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Review Paper

Application of geotextiles in Coastal Protection and Coastal Engineering Works: An overview

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Abstract

Geotextiles, one of the branches of technical textiles, are permeable textile materials or fabrics used for various civil engineering and other geotechnical applications. Geotextiles were one of the first textile products used in human history, and invention of geotextiles forms a bridge between civil engineering and textile technology. The application areas of geotextiles are very wide and during the last decade the areas have expanded further very fast worldwide. With the rapidly growing technological advancement, geotextiles have made inroads into a large variety of domains and have been acclaimed all over the world because of some of their built-in advantages like easiness and flexibility of use, softness (as compared to monolithic and rock constructions), rapidity of installation and long term efficacy. Geotextiles provide a relatively safe and economically feasible solution to day-to-day engineering demands and construction challenges. Used as replacement of natural materials, geotextile products perform a wide range of functions such as erosion control, soil stabilization, filtration, drainage, separation and reinforcement requirements. Geotextile bags, tubes and containers made with geotextiles are playing a proactive role in hydraulic, coastal, offshore engineering and river protection works as eco-friendly, construction-friendly and cheaper alternatives of conventional protection and engineering methods which are generally hard, expensive, temporary (having short life), and not environmental-friendly. The global geotextile market is enjoying strong growth but it is also highly competitive. In this paper, the constructional and functional aspects of geotextiles have been highlighted, and the potential role of various geotextile products in the domain of coastal protection, coastal engineering and off-shore engineering has been elaborated with some real-life ventures both in India and abroad.

Keywords: Geotextiles, Geosystems, Groins/Groynes, Dykes, Revetment, Levees, Breakwaters.

Introduction

Geotextiles, one of the branches of technical textiles, are permeable textile materials or fabrics used for various civil engineering and other geotechnical applications. Invention of geotextiles, probably the first textile products in human history, forms a linkage between civil engineering and textile technology. Excavations of ancient Egyptian sites show the use of mats made of grass and linen. Geotextiles have been used for thousands of years. In the days of the Pharaohs, geotextiles were primarily used in roadway construction to stabilize the body and the edges of roadways. These primitive geotextiles were made of natural fibres, fabrics or vegetation mixed with soil to enhance road quality, particularly when roads were made on unstable soil[1-2].

The term 'geotextile' was first coined by Giroud and Perfetti in 1977. Before 1988, geotextiles were called plastic filler cloth or filter fabric[1]. Geotextiles were first introduced into civil construction projects in the USA and Europe in the 1960s for road construction due to their efficient drainage and separation functions. From that point onwards, the technology developed so rapidly that it was an urge to organize the first International Conference on Geotextiles in Paris in 1977. The International Geosynthetics Society (IGS) was founded in 1982 because of the need for greater knowledge and understanding of the material[3].

Geotextiles are either woven or non-woven permeable fabric or synthetic material which can be used in combination with geotechnical engineering material. They are applied in a broad range of civil engineering applications including construction, paving, drainage and other applications. Geotextiles are profusely employed with soil, rock, earth or any other geotechnical engineering-related material.

The application of geotextiles has now-a-days expanded to such an extent that virtually every civil construction project employs a member of geosynthetic family. The marine and coastal environment is an extremely harsh and adverse environment. Hence, geotextiles, as relatively thin light weight material, when used in that environment as replacement of costlier, heavier and permanent civil constructions, will be subjected to severe abrasion from armour rock and marine sediment, large dynamic flow conditions from both tidal action and wave impact. Consequently, geotextiles used in coastal and marine environment must be able to resist conditions which are far more aggressive than the road construction applications.

Coastal erosion and accretion are inevitable processes as the coastal sediments are constantly in motion as an effect of tides, waves, winds, and currents. Human activities such as sand dredging and harbour construction have been disrupting the continuity of sediment transport and accelerate the coastline erosion. In addition, climate change, sea level rise, and storm surges added another layer of complexity to the eroding coasts[4]. Coastal structures are built to prevent further erosion of shorelines as well as restoring the eroded beaches to their initial phase. Hence, without coastal protection measures, eroded coastline can ravage the public properties. Therefore, coastal structures are imperative to protect the environment, ecology, infrastructures, and economic activities near shore[5].

The conventional coastal structures (i.e., breakwater, groins, revetment, and seawalls) have been constructed using wood, rock, and concrete. Nonetheless, the recent consideration of environmental approaches and the limited resources of natural rocks in certain regions led to an increase in the application of geosynthetics in coastal protection[6].

Therefore, for the design of new, cost effective shore protection structures as well as for the reinforcement of existing threatened coastal barriers and structures, including dune reinforcement and scour protection[7], more versatile materials and innovative solutions are required, which will supplant the conventional methods most of which are hard, short lived, expensive and not eco-friendly. The recent trend in the mitigation of coastal erosion and costal protection has been shifted now-a-days towards soft yet novel and eco-friendly methods. Pro-active methods and solutions are being developed and employed, which are not only eco-friendly, construction-friendly and cheaper but also address the root cause of the problem without much ‘adverse effects’. Many contemporary ways are being used more and more to armour, stabilize, or restore beeches, including the use of patented precast concrete units, geotextile sand-filled bags, green belts, bio-engineering, sand fencing, beech-face dewatering systems, and integrated coastal protection methods. Retreat from the coast is also thought about, in many circumstances[8].

Geotextiles and geosynthetics

Construction and raw materials used: Geotech segment comprises of technical textile products used in geotechnical applications pertaining to soil, rock, earth etc. This class of products is loosely called Geotextiles. However, geotextiles particularly refer to flat, permeable, polymer-synthetic or natural textile materials which can be non-woven, woven, knitted or knotted materials. They are used in contact with soil or rock and/or any other geotechnical materials in civil engineering earthworks and building constructions. In fact, geotextiles is one of the members of the geosynthetic family which comprises of geogrids, geonets, geotextiles, geomembranes, geosynthetic clay linters, geopipe, and geocomposites[1-3,9].

Geotextiles are made from polypropylene (PP), polyester (PET), polyethylene (PE), polyamide (nylon), polyvinylidene chloride (PVC), and fiberglass, and their GSM varies from under 40 to over 3000 which is mainly used in landfill end uses. PP and PET are the most widely used. Sewing thread for geotextiles is made from Kevlar or any of the above polymers[9-10]. Different fabric composition and construction are suitable for different applications.

To survive aggressive underground environments, geotextiles must be resistant to various forms of attack, such as mechanical, chemical and biological. Chemical attack may be initiated directly by acidic and alkaline soils or indirectly by the active wastes present in the landfills. Depending on the type of chemical compound, changes in the polymer structure can be brought about by oxidation, chain scission, cross linking, swelling or dissolution of the polymers, volatilization or extraction of ingredients of the polymeric compound, or an increase in the crystallinity of the polymer. In addition the service temperature may accelerate the effects of chemical degradation.

Types, desired characteristics and functions: In general, the vast majority of geotextiles are made from polypropylene or polyester and formed into the following fabric categories[2,9]:

Woven monofilament, Woven multifilament, Woven slit-film monofilament, Woven slit-film multifilament, Nonwoven continuous filament heat bonded, Nonwoven continuous filament needle-punched, nonwoven staple needle-punched, Nonwoven resin bonded, other woven and nonwoven combinations, Knitted.

The non-woven geotextiles provide planar water flow in addition to stabilization of soil. Typical applications include i) access road and rail building, ii) dam, canal and pond lining, iii) hydraulic works, sewer lines, iv) asphalt pavement overlays, v) soil stabilization and reinforcement, vi) soil separation, vii) drainage, viii) landfill, ix) filtration, x) weed control, xi) sport surfaces, xii) drainage channel liners, xiii) sedimentation and erosion control, etc. Woven geotextile looks like burlap. It is a fabric made of two sets of parallel strands systematically interlaced to form a thin, flat fabric. The strands are of two kinds - slit film which are flat, or monofilaments which are round. Woven geotextiles are generally preferred for applications where high strength properties are needed, but where filtration requirements are less critical and planar flow is not a consideration[9-10]. Woven geotextiles are mainly used in coastal works, embankment and in or near dams, waterways, and woven geogrids for reinforcement. Both woven and knitted geotextiles are beneficially used for a wide range of both cohesive and non-cohesive soils and they support quick formation of a natural soil filter. They facilitate dissipation of pore pressures and, thanks to their strength characteristics and low elongation, they improve mechanical properties of soil and enable the construction of reinforcing ground structures in this way[10].

The desired characteristics of woven geotextiles are: i) Ability to resist clogging, ii) Excellent elongation at break, iii) Excellent water permittivity, iv) Good grab tensile strength, v) Good puncture resistance, vi) Trapezoidal tear strength, vii) UV resistance, viii) Very good Mullen burst, etc.[1].

There are mainly four segments of Geotech family namely, i) Geogrid, ii) Geonet, iii) Geomembrane, and iv) Geocomposites.

Geotextiles perform one or more basic functions in a structure like filtration, drainage, separation, erosion control, sediment control, reinforcement, and (when impregnated with asphalt) moisture barrier. In any one application, a geotextiles may be performing several of these functions.

Solutions incorporating geosystems: Geosystems are systems of geotextile encapsulated granular soils that may be used to replace rock as conventional building blocks in coastal and marine engineering structures. They include geotube systems, geocontainer systems and geobag systems. Geotube systems involve tubular units that are typically hydraulically filled. Geocontainer systems involve units that are tailor made to match split bottom barges; within which the units are filled, sealed and dropped into position. Geobag systems involve a wide array of bag designs and geometry, and are typically dry filled in site, sealed and deployed[11-12].

Role of geotextiles in coastal protection and off-shore engineering

Due to sea or river current, fine soils of the bank start migrating causing erosion. Conventional design of cementing the banks is not a solution due to hydraulic pressure of the soil. Only feasible solution is the application of geotextiles or geosynthetics. Geotextiles allow water to pass through but resist the fine soil migration.

Coastal protection measures are designed to protect inland flooding and minimise the erosion of the coastline caused by the constant motion of the sea. Geotextiles protect the coast line as their flexibility and permeability ensure withstanding of the impact of waves and currents, preventing erosion and washing out of lines (figure-1).

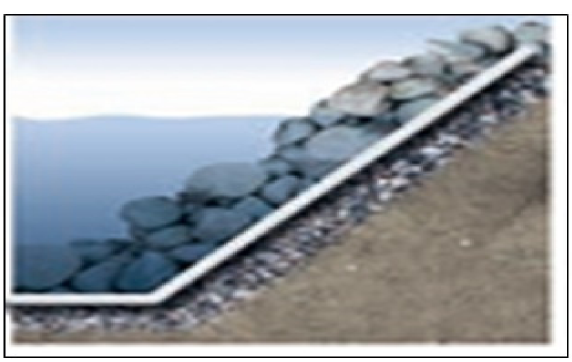

Figure-1
Geotextiles preventing coast line erosion

Geosynthetics are used in various coastal protection applications such as filters in dykes and dams, for foundations under groynes and breakwaters, as well as by using geotextile containers as structural elements in groynes, seawalls, breakers or for bed and embankment stabilisation.

Woven geotextile containment systems in tubular forms filled with locally available sand/slurry are formed in-situ on land or in water to protect shore and marine environments. Geotextile tube, for example, is one of the geosynthetics structures that are increasingly used in coastal protection. Geotextile tubes are made from high-strength geosynthetic fabrics that allow the water to flow through pores while retaining the filing materials. They are widely used for dewatering, flood control, and coastal protection. Geotextile tube can be used in various conditions as a result of the low consumption of construction cost and time, requirement of simple equipment, and low skilled workers. Geotextile tubes are good alternatives for the conventional hard coastal structures[6].

Geotextile tubes are used as a cost-effective alternative to mitigate erosion on coastal shorelines, riverbanks, and lakes using readily available materials for infill. Geotextile tubes filled with dredged materials or sand and strategically placed will dissipate the wave energy, as well as provide structural support against other erosive forces. Geotextile tubes can be set in place along shorelines and river fronts either to be left exposed to battle the elements, or incorporated into the environment as part of a manmade dune or riverbank. They can also be placed in the water to serve as jetties and groins[10].

Geotextile Sand Containers (GSC), for example, is another low cost, soft and reversible solution for the above problem and it has a history of more than 50 years in hydraulic and marine applications. Coastal structures built with GSCs are obtained by substituting rocks or concrete units with containers made of geotextile and filled with locally available sand or slurry. A range of successful coastal protection structures using GSCs have been constructed in many parts of the world, especially in Australia and Germany[7].

Working principle of geotextiles/geosynthetics

Due to the continuous action of waves, tides, currents and other water motion, coastal and marine environments are susceptible to erosion, the consequence of which can range from a simple loss of surface soil to the wholesale undermining and collapse of structures. To positively influence the morphology and prevent erosion at designed locations a variety of measures are used. Generally, these measures fall into one of three categories: *Geometrical measures*, where the shape of the structure and adjacent profile is altered in order to reduce the water forces below a minimum threshold. *Stabilisation measures*, where the exposed structure is protected from erosion by stabilising the susceptible soil. Examples include the provision of revetments, etc.

External measures, where the exposed structure is protected from erosion by the provision of a protection structure, placed at some distance. Examples include breakwaters, etc.

TenCate® and Terrafix® Geosynthetics, for example, with filtration, containment or reinforcement functions, are used as integral components in the design and construction of a variety of coastal and marine structures such as revetments, scour protection layers, levees, dykes, groynes/groins, jetties and breakwaters. These Geosynthetics are easy to install beneath the water surface, in difficult conditions, and once in place provide continued performance[11-12].

The conduction of the coastal protection measures is significantly site dependent as there are various interrelated and locally diverse parameters. These parameters include sediment properties, water elevation, wave and current characteristics, geomorphology setting, protection goals, required intervention level, safety level, and social, economic, and politic factors. Coastal protection methods for the sandy beaches, for example, focus on erosion prevention and beach restoration, while, for the mudflat, protection and rehabilitation of mangrove can be considered as a key method. Construction cost is one of the major considerations for the selection of coastal management method[6].

Coastal and marine structures as measures of coastal protection and coastal engineering[11-19]

Stabilisation of dykes: Dykes and related structures typically consist of a general rock fill core and an outer armour protection for long term design against wave and current attacks. Needle-punched geotextiles are used to protect the coastline when used in the toe area of sea walls and dykes. They improve the construction efficiency if the sea currents cause surface erosion or unacceptable soil displacement. The three-dimensional, labyrinth-like pores and channels of needle-punched nonwovens are not only similar to the soil structure itself, but, if correctly designed, also increase the stability of the revetment against impact stress caused by the motion of the sea.

A geotextile with a minimum mass per unit area of 600 g/m² is necessary wherever type II or III armor rock with individual weights ≤ 60 kg are placed directly on geotextiles, or where concrete revetments for high-stress applications have been installed. Where individual stone weights exceed 60 kg, geotextiles with yet a higher mass per unit area is recommended. In the case of low-stressed dykes, filter geotextiles (like Terrafix®) with a minimum mass of 500 g/m² and minimum thickness of 4.5 mm serve to encapsulate and stabilise the sand core from erosion. When flooding occurs, they prevent washout of the sand and ensure the stability of the dyke. Top soil as well as concrete blocks can act as an effective cover layer over the geotextile[12].

Coastal revetments: A revetment is a facial or veneer layer applied to the sloping surface of soils to prevent their erosion against wave action and currents. Revetments are often used to protect coastlines. Coastal revetments may be deployed to protect toes of coastal cliffs, bluffs, dunes, etc, and to fortify coastal embankments and flood levees. Functionally, as slopping structures, revetments reduce wave reflection and absorb wave energy through a combination of energy dissipation within the structure and wave run-up over the structure surface. They may also serve other purposes such as limiting wave overtopping or wave reflections. Natural sand dunes may be found at the landward extent of an active beach and can offer some form of protection against wave attack under extreme tidal or surge conditions. When natural dunes do not exist or when they do not provide sufficient protection, rock revetment structures may be built hidden within covered sand for beach aesthetics and recreation purposes. During an event of storm, erosion of the front sand cover may take place but the exposed revetment would prevent further damage from occurring. After the storm event, the sand cover is then replaced[11-13].

TenCate® and Terrafix® Geotube Systems, for example, are commonly used as a very cost effective alternative to hidden revetments in the sand dune zone.

Levees and flood control dykes: Sea levels rise above inland areas due to many reasons. One of the reasons is tides. Tides result in regular rise and fall in sea levels. Although the typical tidal range in the open ocean is about 0.6 m, coastal tidal ranges can vary between zero to over 10 m in height, depending on the coastal geography and location. Due to global warming, the mean sea level is expected to gradually rise with time. Water levels can also rise as a result of waves and surges.

Flood control dykes or levees are constructed along estuaries and coastlines to protect flooding of low lying areas. The top of flood control dykes or levees should be higher than the design high water level plus a safety freeboard. In addition the levees should be designed to prevent seepage through the core structure[11-13].

Estuarial barriers and barrages: Tides cause sea levels to rise and fall in constant cycles. Tidal effects are experienced in coastal and river delta areas. Estuarial barriers and barrages allow river discharges while holding back rising sea levels. They are special dam structures that are designed to hold back the sea during high sea levels while allowing river discharges during normal sea levels. The primary objective of such structures is usually flood prevention[11-12].

Coastal groynes/groins: Groynes are finger-like hydraulic structures that jut perpendicularly out of coastlines. Their primary engineering function is to interrupt or reduce long-shore sediment transport. This interruption will produce accretion updrift of the groynes and produce concomitant erosion downdrift of the groynes. Groynes are usually constructed in groups otherwise referred to as groynefields. When constructed in concert with beach restoration, the groyne field will act to reduce future beach maintenance and nourishment requirements. The sectional requirement of a groyne structure is the same as that of a basic dyke structure. Geotextiles are used as a filter layer to prevent sand beneath from being eroded away. Alternatively, Geotube Systems may be used to construct coastal groynes[11-12, 14, 16-17].

Land reclamations: The shortage of land along certain coastlines requires land to be reclaimed from the sea. Reclamation dykes are cofferdam units that retain fill while providing protection against wave attack during construction, prior to placement of long term armour protection cover. Conventionally, the cofferdam units are constructed of rock fill material in much the same way as the rock fill core of groynes, jetties, etc. Depending on the grading of the rock fill material, geotextiles may be laid on the inner side of the reclamation dyke to prevent washout of sand fill through the rock fill dyke. Geotextiles may also be laid over the sea side of the reclamation dyke prior to placement of the armour protection. Alternatively, Geotube Systems and Geocontainer Systems may be used to replace the rock fill reclamation dyke[11-12, 14-19].

Creating islands: Artificial islands are constructed for a variety of reasons. They may provide land for development of prime residential and commercial properties; create eco-friendly habitats and sanctuaries; act as barrier islands to protect coastal habitats,etc. Reclamation dykes are used to form the shorelines of the islands in very much the same way as land reclamation techniques. Geotextiles may be laid on the inner side of the reclamation dyke to prevent washout of sand fill through the rock fill dyke. Geotextiles may also be laid over the sea side of the reclamation dyke prior to placement of the armour protection. Alternatively, Geotube Systems and Geocontainer Systems may be used to replace the rock fill reclamation dyke[11-12, 14-17].

Coastal breakwaters: Coastal breakwaters are marine structures that have the primary function of sheltering a coastal development by preventing longshore currents from causing erosion and reducing wave energies impacting a shoreline. They are connected to the shoreline like groynes and jetties but differ in function and massiveness. Like groynes and jetties they impact the littoral functions but coastal breakwaters differ with the additional function of forcing waves to break offshore. Coastal breakwaters also tend to have special end details in the sea e.g. fishtailed, L-shapes or T-shaped that are designed to eliminate problems of downdrift erosion and promote the formation of beaches. Geotextiles are used as filter layers for the construction of coastal breakwaters. Geotextiles can also be prefabricated onshore into a large panel of fascine mattress that can be floated out to sea. This panel of fascine mattress can then be ballasted into position on the seabed by dropping rock onto the floating fascine mattress. Alternatively, Geotube Systems, Geocontainer Systems and Geobag Systems may be used to replace the rock fill core of breakwaters[11-12, 14, 16].

Offshore breakwaters: Offshore breakwaters are marine structures that have the primary function of reducing wave energies impacting a shoreline. Offshore breakwaters reduce wave energies by partially reflecting some wave energy seawards as well as forcing some wave energies to be expensed through wave breaking on the structure before such destructive waves can reach the shoreline. Offshsore breakwaters are generally constructed parallel to shorelines. Offshore breakwaters are sometimes designed to be permanently submerged and are often designed to retain a perched or artificial beach. As offshore breakwaters tend to involve construction in relatively deep waters, the installation of geotextiles can often be challenging. Geotextiles can be specially designed to make installation in deep waters a simple and efficient task. Construction of this marine structure is just similar to that of coastal breakwaters[11-12, 14, 16-19].

Some major applications as measures of coastal protection or coastal engineering

Applications in India: In India, the use of geotextile tubes for the purpose of coastal defense started in the last decade. In Indian scenario, the use of sand-filled geotextile tubes for the coastal protection works is in the developing phase. The compilation and analysis of the data regarding success/failure of projects may improve the techniques of using geotextile tubes[20].

The below is mentioned a few real-life projects on application of geotextile products for coastal protection and off-shore engineering works: Installation of geotextile bags and geotextile tubes along the coast line of the Bay of Bengal from Shankarpur to Haldia, West Bengal (figure-2). Nearshore geotextile tubes reef at the coastal area of INS Hamla, Malad (W), Mumbai. The coast at the INS Hamla has been facing sea erosion since last few years. In order to mitigate the erosion, the project authorities constructed a 900 m vertical UCR wall at the eroding coast along with the beach nourishment. The geotextile tubes laying and beach nourishment work were completed in the month of March, 2010. Application of geotextile tubes to protect sea wall of Uppada, Andhra Pradesh. Reclamation bundh using imported geotextile containers at Adani Port, Gujarat (figure-3). Installation of geotextile tubes at Devbag, Malvan, Maharashtra to mitigate severe erosion during 2006 monsoon. Tubes were aligned parallel to the coast, having a total length of 150m. Application of nearshore geotextile tubes reef at Candolim beach situated at about 15 km north of the Panjim, Goa, the construction of the off-shore reef with geotextile tubes for a length of 800 m and the beach nourishment work were completed in the April 2010. Nearshore geotextile tubes reef at Dahanu, about 110 km north of Mumbai, Maharashtra, The beach is extensively used by the tourists for recreational activities. About 400 m length of the beach is protected by constructing PCC retaining wall with steps towards sea side to facilitate the tourists. The beach is also enhanced by providing beach nourishment. A series of off-shore reefs with sand-filled geotextile tubes was constructed to hold the nourished sand in the year 2010-2011.

After Installation - During High Tide

Figure-2

Installation of geotextile tubes

Figure-3

Reclamation bundh using geotextile container

Applications in abroad[11-12]: Coastal Revetment, CT, USA, The town of East Lyme in CT, USA wanted to connect two separate beaches facing the Atlantic Ocean with a new elevated pedestrian and bike path. This elevated pedestrian and bike path would also serve as a buffer to an existing high speed train line that was located beside it. A coastal revetment was constructed to protect the new coastline. The armour layer of the coastal revetment consists of approximately 1.8 m of large heavy rip rap. TenCate geotextiles were used as filter layer underneath the rip rap (figure-4).

Figure-4

Coastal revetment, CT, USA

Flood Control Dykes, Germany: The Big Flood of 1953 that affected the Netherlands also caused flooding and severe damages to land and property in northern Germany. As a result, a 7 km long flood control coastal dyke was constructed beginning in 1992. The 8.8 m high dykes facing the North Sea at Leybucht would keep inland areas of up to 31 km from flooding during extreme events. TenCate geotextiles were used as filtration layer beneath the rock armour protection for the dyke as well as for the bed protection in the inlet-outlet channel. Geotube systems were used as reclamation dyke to raise the earthworks platform above high water levels (figure-5).

Figure-5

Flood control dyke, Germany

Eastern Scheldt Barrier, The Netherlands: The Eastern Scheldt Barrier is part of the Delta Project to protect the Netherlands against a repeat of the big flood of 1953. The Eastern Scheldt Barrier with a length of 8 km, seals of an estuary with a tidal volume of 2.2 billion m^3. TenCate geotextiles are supplied for the fabrication of foundation mattresses for the 65 prefabricated reinforced concrete piers, each with the height of a 12-storey building and weighing 18,000 tonnes (figure-6).

Figure-6

Eastern Scheldt Barrier, The Netherlands

Bald Head Island, NC, USA: The South Beach of Bald Head Island in North Carolina experienced severe coastline erosion. Geotube systems were used to construct a field 14 coastal groynes for long term protection of 3.7 km of South Beach shoreline. The Geotube groynes had a circumference of 2.75 m and were underlain with a 7.3 m wide scour protection apron (figure-7).

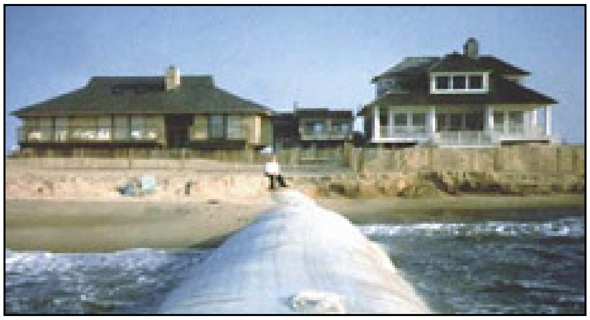

Figure-7
Geotube groyne

Bengkulu Breakwater, Indonesia: The Port of Bengkulu in Indonesia completed in 1985 is protected with two rubble mound breakwaters with approximate crest lengths of 390 m and 420 m. The heads of the breakwaters were constructed with blocks weighing up to 10 tons. A total of 110,000 m^2 of TenCate geotextiles were used for the project (figure-8).

Figure-8
Bengkulu breakwater, Indonesia

Kerteh Breakwater, Malaysia: The onshore operation base for Peninsular Malaysia's offshore petroleum production is situated along Kerteh Bay. Coastal erosion threatened the school and housing facilities, as well as a golf course. Offshore breakwaters together with beach nourishment was the solution of choice as this option would allow the recreational beach to be fully accessible without imposing rock structures along the shoreline. TenCate geotextiles were prefabricated onshore into large panels of fascine mattresses. These large panels of fascine mattresses were then floated offshore and sunk into position by ballasting with bedding stones (figure-9).

Figure-9
Kerteh breakwater, Malaysia

Coastal protection at Lombang Beach, Indonesia (2010) (figure-10). Revetment of Thorpeness beach, Suffolk, UK (2011) (figure-11).

Figure-10
Coastal protection at Lombang Beach, Indonesia

Figure-11
Thorpeness Beach revetment, Suffolk, UK

Conclusion

Geotextiles or geosynthetics which belong to the so-called technical textiles family possess high potential in various geotechnical and civil engineering applications including road construction, railway track-bed stabilization, soil stabilization, erosion control, reinforcement, separation and drainage. Application domain is vast enough, and has been expanding in a galloping way all over the world. Apart from the regular uses, geosystems made with geotextiles like geotextile tubes, bags, containers etc. are playing a proactive role in hydraulic, coastal, offshore engineering and river protection works as eco-friendly, construction-friendly and cheaper alternatives of the traditional protection and engineering solutions which generally are hard, short lived, expensive and not eco-friendly. The applications of geotextiles or geosynthetics in the form of geocontainer, geobag, geomat, geotube etc in various coastal and marine structures have been highlighted as measures of coastal protection and coastal engineering works, followed by some of the real-life ventures in our country and abroad. It must be remembered that due to the uniqueness of majority of the coastal and marine structures mentioned above, the installations of geotextiles/geosystems are application specific and require sound understanding of the nature of problem to be solved, the behavior of material to be used in real world, the optimum utilization of machineries involved without creating so much environmental impact etc. Actual field trials are always recommended prior to final application. The global geotextile market is enjoying a strong growth though it is also highly competitive. In Indian scenario, the use of sand-filled geotextile tubes and geobags for the coastal protection works is in the developing phase.

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