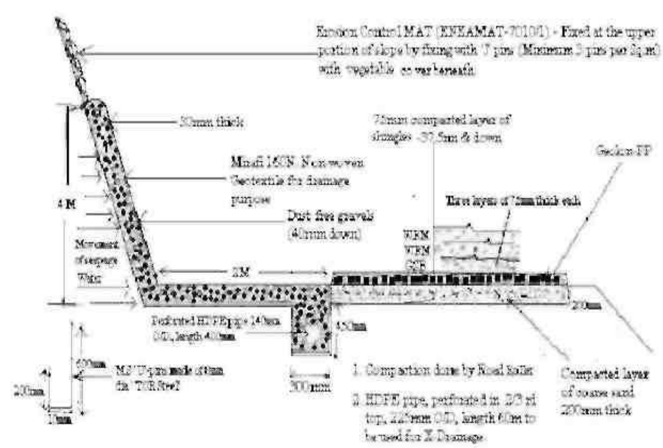

Fig. 3 : Application of geosynthetics at “Pango link”

The hill sides were excavated and dressed up to 4 m heights to receive the geotextlle layer which was extended onto the road edge, taken around a 45 cm x 30 cm subsurface drain and returned back to form a 30 cm thick envelope over the already laid bottom layer of the geotextlle. Effective functioning of the drainage gallery made it mandatory to select and provide clean, dust-free river shingle of size 37.5 mm and down, free to allow flow of seepage water to the 2/3rd perforated 140 mm dia HDPE pipe (perforations of 12 mm dia to 20 mm dia @ 100 mm to 150 mm centre to centre staggered) to carry it away to the nearby available natural water course. The arrangement was supplemented by construction of 4 m high conventional sausage wall (to support the drainage gallery). Surface drains running along the road alignment were added roughly above the sub-surface drains to carry the surface run-off. The resultant retention of the 4 m high porous soil columns and easy escape of seepage water proved very effective in reducing the soil saturation levels (Photos 3 & 4).

(b) *Protecting Upper Slopes*

Besides protecting the hill slopes up to 4 m height, need was felt to also protect against surface erosion and sliding down of over-burden from the hill slopes extending beyond the initial 4 m height. A product named ENKAMAT-7010/1, produced by M/s. Colbond Geosynthetics, having a tensile strength of 1.5 KN/m, was selected because of it's 3-dimensional properties which help in assisting the nature in developing a strong vegetation cover, slowing down the speed of run-off and promote sedimentation to provide an effective erosion control mat. The rich growth of vegetation that we see today on the treated slopes stands testimony to the effectiveness of the application.

(c) *Stabilising the Sub-grade*

As the link road displayed very low bearing capacity of the sub-grade worsened by the saturation of sub-grade, a product was needed which could (i) strengthen the sub-grade by separating it from the overlaying soling, (ii) stop deformation, (iii) stop or reduce dispersion of the aggregate layer to prevent pot-holes, and (iv) help in distribution of traffic-load over the pavement.

The choice of GEOLON PP80, produced by M/s. TC MIRAFI, a polypropylene woven geotextile, has proved quite effective because of its' high strength, high separation and high reinforcement properties. The fabric has displayed good puncture and tear resistance and has proved to be a very effective barrier between the compacted layer of 200 mm thick coarse sand (laid over sub-grade) and the overlaying shingle layer to provide separation, confinement and traffic-load distribution. A relatively trouble-free riding surface, with lesser rut-formations, ever-since the application of GEOLON PP80 has added to the utility value of the 'Pango link'.

5.1.2 *The Camel Back*

The long-term stabilisation of 'Camel back' was a necessity acknowledged by the Project Authorities as early as in the year 1999. The periodic treatment of slopes, with infiltration galleries and conventional RRM/surface drain combinations, were not proving very effective. The wooded area, with rivulets in-between, required treatment to prevent any extensive movement of the soil-mass. A total stabilisation plan to provide surface and subsurface drainage control was, therefore, devised and implemented.

The site presented stringent demands, namely :

- Need for preventing the loss of soil particles/mass due to water erosion.
- Allowing the passage of water while preventing the un-controlled passage of soil particles.
- Resistance to stresses causing deformation in soil structures.

Photo 3 : Installation of GEOLON PP80 at Pango link

Photo 4 : Installation of perforated HDPE pipes at Pango link

- Control of erosion of slopes against surface run-off by imparting resistance to downhill flow velocities.

The composite plan also had to be economical and easily implementable. The arrangements made at site are discussed in the ensuing description.

The ingress of water and heavy surface flows make the slopes vulnerable to landslides. The formation of wedges or slip-circles tend to separate the overlaying soil from the main body of the earth-mass/rock. Geo-grids laid in horizontal layers are known for providing reinforcement to the slopes by intercepting potential failure surfaces and providing horizontal anchorage to the sliding mass. Earth walls constructed with the help of geo-grids are relatively flexible compared to mass gravity structures such as the gabion or stone masonry walls. The earth walls are relatively economic and faster to construct and gel better with the environment and surroundings. The high tensile strength and stiffness provided by the geo-grids make them ideal reinforcing material resistant to even very aggressive environmental demands.

The hill slopes from El 1010 m, right down to El 765 m were quite steep & almost bereft of vegetation after the August 2000 rain havoc. It was observed that the road benches at El 830 m and “Camel back” suffered extensive tension cracks, allowing seepage water to enter and cause base failure and triggering land-slides. The surface interception drainage provided at El 830 m was buried under the sliding mass from the upper slopes. The soil encountered had little silt and the loose rocks over the slopes had a tendency to roll down immediately after the catchment area between El 1010 m and El 830 m discharged huge quantities of water during peak monsoons.

Land slips have been controlled to a great extent with the help of:

- Surface catch water drains at El 1010 m, El 830 m, “Camel back” and El 765 m to drain surface run-off.
- Subsurface drainage galleries at the base of slopes to trap and evacuate seepage water.
- Mechanically stabilised reinforced earth walls to replace the conventional gabion walls for better flexibility, lesser local settlement, lighter weight, lesser cost, minimum environmental impact and no possibility of toppling over.
- Quick growth of vegetation over the hill slopes and the ‘soil wall’ facia.

5.1.3 *Choice of Geosynthetic Materials*

For the construction of drainage gallery, the choice of non-woven geotextile fell on a product called TYPAR SF-40, manufactured by M/s. DUPONT, which had all the properties needed, viz., providing separation, filtration and drainage with relatively strong diagonal tensile strength (the product had a permeability of 1.5 10^{-4} m/sec to 2.2 10^{-4} m/sec and a tensile strength of 8.5 kN/m and was known to be rot, moisture and chemical attack resistant).

For the construction of mechanically reinforced earth wall, the final choice for a geo-grid resulted in a product called ENKAGRID PRO-60, manufactured by M/s. COLBOND GEOSYNTHETICS. The product had the following properties :

“Uni-axial, rigid polyester geo-grid with a tensile strength of 60 KN/m, long term design strength of 30.3 KN/m, aperture size of 94 mm x 42 mm and a design life of 120 years”.

The product is versatile and could be used to reinforce most types of soils, had rigid junctions, adequate strength, low deformation during construction, low installation damage and long-term durability. It was easy to install the product due to its convenient manufactured widths of 5 m and lesser need for over-laps.

5.1.4 *Construction Work*

(a) *Locations* : The above mentioned geosynthetic materials were received in the project stores in August/ September, 2001. Although the original plan was to provide the “earth-walls” above El 830 m, “Camel back” and El 765 m benches; it was later felt that any construction activity on the road leading to El 765 m tunnel adit just before the ensuing monsoons could seriously undermine the upper slopes as well as disrupt the on-going project works at El 765 m. Since the gabion walls provided earlier on El 765 m approach road had also not shown much distress symptoms, it was decided to take up the earth walls only above El 830 m and the “Camel back” in the first stage.

An earth wall 30 m long (3 m x 3 m size) was constructed above El 830 m and various earth walls totaling 57 m in length (sizes 3 m x 3 m and 2 m x 2 m) were constructed above the “Camel back” during the period Jan. 2002 to April 2002. The measures proved very effective and there has been no significant interruption of traffic at El 830 m or the “Camel back” since then. The earth walls now support rich vegetation. The general arrangement is shown in Fig. 4.

In order to further stabilise the slopes between the “Camel back” and El 765 m, 106 m and 70 m long earth walls (3.5 m high x 3.5 m wide) were provided at approx. El 800 m and El 780 m, respectively, during the period December 2002 to April 2003. The full effect of the measure would be seen in the monsoons of year 2004 although the area has already stabilised to a great extent and has performed well during the monsoon of year 2003 (Photo 5).

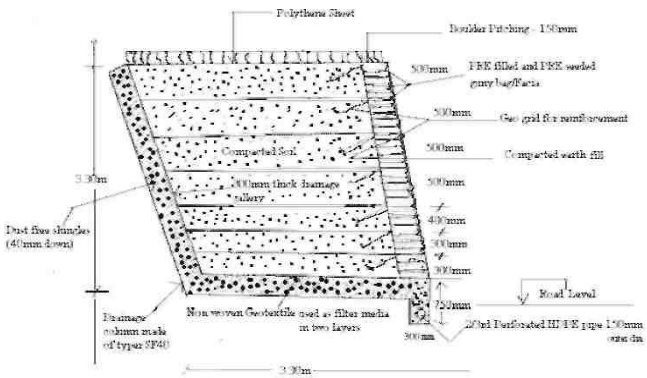

Fig. 4 : General arrangement of soil well at “Camel back”

Photo 5 : Provision of subsurface drainage at the ‘Camel back’

(b) *Methods* : The subsurface drainage galleries provided all along the length of the earth walls were constructed in the same manner as explained earlier in the case of ‘Pango link’ application. The non-woven geotextlle Mirafi 160N used on the Pango link was, however, replaced In this case by Typar SF-40, primarily for the ease of procurement and cost consideration.

The soil walls were constructed by laying ENKA-GRID (from the slope end) on the already laid infiltration gallery, filling and ramming native soil to varying heights to keep them equal to the height of tightly filled gunny bags placed as ‘facia’. The entire procedure was repeated till the designed heights of earth wall i.e., 3.5 m were achieved. The top of the ‘earth wall’ was provided with an impermeable membrane sheet pressed down with a boulder layer 150 mm thick to stop any surface water from the slopes to penetrate and saturate the fill material. It was initially planned to mix grass seeds with good earth in the gunny bags to form the facia. This arrangement was not practically followed for the works carried out in early 2002 and instead grass seeds were introduced in the facia by using ‘samplers’ after the erection of walls to full height. The revised methodology at site, however, suffered from the drawback of un-equal distribution of seeds and some damage to the gunny bags. Learning from the experience, the original seed impregnation plan was followed for the works executed in the year 2003 with far better results (Photo 6).

(c) *Costs*: The cost effectiveness of the earth walls provided at Tala HEP has also been established. The cost of a ‘gabion wall’ as per the then prevalent Bhutan Schedule of Rates worked out to about Rs. 1325/m^3 whereas the cost of the ‘soil-wall’ constructed using Typar SF-40 and Enka Grid PRO-60 geotextiles worked out to about Rs. 1225/m^3.

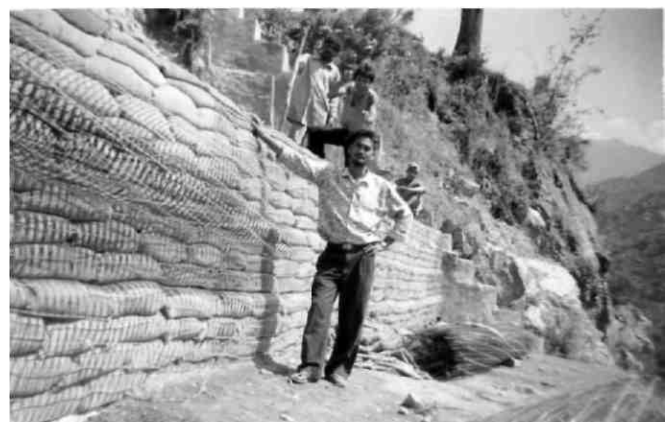

Photo 6 : Installation of soil wall at ‘Camel back’

6. CONCLUSIONS

The geosynthetic techniques applied at the ‘Pango link’ and the ‘Camel back’ of Tala HEP have proved very successful. Both locations were very important for ensuring an all season, round the clock access to the power- house area experiencing peak project activities. Monsoon seasons of 2001, 2002 and 2003 have already gone past with almost no traffic interruptions and it is felt that the arrangements will get further consolidated over a period to provide years of trouble free service.

Engineering fraternity planning to carry out similar stabilisation works must, however, ensure that success of the arrangement will depend greatly on following the correct laying procedures on the ground. The executing agency or the contractors have to ensure that the work supervisors understand the basic mechanism; functions of each geosynthetic material being placed and the efficacy of the whole arrangement. If small requirements like proper pre-mixing of grass seeds in the soil filled bags, proper placement of plastic sheet over the soil wall or providing properly perforated drainage pipes are not given due attention, the whole project could get jeopardized. We surely do not want to see that happen.

INTERNATIONAL GEOSYNTHETICS SOCIETY

The International Geosynthetics Society (IGS) was founded in Paris, on 10 November 1983, by a group of geotechnical engineers and textile specialists. The Society brings together individual and corporate members from all parts of the world, who are involved in the design, manufacture, sale, use or testing of geotextiles, geomembranes, related products and associated technologies, or who teach or conduct research about such products.

The IGS is dedicated to the scientific and engineering development of geotextiles, geomembranes, related products and associated technologies. IGS has 47 chapters, over 3,000 individual members and 161 corporate members.

The aims of the IGS are:

- to collect and disseminate knowledge on all matters relevant to geotextiles, geomembranes and related products, e.g. by promoting seminars, conferences, etc.
- to promote advancement of the state of the art of geotextiles, geomembranes and related products and of their applications, e.g. by encouraging, through its members, the harmonization of test methods, equipment and criteria.
- to improve communication and understanding regarding such products, e.g. between designers, manufacturers and users and especially between the textile and civil engineering communities

The IGS is registered in the USA as a non-profit organization. It is managed by five Officers and a Council made up of 10 to 16 elected members and a maximum of 5 additional co-opted members. These Officers and Council members are responsible to the General Assembly of members which elects them and decides on the main orientations of the Society.

IGS CHAPTERS

The IGS Chapters are the premier vehicle through which the IGS reaches out to and influences the marketplace and the industry. Chapter activities range from the organization of major conferences and exhibits such as the 10th International Conference on Geosynthetics in September 2014 in Berlin, Germany and its predecessors in Guaruja, Yokohama, Nice and Atlanta to the presentation of focused seminars at universities, government offices and companies. Chapters create the opportunity for the chapter (and IGS) membership to reach out, to teach and to communicate and they are the catalyst for many advances in geosynthetics. Participation in an IGS chapter brings researchers, contractors, engineers and designers together in an environment which directly grows the practice by informing and influencing those who are not familiar with our discipline.

MEMBERSHIP

Membership of IGS is primarily organised through national Chapters. Most individual members (94%) belong to the IGS through Chapters. Chapter participation allows members to be informed about, and participate in, local and regional activities in addition to providing access to the resources of the IGS.

IGS Offers the following categories of membership:

Individual

Individual member benefits are extended to each and every individual member of the IGS including Chapter Members. Additional chapter benefits are provided to Individual Members who join the IGS through a chapter.

Individual Member Benefits include:

- a membership card
- an IGS lapel pin
- on-line access to the *IGS Membership Directory*
- the IGS News, Newsletter, published three times a year
- on-line access to the 19 IGS Mini Lecture Series for the use of the membership
- information on test methods and standards
- discount rates:
  - for any document published in the future by IGS
  - at all international, regional or national conferences organized by the IGS or under its auspices

- preferential treatment at conferences organized by the IGS or under its auspices
- possibility of being granted an IGS award
- Free access to the *Geosynthetics International* journal, now published electronically.
- Free access to the *Geotextiles and Geomembranes* journal, now published electronically.

Corporate

Corporate Membership Benefits include:

- a membership card
- an IGS lapel pin
- on-line access to the *IGS Membership Directory*
- the IGS News newsletter, published three times a year
- on-line access to the 19 IGS Mini Lecture Series for the use of the membership
- information on test methods and standards
- discount rates:
    - for any document published in the future by IGS
    - at all international, regional or national conferences organized by the IGS or under its auspices
- preferential treatment at conferences organized by the IGS or under its auspices
- possibility of being granted an IGS award
- free access to the *Geosynthetics International* journal, now published electronically.
- free access to the *Geotextiles and Geomembranes* journal, now published electronically.
- **advertisement in the *IGS Member Directory* and on the IGS Website**
- **IGS Corporate Membership Plaque**
- **Company Profile in the IGS News**
- **right of using the IGS logo at exhibitions and in promotional literature**
- **priority (by seniority of membership within the IGS) at all exhibits organized by the IGS or under its "auspices"**
- **opportunity to join IGS committees in order to discuss topics of common interest.**

Student

Student Membership Benefits include:

- Electronic access to the IGS News, published 3 times a year
- Special Student discounts at all IGS sponsored/supported conferences, seminars etc.
- Listing in a special student members category in the IGS Directory
- Eligibility for awards (and in particular the IGS Young Member Award).

List of IGS Chapters

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INDIAN CHAPTER OF IGS

In the year 1985, Central Board of Irrigation and Power, (CBIP) as part of its technology forecasting activities identified geosynthetics as an important area relevant to India's need for infrastructure development, including roads. After approval of IGS Council for the formation of Indian Chapter in October 1988, the Indian Chapter of IGS was got registered under Societies Registration Act 1860 of India in June 1992 as the Committee for International Geotextile Society (India), with its Secretariat at Central Board of Irrigation and Power. The Chapter has since been renamed as International Geosynthetics Society (India), in view of the parent body having changed its name from International Geotextiles Society to International Geosynthetics Society.

The activities of the Society are governed by General Body and Executive Board.

Executive Board of Indian Chapter of IGS 2020-2022

The Executive Board of the IGS (India) consists of President, elected by the General Body, two Vice-Presidents and 16 members. The Secretary and Director (WR) of the CBIP are the as the Ex-Officio Member Secretary and Treasurer, respectively, of the Society.

The present Executive Board is as under:

President

- **Mr. Vivek P. Kapadia,** *Secretary to Government of Gujarat and Director*, SSNNL

Vice-Presidents

- **Dr. R. Chitra,** *Director,* Central Soil & Materials Research Station
- **Dr. Jimmy Thomas,** Geotechnical Consultant

Immediate Past President

- **Mr. M. Venkataraman,** *Chief Executive Officer,* Geosynthetics Technology Advisory Services LLP and Guest Professor, Department of Civil Engineering IIT Gandhinagar

Hon. Members

- **Dr. G.V. Rao,** *Former Professor,* Department of Civil Engineering, IIT Delhi and Guest Professor, Department of Civil Engineering, IIT Gandhinagar
- **Dr. K. Rajagopal,** *Professor,* Department of Civil Engineering IIT Madras

Member Secretary

- **Mr. A.K. Dinkar,** *Secretary,* Central Board of Irrigation & Power

Treasurer

- **Mr. K.K. Singh**, *Director (WR),* Central Board of Irrigation & Power

Past Presidents

The presidents of the society in the past were:

- Dr. R.K. Katti, Director, UNEECS Pvt. Ltd. and Former Professor, IIT Bombay
- Mr. H.V. Eswaraiah, Technical Director, Karnataka, Power Corporation Ltd.
- Dr. G.V. Rao, Professor, Department of Civil Engineering, IIT Delhi
- Dr. D.G. Kadade, Chief Advisor, Jaiprakash Industries Ltd.
- Dr. K. Rajagopal, Professor, Department of Civil Engineering, IIT Madras

Indian Representation on IGS Council

- Dr. K. Rajagopal, Professor, Department of Civil Engineering, IIT Madras
- Dr. G.V. Rao, Former Professor, Department of Civil Engineering, IIT Delhi
- Mr. M. Venkataraman, Geotechnical and Geosynthetic Consultant
- Mr. Vivek P. Kapadia, Secretary to Government of Gujarat and Director, SSNNL

IGS Student Award Winners from India

The IGS has established Student Paper Award to disseminate knowledge and to improve communication and understanding of geotextiles, geomembranes and associated technologies among young geotechnical and geoenvironmental student engineers around the world. The IGS student award consists of US$1,000 to be used to cover travel expenses of each winner to attend a regional conference.

Following from India have been honoured with IGS Student Paper Award:

- Dr. J.P. Sampath Kumar, National Institute of Fashion Technology, Hyderabad
- Dr. K. Ramu, JNTU College of Engineering, Kakinada
- Mrs. S. Jayalekshmi, National Institute of Technology, Tiruchirappalli
- Dr. Mahuya Ghosh, IIT Delhi
- Dr. S. Rajesh, Department of Civil Engineering, IIT Kanpur
- Mr. Suresh Kumar S., Department of Textile Technology, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar

Publications/Proceedings on Geosynthetics

In addition to the proceedings of the events on Geosynthetics, following publications have been brought out since 1985:

1. Workshop on Geomembranes and Geofabrics (1985)
2. International Workshop on Geotextile (1989)
3. Use of Geosynthetics – Indian Experiences and Potential – A State of Art Report (1989)
4. Use of Geotextile in Water Resources Projects - Case Studies (1992)
5. Role of Geosynthetics in Water Resources Projects (1993)
6. Monograph on Particulate Approach to Analysis of Stone Columns with & without Geosynthetics Encasing (1993)
7. 2nd International Workshop on Geotextiles (1994)
8. Directory of Geotextiles in India (1994)
9. An Introduction to Geotextiles and Related Products in Civil Engineering Applications (1994)
10. Proceedings of Workshops on Engineering with Geosynthetics (1995)
11. Ground Improvement with Geosynthetics (1995)
12. Geosynthetics in Dam Engineering (1995)
13. Erosion Control with Geosynthetics (1995)
14. Proceedings of International Seminar & Techno Meet on “Environmental Geotechnology & Geosynthetics” (1996)
15. Proceedings of First Asian Regional Conference “Geosynthetics Asia’1997”
16. Directory of Geosynthetics in India (1997)
17. Bibliography – The Indian Contribution to Geosynthetics (1997)
18. Waste Containment with Geosynthetics (1998)
19. Geosynthetic Applications in Civil Engineering- A Short Course (1999)
20. Case Histories of Geosynthetics in Infrastructure Projects (2003)
21. Geosynthetics – Recent Developments (Commemorative Volume) (2006)
22. Geosynthetics in India – Present and Future (2006)
23. Applications of Geosynthetics – Present and Future (2007)
24. Directory of Geosynthetics in India (2008)
25. Geosynthetics India’08

26. Geosynthetics India’ 2011
27. Geosynthetic Reinforced Soil Structures - Design & Construction (2012)
28. Applications of Geosynthetics in Infrastructure Projects (2013)
29. Applications of Geosynthetics in Railway Track Structures (2013)
30. Silver Jubilee Celebration (2013)
31. Directory of Geosynthetics in India (2013)
32. Applications of Geosynthetics in Infrastructure Projects (2014)
33. Geosynthetics India 2014
34. Three Decades of Geosynthetics in India – A Commemorative Volume (2015)
35. History of Geosynthetics in India - Case Studies (2016)
36. Proceedings of 6th Asian Regional Conference on Geosynthetics (2016)
37. Coir Geotextiles (Coir Bhoovastra) for Sustainable Infrastructure (2016)
38. Proceedings of the Geosynthetics Applications for Erossion Control and Costal Protection (2018)
39. Geosynthetics Testing – A Laboratory Manual (2019)

Indian Journal of Geosynthetics and Ground Improvement

The Indian Chapter of IGS has taken the initiative to publish Indian Journal of Geosynthetics and Ground Improvement (IJGGI), on half yearly basis (January – June and July-December), since January 2012.The aim of the journal is to provide latest information in regard to developments taking place in the relevant field of geosynthetics so as to improve communication and understanding regarding such products, among the designers,manufacturers and users and especially between the textile and civil engineering communities.The Journal has both print and online versions.

Events Organised/Supported

1. Workshop on Geomembrane and Geofabrics, September 1985, New Delhi
2. Workshop on Reinforced Soil, August 1986
3. International Workshops on Geotextiles, November 1989, Bangalore
4. National Workshop on Role of Geosynthetics in Water Resources Projects, January 1992, New Delhi
5. Workshop on Geotextile Application in Civil Engineering, January 1993, Chandigarh
6. International Short Course on Soil Reinforcement, March 1993, New Delhi
7. Short Course on Recent Developments in Design of Embankments on Soft Soils, Nov./Dec. 1993, New Delhi
8. 2nd International Workshop on Geotextiles, January 1994, New Delhi
9. Short Course on Recent Developments in the Design of Embankments on Soft Soils, January 1994, Kolkata
10. Workshop on Role of Geosynthetics in Hill Area Development, November 1994, Guwahati
11. Workshop on Engineering with Geosynthetics, December 1994, Hyderabad
12. Short Course on Recent Developments in the Design of Embankments on Soft Soils, May 1995, New Delhi
13. Seminar on Geosynthetic Materials and their Application, August 1995, New Delhi
14. Short Course on Recent Developments in the Design of Embankments on Soft Soils, October 1995, New Delhi
15. Short Course on “Ground Improvement with Geosynthetics”, October 1995, New Delhi
16. Workshop on “Environmental Geotechnology”, December 1995, New Delhi
17. Workshop on “Role of Geosynthetics in Hill Area Development”, February 1996, Gangtok
18. Workshop on “Engineering with Geosynthetics”, March 1996, Visakhapatnam

19. Workshop on “Ground Improvement with Geosynthetics”, March 1996, Kakinada
20. Workshop on “Engineering with Geosynthetics”, May 1996, Chandigarh
21. International Seminar & Technomeet on “Environmental Geotechnology with Geosynthetics”, July 1996, New Delhi
22. Seminar on “Fields of Application of Gabion Structures”, September 1997, New Delhi
23. First Asian Regional Conference “Geosynthetics Asia’1997”, November 1997, Bangalore
24. Short Course on “Waste Containment with Geosynthetics”, February 1998, New Delhi
25. Symposium on “Rehabilitation of Dams”, November 1998, New Delhi
26. Training Course on “Geosynthetics and their Civil Engineering Applications”, September 1999, Mumbai
27. Seminar on “Coir Geotextiles-Environmental Perspectives”, November 2000, New Delhi
28. Second National Seminar on “Coir Geotextiles – Environmental Perspectives”, April 2001, Guwahati, Assam
29. National Seminar on “Application of Jute Geotextiles in Civil Engineering”, May 2001, New Delhi
30. International Course on “Geosynthetics in Civil Engineering”, September 2001, Kathmandu, Nepal
31. Workshop on “Applications of Geosynthetics in Infrastructure Projects”, November 2003, New Delhi
32. Geosynthetics India 2004 – “Geotechnical Engineering Practice with Geosynthetics”, October 2004, New Delhi
33. Introductory Course on Geosynthetics, November 2006, New Delhi
34. International Seminar on “Geosynthetics in India – Present and Future” (in Commemoration of Two Decades of Geosynthetics in India), November 2006, New Delhi
35. Workshop on “Retaining Structures with Geosynthetics”, December 2006, Chennai
36. Special Session on “Applications of Geosynthetics” during 6th International R&D Conference, February 2007, Lucknow (U.P.)
37. Workshop on “Applications of Geosynthetics – Present and Future”, September 2007, Ahmedabad (Gujarat)
38. International Seminar “Geosynthetics India’08” and Introductory Course on “Geosynthetics”, November 2008, Hyderabad
39. Special Session on “Applications of Geosynthetics” during 7th International R&D Conference, February 2009, Bhubaneswar (Orissa)
40. Seminar on “Applications of Geosynthetics”, July 2010, New Delhi
41. International Seminar on “Applications of Geosynthetics”, November 2010, New Delhi
42. Geosynthetics India’ 2011, September 2011, IIT Madras
43. Seminar on “Slope Stabilization Challenges in Infrastructure Projects”, October 2011, New Delhi
44. GEOINFRA 2012 – A Convergence of Stakeholders of Geosynthetics, August 2012, Hyderabad
45. Seminar on “Ground Control and Improvement”, September 2012, New Delhi
46. Workshop on “Geosynthetic Reinforced Soil Structures - Design & Construction”, October 2012, New Delhi
47. Seminar on “Landfill Design with Geomembrane”, November 2012, New Delhi
48. Seminar on “Slope Stabilization Challenges in Infrastructure Projects”, November 2012, New Delhi
49. Seminar on “Applications of Geosynthetics in Infrastructure Projects”, June 2013, Bhopal
50. Seminar on “Applications of Geosynthetics in Railway Track Structures”, September 2013, New Delhi
51. Silver Jubilee Celebration, October 2013, New Delhi
52. Seminar on “Applications of Geosynthetics in Infrastructure Projects”, July 2014, Agra
53. Geosynthetics India 2014, October 2014, New Delhi

54. Seminar on Geotextiles: A Big Untapped Potential, September 2015, New Delhi
55. Three Decades of Geosynthetics in India – International Symposium Geosynthetics - The Road Ahead, November 2015, New Delhi, India
56. North Eastern Regional Seminar on “Applications of Geosynthetics in Infrastructure Projects”, June 2016, Guwahati
57. Workshop on “Applications of Geosynthetics in Infrastructure Projects”, June 2016, Thiruvananthapuram
58. Training Course on Geosynthethics, November 2016, New Delhi
59. Workshop on Coastal Protection, November 2016, New Delhi
60. 6th Asian Regional Conference on Geosynthethics, November 2016, New Delhi
61. Training Course on "Geosynthetic Reinforced Soil Structures", February 2017, New Delhi
62. Training Course on “Applications of Geosynthetics”, December 2017, Dharwad (Karnataka)
63. Workshop on “Design and Construction of Pavements using Geosynthetics”, January 2018, New Delhi
64. IGS Educate the Educators Program, February 2018, IIT Madras
65. Training Course on “Applications of Geosynthetics”, February 2018, Trichy (Tamil Nadu)
66. Training Course on Design and Construction of Pavements with Geosynthetics and Geosyntheics Reinforced Soil Slopes and Walls, 15 June 2018, New Delhi
67. Seminar on Slope Stabilization Challenges in Infrastructure Projects, 21-22 June 2018, New Delhi
68. Training Programme on “Applications of Geosynthetics in Dams & Hydraulic Structures”, August 2018, Bhopal
69. Training Course on “Slope Stabilization Challenges in Infrastructure Projects”, October 2018, Dehradun
70. Seminar on “Geosynthetics Applications for Erosion Control and Coastal Protection”, October 2018, Bhubaneswar
71. Workshop on Natural Hazard Mitigation with Geosynthetics, January. 2019, Thiruvananthapuram, (Kerala)
72. Symposium of International Association for Computer Methods and Advances in Geomechanics (IACMAG) – Special Session of Indian Chapter of IGS, March 2019, IIT Gandhinagar
73. Seminar on Geosynthetics for Highway Infrastructure with Marginal Materials and Difficult Soils, September 2019, Jaipur
74. Workshop on Testing and Evaluation of Geosynthetics, September 2019, Jaipur
75. Workshop on Best Practices for Implementation of Geosynthetic Reinforced Soil Walls. January 2020, Jaipur
76. Webinar on Challenges in Developing Codes of Practice for Geosynthetics for Durable Infrastructure Development, 14 September 2020
77. Webinar on Challenges in Geosynthetic and Geotechnical Testing, 15 September 2020
78. Virtual Training Sessions on Erosion Control, 28 July 2021
79. Virtual Training Programme on the Failure of Reinforced Soil Walls: Lessons and Remedies, 29 September, 2021

IGS NEWS

IGS ELECTION RESULTS ANNOUNCED!

The results are finally in – IGS North America's Sam Allen has been elected as the new President of the IGS with IGS South Africa's Edoardo Zannoni as Vice President.

They, and eight newly elected Council members, will begin their terms this September and serve until 2026. Outgoing IGS President Chungsik Yoo will continue on the Council as Past President.

IGS President 2022-2026
Sam Allen (USA)

IGS Vice President 2022-2026
Edoardo Zannoni (South Africa)

Mr Allen said: "It is my highest honor to be elected to lead the IGS. I have benefitted by learning from an esteemed group of IGS leaders, colleagues and experts that have given their time and talents to the Society, and feel fortunate to have this opportunity to embrace our exciting future.

"There is much to accomplish. As humankind encounters substantial challenges, the IGS and our products are an integral part of the needed solutions. We will communicate the amazing benefits of geosynthetics in new state-of-the-art platforms and present the IGS as a responsible member of our global community in building a more sustainable and resilient future.

"The IGS has a brilliant and urgent future. I look forward to working with our gifted IGS Council and our talented global membership to realize continued success for the IGS."

Mr Zannoni, the IGS's first Vice President from South Africa, and outgoing IGS Secretary General, said: "It is a privilege to be elected through one of the highest turnouts in IGS election history. It is a vote of confidence in the IGS as an organization that is leading the way in addressing challenges such as sustainability, credentialling and growing our presence beyond our sister societies, establishing a direct communication with cross-discipline societies, and adapting to a fast evolving world and membership.

"I look forward to working with Sam, our new Council and the wider membership in continuing to develop the IGS to benefit the growth, impact and innovation of geosynthetics around the world."

IGS members voted from April to June for their favourite candidates to lead the next IGS Council. This year saw a record 22 candidates spanning 16 countries. It was also the highest ever voter turnout of 26.9%.

Also elected as Council Members were: Dimiter Alexiew (Germany), Eric Blond (Canada), Mikio Kubo (Japan), Patricia Guerra-Escobar (UK), Erol Tutumluer (USA), Amir Shahkolahi (Australia), Chiwan Wayne Hsieh (Taiwan), and Nicola Moraci (Italy).

The IGS Council will vote on who will be the next Secretary and Treasurer at its next meeting on July 7. Committee chairs are expected to be decided during the IGS Council meeting at EuroGeo7 in Warsaw, Poland, on September 8.

The Society congratulates all elected candidates, and thanks those unsuccessful this time for their participation and continued commitment to the IGS. The Society also thanks everyone who voted; participation in elections is critical to ensuring the IGS stays true to its mission and hears all members' voices.

IGSF HELPS HARNESS THE POWER OF VIRTUAL EDUCATION

Last year the IGS Foundation (IGSF) supported the work of the IGS Educate

The Educators (EtE) program to repackage its 'Introduction to geosynthetics' lecture, normally only delivered in-person, into a series of on-demand videos for students and educators.

The new resources built on an initiative already spearheaded by IGS Brazil in its EtE programs since 2020 – the use of virtual teaching sessions.

Thanks to a grant from the IGSF, the one-hour in-person lecture was reimagined as five bite-size videos. These were delivered by former IGS President Professor Jorge Zornberg while complementary videos presented by IGS Brazil Vice-President Maria das Graças Gardoni guided educators on how they could structure and present the virtual lessons to make them more interactive.

Less than a year into their launch, the impact of the initiative on its audience, users and creators has been significant.

Prof. Gardoni, an undergraduate professor at the Federal University of Minas Gerais, Brazil, described the development of EtE in Brazil as "the realization of a dream", knowing students would take the knowledge they gained into the diverse industries they were set to enter. Ensuring the videos were as interactive as possible was a key focus for Prof. Gardoni.

She said: "The video of the practical class on the application of geosynthetics in engineering works was created by me with the specific objective of consolidating the knowledge learned in the theoretical classes. But this class should have a dynamic and interactive character. I had been testing this interactive method – Integrated Panel and Geosynthetic Design – for many years in my undergraduate courses in civil and environmental engineering, and the results have always been outstanding. The results obtained with them in EtE have also been exceptional and the participants evaluate it as one of the best parts of the course."

She added: "When I delivered these videos to the IGS I felt an indescribable happiness of someone who fulfilled their duty and, therefore, reached the goal of teaching with joy and lightness. When I received the final formatted video and saw those students analyzing and discussing each type, function, and main properties of geosynthetics, in another language, but with great enthusiasm, I must confess I was very thrilled and my feeling was 'mission accomplished'."

Prof. Zornberg similarly described delivering the videos as "an awesome experience".

He said: "I have been delivering this content for quite some time, both as part of the EtE programs and to my own undergraduate students at the University of Texas at Austin. However, in this case I took the opportunity to rethink the educational strategy. You will see that I have made significant use of 'inking' [live annotation] as I believe this approach allows students to be 'active' while watching the video."

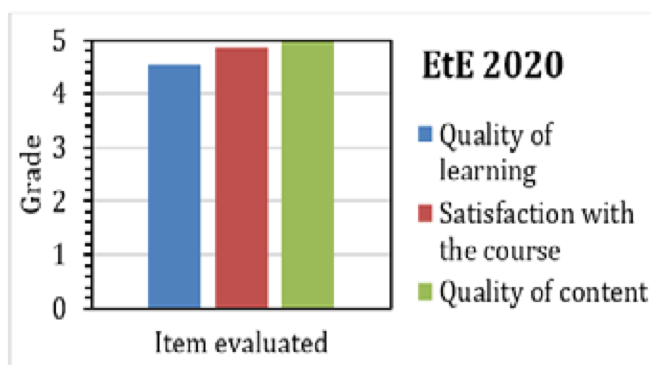
Both acknowledged adopting a didactic approach to communicating the information was key for clarity and international accessibility.

Prof. Zornberg said: "Pedagogy and clarity were the overriding objectives in these videos because the goal was to ultimately reach every single undergraduate civil engineering student on the planet. This was not an easy goal, but the content needed to be such that it was understood by a wide range of students with different backgrounds."

Prof. Gardoni said the use of videos – already a method of teaching in IGS Brazil's EtE program since 2020 – scored highly with students when they evaluated quality of learning, quality of content, and course satisfaction.

Prof. Gardoni added: "I'd like to thank the IGSF and its donors for helping make this initiative possible. This pioneering project has elevated EtE to its rightful level, given the importance to have the 'Introduction to geosynthetics' information included in undergraduate university courses.

"I hope that the companies that invested so wisely in geosynthetics education at the beginning of the IGSF's work will continue in this direction because education requires time to produce its fruits. There is no better way to reach a high goal in geosynthetics engineering than by means of education."



Graph shows the first evaluation made by participants immediately after the end of the Brazil EtE 2020 course.

Prof. Zornberg added: "Education is a long-term goal hard to quantify and value within the rewards system of typical corporations and industry partners. That's why it is so important that the IGSF has stepped up to fill the gap on a need that may not have been emphasized enough by our industry because the results will not be immediately quantified on the balance sheet.

"I hope Chapters will be encouraged to conduct full-scale EtE programs and that educators will request such programs. Ultimately, I hope that all undergraduate students would graduate having heard (at least once) the term ‘geosynthetics’.”

IGSF Secretary-Treasurer Boyd Ramsey said: “IGS Brazil pioneered virtual EtE teaching and thanks to the help of our generous donors we can develop and extend the benefits of these resources worldwide. This is another example of our donations in action, making such a widespread impact, and is why the Foundation does what it does.”

IGSF FUNDS BARRIER SYSTEMS RESEARCH PROJECT

A major research project to collate key information on geosynthetic barrier systems is underway thanks to a grant from the IGS Foundation (IGSF).

The IGSF has awarded Master’s student Vahid Vakili funding to collect and summarize the worldwide regulations, design recommendations and guidelines for geosynthetic barrier systems. The findings will be publicly available for all to access.

Mr Vakili, who is studying at Ryerson University in Toronto, Canada, works in the geotechnical and environmental engineering fields and has experience with North American geotechnical design regulations and environmental assessment guidelines. He is supported by IGSF Board of Trustees member Kent von Maubeuge, together gathering the latest findings on geosynthetics landfill barriers.

Mr Vakili said: “Developing knowledge about geosynthetics in landfill use will help improve and preserve the quality of the surrounding environment while meeting the requirements for waste removal. This project will allow me to learn more about this new field of technology, network with fellow professionals, and work on a project that helps the environment.”

He added he hoped his findings will better inform engineering and construction professionals in their decision-making when considering and implementing geosynthetic barriers. Mr Vakili is expected to begin his research this month and conclude the project in early 2023.

Jonathan Shamrock, chairman of the IGS Technical Committee on Barrier System (TC-B), said the TC-B fully supported Mr Vakili’s work, which would build on efforts previously carried out by the TC-B.

IGSF Secretary-Treasurer Boyd Ramsey said: “Vahid’s proposal is an ambitious undertaking which is expected to have worldwide impact in its reach and usefulness. The Foundation is proud to be able to facilitate such an endeavour, made possible by our generous donors and supportive community.”

The IGSF was set up in 2019 to support and expand the education and learning initiatives of the IGS. It has already amassed nearly $100,000 in donations with previous grants providing 19 scholarships to attend the virtual GeoAmericas 2020 conference and creating video versions of the Educate the Educators ‘Introduction to geosynthetics’ lectures available on demand. It has most recently given funding to the Federal University of São Carlos in São Paulo, Brazil, to create a series of videos demonstrating various geosynthetics materials and how they respond to different forms of testing.

DID YOU KNOW?... LIFE CYCLE ASSESSMENT TOOLS SHOW GEOSYNTHETICS AS THE GREENER CHOICE

Did You Know?... Life Cycle Assessment tools consistently show geosynthetics are the greener choice when it comes to construction

Life Cycle Assessment (LCA) is a key tool used to evaluate the environmental benefits of using different technologies or products during construction. It offers not only a basis for better economic decision-making but shows the ecological impact of choosing a particular method of construction.

So how does it work? LCA measures the environmental impact of products or systems over their lifetime. This includes the extraction of raw materials, production, use, recycling and disposal of waste. The method is often used to compare the impact of two competing products or systems, with the analysis process informed by ISO14040 (ISO 2006a) and ISO14044 (ISO 2006b) or other approved tools.

One of the most common measurements made by a LCA is calculating the Embodied Carbon (EC) of geosynthetic construction solutions. EC means all the carbon dioxide emitted in producing materials, from the construction process to disposal at the end of its lifetime. Outcomes show that incorporating geosynthetics in construction projects is consistently more sustainable than traditional construction materials based on EC and other environmental indicators.

Savings in EC are often realised because geosynthetics enable the use of ‘marginal’ soils – land that has little agricultural or industrial benefits – and which are often site-derived, thus reducing the amount of imported fill material. This minimises transport-related carbon emissions.

Beyond LCA

There is a growing body of evidence detailing the sustainability credentials of geosynthetic-based solutions. These invariably use a variation of the LCA approach, and all include comparisons with non-geosynthetic solutions. The amount of savings differs from application to application, but all LCAs to-date have shown that the use of geosynthetics results in the reduction of environmental impacts.

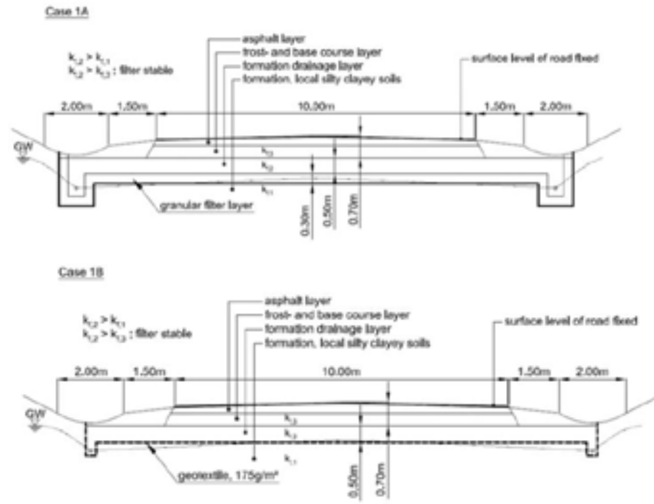
These studies include:

- WRAP – case studies from the UK-based climate action group, which works in more than 40 countries to tackle the causes of the climate crisis, showed how the use of geosynthetics, amongst other benefits, could reduce the amount of imported fill. This provided CO_2 savings from EC emissions from the quarrying of fresh fill, and also eliminating the need to transport these materials on and off site. The study (2010) concluded that construction solutions incorporating geosynthetics led to significant cost and CO_2 savings for reinforcement applications.
- European Association of Geosynthetic Manufacturers (EAGM) – considering four construction systems against eight environmental impact indicators, the EAGM-commissioned study found geosynthetic-based solutions were consistently assessed as more sustainable compared to the performance of traditional construction materials.

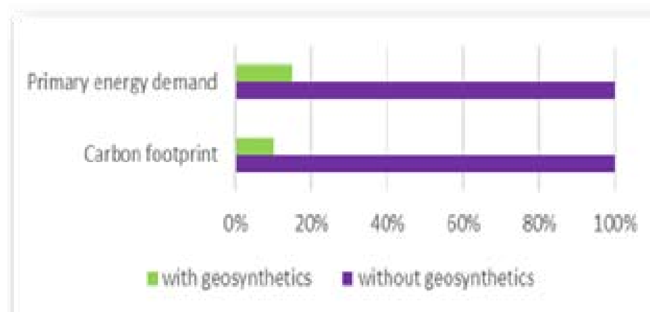
The construction systems considered were filtration, foundation stabilization, a landfill drainage layer, and a soil retaining wall. The alternatives in each case were defined such that they can be considered technically equivalent or at least comparable. The eight environmental impact indicators were cumulative energy demand, climate change (global warming potential, GWP100, carbon footprint), photochemical ozone formation, particulate formation, acidification, eutrophication, land competition, and abiotic resource depletion (excluding fossil fuels).

Several studies also concluded that geosynthetic-based solutions delivered significant cost savings. The methods outlined can be used to undertake site-specific calculations that inform decisions on a selection of construction approaches that contribute to sustainable practice.

One example of the benefits is in the case of filter layers. Geosynthetics are used in soil engineering, where they can serve as a filter medium. The cross-section diagram here shows a mineral filter system (Case 1A) compared to a filter using geosynthetics (Case 1B).



As shown in the figure below, the energy demand and carbon footprint in Case 1B is significantly lower than in Case 1A.



Summary

Across the board, LCAs consistently demonstrate the environmental and cost benefits of using geosynthetic solutions in construction over other methods. These include:

- Minimizing CO_2 and preventing further emissions
- Saving natural resources
- Reducing the energy demand (CED, or cumulative energy demand)
- Saving fresh water
- Reducing construction costs

Clearly, geosynthetics are a key part of the solution when it comes to making cost savings and a positive environmental impact before, during and after construction projects.

Geosynthetic solutions should be fully investigated on every infrastructure project to ensure they meet the needs of the present without compromising the ability of future generations to meet their own needs.

BEAT THE DEADLINE FOR GEOAFRICA ABSTRACTS – JUNE 15, 2022

Share your ideas, work and passion for geosynthetics on a world stage by submitting your papers to GeoAfrica 2023.

One of the region's largest conferences on geosynthetics has extended its deadline for abstracts to June 15, 2022.

Hosted by the Egyptian chapter of the IGS, the 4th African Regional Conference on Geosynthetics is due to take place in Cairo, Egypt, on February 20-23, 2023. Themed ''Geosynthetics in sustainable infrastructures and mega projects', the event aims to explore the region's increasing use of geosynthetics in major programs including utilities, highways, railways, industrial and commercial zones, and tank farms.

The program will also include keynote lectures from industry experts Professors Richard Bathurst, Jorge Zornberg, John McCartney and Abdelmalek Bouazza.

Mohamed Salah, the event's Secretary General, said: "GeoAfrica 2023 will bring together experts in geosynthetics from all over the world to share with each other the latest advances in this vibrant field both in practice and research. It is a great opportunity for individuals interested in geosynthetics applications to attend especially that Egypt is now working on mega infrastructure projects that involve using geosynthetics."

The considerable geosynthetic development opportunities in the region was earlier showcased when Egypt was the focus of the IGS Technical Committee on Hydraulics' (TC-H) canals webinar series. Led by TC-H chairman Eric Blond, the three-day event explored the hydraulic applications that could support the major canal upgrade program the country is currently undergoing.

'GREEN' GEOSYNTHETICS EXPLORED AT UK TALK

Pollution-reducing geosynthetics and their development were discussed at an in-person talk hosted by IGS UK.

Christopher Quirk, managing director of Naue Geosynthetics, spoke on 'Biodegradable nonwovens for geotechnical applications: the first in a new generation of geosynthetics'.

The face-to-face event in Warrington, UK, co-hosted by ICE North West (ICE NW) Geotechnical Group, explored the principles of a biodegradable geotextile and where it fitted in with standard products used in the industry.

Mr Quirk shared the application example of use at the common land at Northam Burrows in North Devon, UK, a seaside dune system designated as a Site of Special Scientific Interest and Area of Outstanding Natural Beauty.

Natural England, a public body that advises the UK Government on the natural environment, said any geotextiles used in construction on the site – which included the Visitor Centre and vehicular access road – should be plastic-free. The geotextile used was manufactured exclusively from organic, natural, renewable raw materials, and certified as 100% biodegradable by TÜV Austria. It delivered similar properties of separation, filtration and protection to a traditional plastic non-woven geotextile.

Twenty-one people attended the talk last month, with several expressing an interest in the technology and progress being made for certain applications and environmentally-sensitive regions.

INDIAN JOURNAL OF GEOSYNTHETICS AND GROUND IMPROVEMENT

GUIDELINES FOR AUTHORS

This journal aims to provide a snapshot of the latest research and advances in the field of **Geosynthetics**. The journal addresses what is new, significant and practicable. **Indian Journal of Geosynthetics and Ground Improvement** is published twice a year (January-June and July-December) by IndianJournals.Com, New Delhi. The Journal has both print and online versions. Being peer-reviewed, the journal publishes original research reports, review papers and communications screened by national and international researchers who are experts in their respective fields.

The original manuscripts that enhance the level of research and contribute new developments to the geosynthetics sector are encouraged. The work belonging to the fields of Geosynthetics are invited. **The journal is expected to help** researchers, technologist and policy makers in the key sector of Geosynthetics to improve communication and understanding regarding geotextiles, geomembranes and related products among designers, manufacturers and users The manuscripts must be unpublished and should not have been submitted for publication elsewhere. There are no **Publication Charges**.

1. Guidelines for the preparation of manuscripts for publishing in "Indian Journal of Geosynthetics and Ground Improvement"

The authors should submit their manuscript in MS-Word (2003/2007) in single column, double line spacing. The manuscript should be organized to have Title page, Abstract, Introduction, Material & Methods, Results & Discussion, Conclusion, and Acknowledgement. The manuscript should not exceed 16 pages in double line spacing.

Submission of Manuscript:

The manuscript must be submitted in doc and pdf to the Editor as an email attachment to **sunil@cbip.org.** The author(s) should send a signed declaration form mentioning that, the matter embodied in the manuscript is original and copyrighted material used during the preparation of the manuscript has been duly acknowledged. The declaration should also carry consent of all the authors for its submission to **Indian Journal of Geosynthetics and Ground Improvement**. It is the responsibility of corresponding author to secure requisite permission from his or her employer that all papers submitted are understood to have received clearance(s) for publication. The authors shall also assign the copyright of the manuscript to the Indian Chapter of International Geosynthetics Society.

Peer Review Policy:

Review System: Every article is processed by a masked peer review of double blind or by three referees and edited accordingly before publication. The criteria used for the acceptance of article are: **contemporary relevance, updated literature, logical analysis, relevance to the global problem, sound methodology, contribution to knowledge and fairly good English**. Selection of articles will be purely based on the experts' views and opinion. Authors will be communicated within Two months from the date of receipt of the manuscript. The editorial office will endeavor to assist where necessary with English language editing but authors are hereby requested to seek local editing assistance as far as possible before submission. Papers with immediate relevance would be considered for early publication. The possible expectations will be in the case of occasional invited papers and editorials, or where a partial or entire issue is devoted to a special theme under the guidance of a Guest Editor.

The Editor-in-Chief may be reached at: sunil@cbip.org

ABOUT JOURNAL

Geosynthetics are now being increasingly used the world over for every conceivable application in civil engineering, namely, construction of dam embankments, canals, approach roads, runways, railway embankments, retaining walls, slope protection works, drainage works, river training works, seepage control, etc. due to their inherent qualities. Its use in India though is picking up, is not any where close to recognitions. This is due to limited awareness of the utilities of this material and developments having take place in its use.

The aim of the journal is to provide latest information in regard to developments taking place in the relevant field of geosynthetics so as to improve communication and understanding regarding such products, among the designers, manufacturers and users and especially between the textile and civil engineering communities.

The Journal has both print and online versions. Being peer-reviewed, the journal publishes original research reports, review papers and communications screened by national and international researchers who are experts in their respective fields.

The original manuscripts that enhance the level of research and contribute new developments to the geosynthetics sector are encouraged. The work belonging to the fields of Geosynthetics are invited. The manuscripts must be unpublished and should not have been submitted for publication elsewhere. There are no **Publication Charges**.

EDITORIAL BOARD

INDIA

INTERNATIONAL GEOSYNTHETICS SOCIETY (INDIA)

OBJECTIVES

- to collect and disseminate knowledge on all matters relevant to geotextiles, geomembranes and related products, e.g. by promoting seminars, conferences etc.;
- to promote advancement of the state-of-the-art of geotextiles, geomembranes and related products and of their applications, e.g. by encouraging, through its members, the harmonization of test methods, equipment and criteria; and
- to improve communication and understanding regarding such products, e.g. between designers, manufacturers and users and especially between the textile and civil engineering communities.

MEMBERSHIP ELIGIBILITY

Membership is open to individuals/institutions, whose activities or interests are clearly related to the scientific, technological or practical development or use of geotextiles, geomembranes, related products and associated technologies.

Membership Categories and Subscriptions:

• Individual Membership for 01 Calendar year	:	Rs. 2,500.00
• Individual Membership for 10 Calendar years	:	Rs. 12,500.00
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• Institutional Membership for 02 Calendar years	:	Rs. 45,000.00
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