Available online ***www.jsaer.com***

***Journal of Scientific and Engineering Research*, 2017, 4(10):337-350**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Geotextiles – A Potential Technical Textile Product

Subrata Chandra Das[1]*, Debasree Paul[2], Mir Muhammad Fahad[1], Tarikul Islam[3], Md. Eanamul Haque Nizam[4]

[1]Pabna Textile Engineering College, Pabna-6600, Department of Textiles, Ministry of Textiles and Jute, Bangladesh
[2]Department of Textile Engineering, Khwaja Yunus Ali University, Sirajgonj-6751, Bangladesh
[3]Department of Textile Engineering, Port City International University, Chittagong, Bangladesh
[4]School of Fashion Design and Engineering, Wuhan Textile University, Wuhan, China

Abstract Technical textiles has the diverse range of products which will lead the future world market and the researchers from the various field of science and engineering will work together for the development of these textile materials. Among various types of technical textiles, geotextiles possess very important class due to its versatile applications in roads, dams and constructions industries. Geotextiles are the permeable textile materials which mainly used for filtration, drainage, separation, reinforcement and stabilization purposes. Geotextiles is the fastest growing industry and a promising field of technical textiles. This paper presented the potential of geotextiles in civil and construction industries. The review paper will be introduced by first discussing technical textiles and geotextiles as awhole. Next, the paper will continue on to discuss the raw materials such as natural and synthetic fibers used in it, the manufacturing process and functional requirements. Finally, the functions and major applications of geotextiles has been presented. The global market of geotextiles has also been addressed here.

Keywords Technical textiles, geotextiles, filtration, woven, non-woven

1. Introduction

Technical textiles are considered to an amazing field in the range of textile science and engineering which have diverse applications in all the sector of science and engineering. The modern age lead by the versatile products of technical textiles. Technical textile can be defined, according to the *Textile Terms & Definitions*, published by the Textile Institute, as "textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics". Technical textiles are reported to be the fastest growing sector of the textile industrial sector and the global technical textiles market is expected to reach USD 193.16 billion by 2022, according to a new report by Grand View Research, Inc. Global technical textile market demand was 26.58 million tons in 2014 and is expected to reach 35.47 million tons by 2022, growing at a CAGR of 3.7% from 2015 to 2022 [1, 2].

The leading international trade exhibition for technical textiles, Techtextil (organized biennially since the late 1980s by Messe Frankfurt in Germany and also in Osaka, Japan), defines 12 main application areas such as agrotech (agriculture, aquaculture, horticulture and forestry), buildtech (building and construction), clothtech (technical components of footwear and clothing), geotech (geotextiles and civil engineering), hometech (technical components of furniture, household textiles and floorcoverings), indutech (filtration, conveying, cleaning and other industrial uses), medtech (hygiene and medical), mobitech (automobiles, shipping, railways and aerospace), oekotech (environmental protection), packtech (packaging), protech (personal and property protection) and sporttech (sport and leisure). Among these geotech or geotextiles has widely used all over the world and one of the essential product for civil and construction engineering sector[1].

The word "Geotextiles" comes from two words. The Greek word "Geo" means "Earth", so it can be said that any textile materials used in the earth or soil for technical purpose is called geotextiels. The Textile Institute defined geotextiles in *Textile Terms and Definitions* as "Any permeable textile material used for filtration, drainage, separation, reinforcement and stabilization purposes as an integral part of civil engineering structures of earth, rock or other constructional materials" [3]. Another definition of geotextiles is, "Geotextiles are permeable textiles used in conjunction with soils or rock as an integral part of a manmade project" [4]. The economic and environmental merits of using textiles to reinforce, stabilize, separate, drain and filter have already well proven. It is basically employed for temporary roads and yards, permanent roads, repair of permanent roads, railway tracks, embankments in soft ground, drainage applications, sports field construction, retaining walls and erosion control [5-9]. Road construction was the largest application segment in 2015 accounting for over 40% of the market. Geotextiles are increasingly employed in the road construction industry due to their growing awareness of the advantages they provide. Geotextiles are used as a component of the foundation in laying roads, as they are suitable in strengthening soil by holding it together, thus resulting in a longer lifespan of roads. The needs of geotextiles are increasing day by day in developing countries such as China, Russia, India and Bangladesh among others, due to the strong infrastructural development in these countries [5, 7, 8, 11-13].

2. Fibres used in Geotextiles

2.1. Natural Fibres

Natural fibers are obtained from plant, animal and mineral origin and large quantities of these fibers are available worldwide. Natural fibres provide high strength, high modulus, low breaking extension and low elasticity. Yarns and fabrics produced from natural fibres exhibits low levels of creep during applications. Mineral fibres are brittle and not have suitable strength and flexibility. The important plant fibres that can be employed in geotextile fabrication are jute, sisal, flax, hemp, abaca, ramie and coir. Geotextiles produced from natural fibre are biodegradable, so these textile products could be specifically employed for short term functions. Moreover, the primemerits of employing natural fibres in geotextiles are low cost, robustness, strength/durability, availability, good drapeability and biodegradability/environment friendliness.

2.2. Synthetic fibres

Synthetic or man-made fibers are the major raw materials for the production of all types of geotextiles. There are four major polymer families employed as raw materials for geosynthetics, i.e. polypropylene, polyester, polyamide and polyethylene.

2.2.1. Polypropylene

Polypropylene has been the most widely used polymer for the manufacture of geotextiles because of its low cost, suitable tensile properties and chemical inertness. Polypropylene has low density, which results in very low cost per unit volume. The demerits of polypropylene are its sensitivity to ultraviolet (UV) radiation and high temperature and poor creep and mineral oil resistance. Hence, geotextiles made form polypropylene should be employed under suitable installation and environmental conditions.

2.2.2. Polyester

Polyester or PET is also an important polymer applied in the production of geotextiles. It displays superior creep resistance and tenacity values and is used in applications where the geotextile is subjected to high stresses and elevated temperatures. The major demerits of polyester is susceptibility to hydrolytic degradation in soils exceeding pH 10.

2.2.3. Polyamide

Polyamides (nylon 6,6 and nylon 6) are employed in small quantities as traditional geotextiles. It can be noted that although the choice of polymer has a vast influence on geotextiles' strength and creep behavior, other parameters such as fabric structure, finishing treatments applied to the fabric and the confining effect of any surrounding soil could also influence their characteristics [4].

2.3. Comparative study of natural and synthetic fibers for geotextile applications:

In general, man-madefibers, such as polypropylene, polyester, polyethylene, polyamide etc., have lead the geotextile industry, although the advantages of natural fibers should not be ignoreddue to environment friendly, less costly, easily available and ecologically compatible as they are degraded within the soil [14]. Natural fibers are basically used for temporary reinforcements and erosion-control uses of geotextiles. For example, in slope stabilization, natural fibers such as jute, hemp or coir are needed for a relatively short period of time in order to form the root structures after which the geotextile is needed to be decomposed for visual aesthetic reasons.

Several researchers have revealed the application of natural fibers including jute, coir, wood, flax and bamboo in various applications of geotextiles such as soil erosion control, vertical drains, road bases, bank protection and slope stabilization [14-24]. In addition, Ranganathan [25] has revealed the merits and possibility of jute-based geotextiles for new products and applications such as super-sod, temporary haul roads, reinforcement fabric in highway construction, wick drains etc. due to their high water uptake and moisture absorption that builds them suitable materials for such uses. Likewise, the applications of a coir-based geotextile has exhibited a tremendous improvement in the vegetal growth [14]. However, the coir geotextile is degraded because of the microbial action in the soil in addition to the effect of rain and sun. Lekha [14] has found that coir net retained only 22% of its initial tensile strength at the end of seven months after it was buried in the soil. Similar loss of strength in coir netting was reported by Balan and Venkatappa Rao [26]. Thus, in uses where natural fibres are exposed to microbiological agents and solar radiation, such fibers are seemed to have lost effectiveness [27]. Not only natural fibers but also synthetic fibers such as polypropylene have also showed poor resistance to UV radiation. Likewise, nylon with a higher tensile strength than polyester or polypropylene may tend to be degraded by weathering [28]. However, nylon can resist at least twice the level of abrasion in comparison to polyester or polypropylene fiber [29], but polyester has more abrasion resistance on exposure to UV light, whereas polypropylene fiber has a superior resistance to fatigue-flexing. In roofing uses where by the fabric is placed under higher tensile and flexural stresses and also subjected to abrasion or bursting stresses, polyester fibre with greater tenacity and lesser elongation is further suitable. Polyester fibre is also least affected by acidic conditions or changes in temperature that can occur due to seasonal variations. It can be mentioned that polyester fibre may be employed for tidal-barrage protective devices for the same reasons of resistance to solar radiation and mechanical stresses, in addition to resistance to salt solutions [30]. Besides, polypropylene fibre with lower density leading to better buoyancy characteristics is more suitable for tidal barrages, which are frequently subjected to battering [23]. It can be abridged that fiber can be selected for geotextiles applications on the basis of constructions and environmental demand.

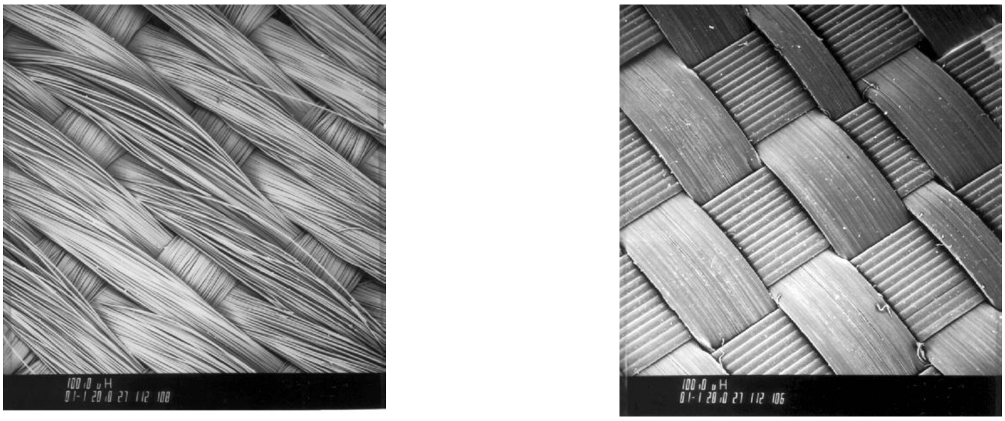


Figure 1: Plan view photomicrographs of woven geotextiles: (a) multifilament fiber (magnified 8×); (b) slit-film fiber (magnified 8×)

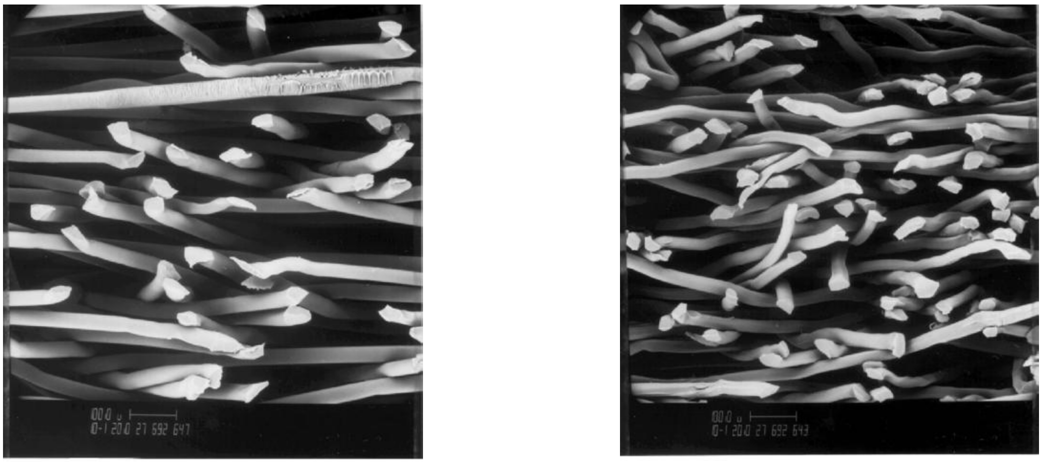


Figure 2: Cross-section photomicrographs of nonwoven geotextiles: (a) continuous filament (magnified 80×); (b) staple fiber (magnified 80×)

The difference in pore structure may be found by comparing cross-section photomicrographs of a continuous filament geotextile as shown in Figure 2 (a) and a staple fiber geotextile in Figure 2(b). The continuous filaments tend to have more order within the cross-section as opposed to the staple fibers, which are random throughout the geotextile. Staple fibers generally have a much tighter pore structure than continuous filaments as shown in Figure 2 [31].

3. Production of Geotextiles

Conventional fabric production methods are majorly used for manufacturing most of the geotextiles. Production techniques for the fabrication of geotextiles are apparently classified by Giroud [32] into two classes, i.e. classical and special geotextiles. Typical products of textile industries such as woven, knitted, nonwoven fabrics etc. are used in classical geotextiles, but in special geotextiles there are similarities in appearance but not the exact products of typical industries. Net, mat, webbing etc. are applied in special geotextiles [32]. Classical geotextiles are manufactured in two steps, i.e. production of fibres, filaments, slit films (tapes) and yarns and converting these component materials into a fabric. Various procedures of manufacturing these constituent materials used in fabrication of geotextiles are as follows [32]:

Filaments: The filaments are manufactured by ejecting a molten polymer through spinnerets or dies in a conventional melt ejection process. To improve molecular orientation along filament, the filaments are drawn afterwards so that the filaments gain a high tensile strength and modulus. For enhancing these mechanical properties, numerous filaments can be extruded through spinnerets and spun, which is called multifilament yarn.

Short (staple) fibres: Filaments generated through spinnerets are cut into short length ranging from 2 to 10 cm and twisted together to form a yarn.

Slit films: Slit dies are used to produce these films in a melt ejection procedure where they are subsequently slitted through by sharp blade. These films can be further fibrillated and fragmented into fibrous strands called fibrillated yarn.

The procedure of converting the linear elements mentioned above, namely filaments, fibres, slit films or yarns, into various kinds of classical geotextiles are described below.

Woven geotextiles:

A woven fabric is constructed through two sets of orthographically interlaced yarn or filament.Depending on the characteristics of interlacement of yarns or filaments the weave design or pattern is determined. The interlaced filaments or yarns of longitudinal direction and transverse direction are respectively known as warp and weft yarns. Comparatively multifilament, spun and fibrillated woven geotextiles are thicker than monofilament and slit woven geotextiles.

Nonwoven geotextiles:

When directionally or randomly oriented fibres are bonded either by friction and/or cohesion and/or adhesion and constructs a batt, web or sheet is called nonwoven fabrics. Typically, nonwoven fabric can be produced in two steps: formation of web (arranging the fibers in certain orientation characteristics) and bonding the fibres by mechanical, thermal or chemical means. This two-step procedure brings the variation the nonwoven structures, i.e. spun bonded, melt blown, carded, air-laid, adhesive bonded, thermal bonded, stitch bonded, needle punched, hydro entangled, etc. Some important process of the production of geotextiles are described below.

Spunbonding:

The process deals with filament extrusion from spinnerets, drawing, lay down and formation of bonding. The first two steps are mainly adapted from a typical melt extrusion technique, but the latter steps include the deposition of filaments on to a conveyor belt in more or less in random manner. There is an important issue that, spunbonded nonwovens are generally self-bonded, but for the development in the tensile properties, they can be subsequently bonded by thermal, chemical or mechanical means.

Chemical bonding:

To produce a chemically bonded nonwoven, a binder such as glue, rubber, casein, latex, cellulose derivative or a synthetic resin is added to fix together filaments or short fibres.

Mechanical bonding:

Mechanical bonding techniques can be classified as two types, i.e. needle punching and hydro entanglement (also known as spun lacing). The factors which make the difference in mechanical bonding techniques are the utilization of metal needles in needle punching, whereas high-pressure multiple rows of water jets are employed to reorient and entangle a loose array of fibers into self-locking and coherent fabric structures in a hydrogen tanglement process [33].

Thermal bonding:

Thermal bonding is generated by the application of heat energy to the thermoplastic component present in fibrous web and the polymer flows by surface tension and capillary action to form the required number of bonds at crossover positions of fibres [34]. It can be categorized in two classes, i.e. through-air bonding and calendaring. In through-air bonding process, the fibrous web is passed through a heated air chamber, where the bonds at the crossover positions are melted and reformed with the other components in the fibre. The calendaring process includes the passage of fibrous web passes through a heated pair of rollers which impart required high pressure and temperature.

Knitted geotextiles:

Interlocking a series of loops of filament or yarn forms a planar structure of this material. Like various designs in woven fabrics, knitted fabrics can also be manufactured in numerous designs interlocking the loops in different ways in the fabric structure.

Braided geotextiles:

Braided geotextiles are narrow rope-like structures making of yarns interlaced at a bias direction. The braided structure is normally tubular in nature and various designs such as diamond, regular and Hercules similar to plain, 2/2 twill and 3/3 twill incorporated in a woven structure [35].

Similarly, a two-step subsequent process is also followed in manufacturing of special geotextiles. They are briefly discussed below [36].

Webbings:

These are produced from strips of moderate width and are similar to coarse woven slit film fabrics.

Mats:

These are made of coarse and rigid filaments having tortuous shape similar to that of open nonwoven fabrics.

Nets:

Nets comprise of two sets of inclined coarse parallel-extruded strands and are bonded at the intersections by partially melting one of the strands. These net structures can furthermore be manufactured employing a melt extrusion method consisting of rotating dies through which the molten polymer is extruded.

Besides, composite geotextiles can be formed by combining several of the above products such as a combination of multiple layers of knitted/woven/nonwoven by means of stitching, needlepunching, thermal bonding etc. In the same way, mats/nets/plastic sheets can be sandwiched with one or two geotextiles especially for drainage applications. Fiber reinforced polymer composites can also be used as geotextiles for different applications [7, 37-43].

Table 1: Geotextile producers and distributors in the United States (Industrial Fabrics Association International 1995) [31].

Woven geotextiles	Nonwoven geotextiles
Amoco Fabrics & Fibers Co.	Advanced Drainage Systems Inc.
Belton Industries Inc.	Amoco Fabrics & Fibers Co.
BonTerra America	Belton Industries Inc.
Carthage Mills	BonTerra America
Construction Techniques Inc.	Bradley Industrial Textiles Inc.
Contech Construction Products Inc.	Carthage Mills
The Geo-Group	Colloid Environmental Technologies Co.
Huesker Inc.	Contech Construction Products Inc.
Hydrotex Synthetics Inc.	The Geo-Group
Linq Industrial Fabrics	Hoechst Celanese Corp.
NicolonMirafi Group	Linq Industrial Fabrics
Siltco Industries Inc.	NicolonMirafi Group
Synthetic Industries	Synthetic Industries
Webtec Inc.	TNS Mills Inc.
Welbeck Technical Textiles	Webtec Inc.
	Wellman Inc.

Table 2: Functional requirements for geotextiles [1]

Properties	**Geotextiles Functions**				
	Reinforcement	**Filtration**	**Separation**	**Drainage**	**Erosion control**
Tensile strength	A	A-B	B	N/A	B
Elongation	C	A-B	C	A-B	B-C
Chemical resistance	B-C	C	C	C	A
Biodegradability	C	C	C	C	C
Flexibility	A	A-B	C	A-B	C
Frictional properties	C	A-B	A	N/A	B
Interlock	C	C	B	B	A
Tear resistance	A	C	C	B-C	B
Penetration	A	B	C	C	B
Puncture resistance	A	B	B	C	A-B
Creep	C	N/A	N/A	N/A	N/A
Permeability	N/A - A	A-C	B-C	C	B
Resistance to flow	A	A	A	A	C
Properties of soil	C	B	N/A	N/A	N/A
Water	C	C	C	C	C

Burial	C	C	C	C	N/A
UV light	B	N/A	N/A	N/A	C
Climate	N/A	C	A	C	C
Quality assurance & control	C	C	B	C	A
Costs	C	C	C	C	C

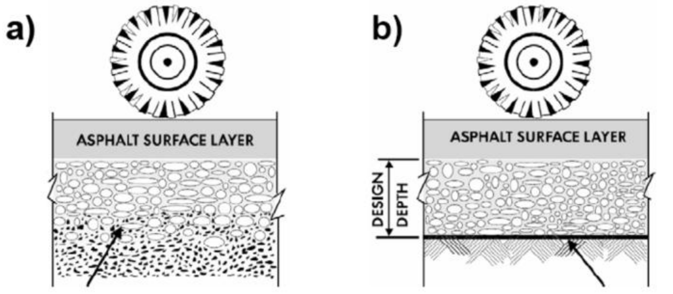
A = Highly important, B = Important, C = Moderately important, N/A = Not applicable

4. Geotextile Functions

The crucial functions of geotextiles used for pavement applications have traditionally involved separation, filtration, drainage, and reinforcement. Nonetheless, different functions can be done by a certain geotextile product, conversely, various types of geotextile products can perform the same function.In addition to their basic function, geotextiles can perform one or more secondary functions—these must also be considered when choosing the geotextile material for optimum performance. For instance, a geotextile can use for separation of two dissimilar soils (e.g., aggregate base and clay subgrade), but it may also use for filtration as a secondary function by reducing the build-up of excess pore water pressure in the soil beneath the separator. Ageneral idea of functions typically done by geotextiles in pavement applications is briefly described below.

4.1 Separation:

Between the two soil layers like coarse material and fine soil geotextile acts as a separator. It sets apart the different materials and prevent mixing under application of load. It can be said that preventing pebbles mixing with subgrade and penetrating the barrier is the function of geotextile [44]. Separationis the introduction of a flexible porous geotextile located between different materials so that the integrity and the functioning of both materials remains intact for the life of the structure or is enriched [45]. Application of geotextiles in constructing pavements, intermixing of two adjacent layers is prevented. For example, the major cause of roads and highways failure is constructing over insufficiently strong foundation which gradually gets contaminated by mixing of aggregate base layers with the adjacent soft underlayer subgrade soil (Figure 3a). A geo textile is subjected between these two layers which minimizes the contamination of aggregate base by the subgrade, working as a separator (Figure 3b).



Pavement without geotextile, showing subgrade intrusion into the base course

Pavement with geotextile, showing reduction of base contamination

Figure 3: Separation function of a geotextile placed between base aggregate and a soft subgrade: (a) without geotextile; (b) with geotextile

4.2 Filtration:

Filtrationis defined as the equilibrium of a geotextile-soil system that permits for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration[45].A common application showing the filtration function is the use of a geotextile in a pavement trench drain (Figure 4). The geosynthetic-soil system should achieve an equilibrium that allows for adequate liquid flow under conditions of consideration. As the flow of liquid is perpendicular to the plane of the geosynthetic, filtration refers to the cross plane hydraulic conductivity or permittivity. Another important property relevant to filtration is apparent opening size (AOS) - the opening size larger than 95% of the geotextile's pores - which is compared to soil particle size characteristics. The coarser-sized particles eventually create a filter bridge, which in turn retains the finer-sized particles, building a stable upstream soil structure.

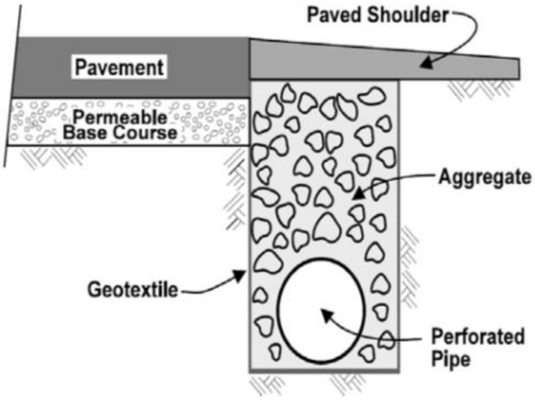


Figure 4: Filtration function provided by a geotextile in a pavement trench drain

4.3 Drainage:

Due to different reasons, liquid and gas can be stocked up gradually. A geotextile material can gather and redirect the liquid or gas towards the vent channel, i.e. the transmission of fluid is in the direction of in-plane flow of fabric without any loss of soil particles [46]. Any geotextile material exhibiting good filtration and permittivity properties can be used in drainage applications [47].

4.4 Reinforcement*:*

When insufficient stability and strength of subgrade soil is complimented, geotextiles with higher tensile strength acts as reinforcement materials. The principle of employing geotextiles as reinforcement is to introduce the geotextiles into the soil structure that increase the cohesion between the grains [48]. This modifies the transmission of the load and the resulting composite is able to sustain higher loads. The forces exerted on the structure as a result of different loads are transferred into tensile stresses, which further influences other mechanical properties, such as puncture resistance [49]. The reinforcement is a complex phenomenon and results from the combined behavior of soil–geotextile interactions [50-52]. Reinforcement is the synergistic improvement in pavement strength created by the introduction of a geotextile into a pavement layer. While the function of reinforcement in the U.S. has often been fulfilled by geogrids, geotextiles have been used extensively as reinforcement inclusions, particularly overseas, in transportation applications [53, 54]. The reinforcement function can be developed primarily through the following three mechanisms [55]:

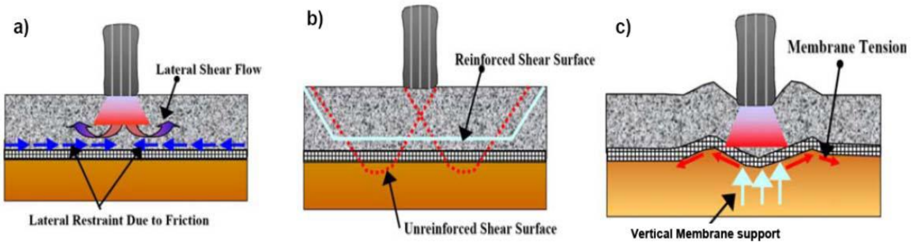


Figure 5: Reinforcement mechanisms induced by a geotextile used for base reinforcement:
(a) *lateral restraint; (b) increased bearing capacity; (c) membrane-type support.*

Subjecting a geotextile to act as a stress relief layer is referred to protection. Fluid barrier is the ability of a geotextile material to prevent the migration of fluid. Typically, geotextile materials are employed as a fluid barrier in roadways in two ways: when placed beneath a pavement overlay saturating with bituminous material and when placed adjacent to a finer material under unsaturated conditions.

Moreover, Giroud [**32**] has identified some other functions of geotextiles which are defined below.

Surfacing– A geotextile works as a surfacing when a smooth and flat ground surface is needed and preventing the soil particles to be eliminated from the soil surface.

Solid barrier– A geotextile acts as a solid barrier when it prevents or ceases the motion of solids.

Container– A geotextile acts as a container when it holds or protects the materials such as sand, rocks, fresh concrete etc.

Tensioned membrane– A geotextile acts as a tensioned membrane when it is sandwiched between two materials having different pressures. The principle of using a geotextile is to even out the pressure difference by balancing with the tension of the geotextile.

Tie– A geotextile acts as a tie when it joins various pieces of a structure that is capable of moving apart.

Slip surface– A geotextile placed between two materials by minimising the frictional characteristics of the structure.

Absorber– A geotextile acts as an absorber when it shares the stresses and strains transmitted to the material that is required to be protected.

5. Major Geotextile Applications

In more or less two decades in the construction of railway, highway, embankments and retaining walls, erosion control and drainage geotextiles or geosynthetics have been applied remarkably. Some of them are mentioned below

5.1 Temporary Roads

Maximum construction sites need access to the site through weak surface deposits. Temporary roads are constructed by spreading a carpet of coarse granular material (stone metal) over the soft subgrade to act as a load dispersing medium which retains the stresses on subgrade low. Nevertheless, extensive rutting occurs on the surface due to the granular fill getting lost into the soft subgrade under continuous pressure from the running vehicles. This provides rise to perennial maintenance problems. The problems can be lessened, if not overcome, by using a suitable layer of geotextile at the interface of the granular fill and the subgrade. This not only keeps the thickness of the granular fill intact but the tensile strength of geotextile allows reduction in thickness of the stone filling as well. Effective use of geotextiles has been made in a fabrication yard on soft dredged fill to make the area suitable for movement of heavy cranes for jacket fabrication [56]. A depth of 700 mm of stone aggregate was placed on the soft subgrade with geotextile at the interface. This not only allowed a saving of 200 mm of stone filling but enabled rapid construction of the fabrication yard.

5.2 Permanent Roads

In a permanent roadway application of textile materials not only reduces the thickness of pavement as well as reduces the chances of damage and maintenance necessity in long term use. Geotextile also prevents the stability reduction of the base subgrade by preventing the possibility of water constancy and intent to flow water into the side drains which saves subgrade layers from getting softened and loosen. Geotextiles also defend reflective cracking of the road surface when bituminous surface layer is cracked for maintenance.

A report was published on use of non-woven geotextiles as a pavement overlay to reduce reflective cracking in the runway of the Ahmedabad airport in Gujarat by Tiwari and Ranjan [57]. At the cracked location strips of fabric were placed on a V-shaped groove filled with a bituminous tack coat. Pressuring by heavy rollers a rigid contact was made between fabric and tuck coat. Comparative analysis shows that, in the treated area without geotextile fabric crack appeared within six months, on the other hand, in the fabricated area crack appeared after two years that too on a very minor scale.

In case of railway, to scatter the huge amount of load into the subgrade soil the rail lines are subjected on a gravel layer. For the regular load, the gravels get start to penetrate gradually which requires a regular inspection and replenishment as the same thing happens for the pavement on week subgrade. High performance geotextiles can be used for separating the gravels and equal load distribution on subgrade. As per estimation 2,400 km of track belonging to Indian Railways is founded on weak soil and approximately 300 km of rail track require strengthening every year [58]. Nonwoven geotextiles have been recommended for reinforcement of tracks in Indian Railways.

5.3 Embankments and Retaining Walls

Geotextile is more effectively used for reinforcement in construction of embankments and retaining walls in soft soil. By filling geotextiles horizontally at the base of embankment it is possible to attain an erect side slope and construction can be cost efficient. More importantly, in urban areas, project can be made cost efficient by reducing the land coverage on the both sides of the embankment. By the limit equilibrium methods and considering the fabric tension capacity the slope stability can be analyzed and applied the data to design. Non-woven geotextiles have been used in Nava-Seva Port near Bombay to stabilize 9 m high guide bunds on soft marine clay [59]. The geotextile was laid on the marine clay at a water depth up to 6 m from a flat-decked barge. It was covered with a rock mattress and earth filling was done in stages to build up the embankment. The use of geotextiles reduced the quantity of natural rock by 30% and the cost by 50% [60].

5.4 Erosion Control

Application of geotextiles in the erosion control sector is growing fast for attaining short term effects. In this sector the materials are applied in a bit different way that they are laid on the surface and bot buried in the soil. The main objective remains to control erosion and for making more efficient vegetation is established which can control erosion naturally. The geo textile is then residue to requirements and can fertilize the soil by degradation. Geotextile can intersect the running off soil particles and protect the unvegetated soil from natural force like sun, rain and wind. Weeds and newly plant trees can also be inhibited by them. Erosion control can be applied to riverbanks and coastlines to prevent undermining by the ebb and flow of the tide or just by wave motion [1, 60].

6. Global Geotextiles Market

The global market for geotextiles is anticipated to grasp $8.24 billion by 2020, in keeping with a new study by Grand View Research Inc. increased concentration on geotextiles and its uses in roadways and erosion prevention is likely to be a key driver for the development of the market. Besides, increasing regulatory support in emerging countries including India, China, UAE and Brazil is also projected to enhance the demand for geotextiles over the forecast period. Road construction and erosion control were the leading applications of geotextiles together accounting for more than 60% of worldwide demand in 2013. Growing infrastructure spending in Asia Pacific, Middle East and Latin America are estimated to act as strategic features for driving geotextile demand for this use. Road construction is likewiseprojected to be the fastest rising fragment over the prediction period, at an estimated CAGR of over 9% from 2014 to 2020 [61-65].

Further significant outcomes from the research are stated below [61-65]:

- The world geotextiles demand is expected to reach 4,323 million square meters by 2020 increasing at a CAGR of 8.9% from 2014 to 2020.
- Asia Pacific was the biggest geotextile end user and is also expected to be the fastest growing regional market over the forecast period, at an expected CAGR of 9.1% from 2014 to 2020. North America is also estimated to observer momentous progress on account of repair and maintenance for the vast road network of the region. European geotextile market profits is estimated to touch USD 1.97 billion by 2020, increasing at a CAGR of 9.6% from 2014 to 2020.
- Non-woven geotextiles were the most frequently used geotextiles in 2013, at an expected consumption of 1,561 million square meters. Low cost and extensive application scope make non-wovens the most desired among other geotextiles goods. Knitted geotextile demand is anticipated to reach 279.8 million square meters by 2020, growing at a CAGR of 7.1% from 2014 to 2020.
- The global geotextiles market is split with the top six companies catering to about 40% of international demand in 2013. Significant companies in the market include Royal Tencate, NAUE, Low & Bonar and Propex among others.

7. Conclusion

Technical textile products are now going essential for every sector of engineering as well as our practical life. Geotextiles has already been extensively used in various fields of constructions and civil engineering all over the world. The market demand of geotextiles are also increasing tremendously. Currently the product serves some functions such as separation, filtration, drainage, reinforcement and so on. But the range of functions of geotextiles can be enhanced and the product can be made more potential and versatility of applications. In this regard, more research has been required to enhance the performance of this valuable technical textile products. Nanotechnology can be applied for this purpose and modification of both natural and synthetic fibers as well as novel finishing process can be performed to attain the best desired properties for the diverse and viable practical application of geotextiles.

References

[1]. Horrocks, A. R., & Anand, S. C. (2000). *Handbook of Technical Textiles*. Woodhead Publishing Ltd, Cambridge, England.

[2]. http://www.grandviewresearch.com/press-release/global-technical-textiles-market (Access date: 13/10/2017)

[3]. Denton, M. J. & Daniels, P. N. (2002). *Textile Terms and Definitions*, 11th Ed., The Textile Institute, Manchester.

[4]. John, N. W. M. (1987). *Geotextiles*. Blackie and Sons, Glasgow, Scotland.

[5]. Ingold, T.S., & Miller, K. S. (1988). *Geotextiles Handbook*. Thomas Telford Ltd., London, United Kingdom.

[6]. Nizam, M. E. H., & Das, S. C. (2014). Geo Textile - A Tremendous Invention of Geo Technical Engineering. *International Journal of Advanced Structures and Geotechnical Engineering*, 3(3):221-227.

[7]. Rawal, A., Shah, T., & Anand, S. (2010). Geotextiles: Production, Properties and Performance. *Textile Progress*, 42(3):181-226. Doi: http://dx.doi.org/10.1080/00405160903509803

[8]. Ingold, T. S. (2013). *Geotextiles and Geomembranes Handbook*, Elsevier, Amsterdam, The Netherlands.

[9]. Koerner, R. M. (2012). *Designing with Geosynthetics*, 6th Ed., Xlibris, Bloomington, Indiana.

[10]. Saha, J., Das, S. C., Rahman, M., Siddiquee, M. A. B., &Khan, M. A. (2016) Influence of Polyester Resin Treatment on Jute Fabrics for Geotextile Applications. *Journal of Textile Science and Technology*, 2(4):67-80.Doi: 10.4236/jtst.2016.24009

[11]. http://www.grandviewresearch.com/industry-analysis/geotextiles-industry(Access date: 13/10/2017)

[12]. Methacanona, P., Weerawatsophona, U., Sumransina, N., Prahsarna, C., & Bergadob, D. T. (2010). Properties and Potential Application of the Selected Natural Fibers as Limited Life Geotextiles. *CarbohydrPolym*, 82:1090–1096.

[13]. Sarsby, W. R. (2007).*Geosynthetics in civil engineering*. Woodhead Publishing, Abington, Cambridge.

[14]. Lekha, K.R. (2004). Field Instrumentation and Monitoring of Soil Erosion in Coir Geotextile Stabilised Slopes—ACase Study. *Geotextiles and Geomembranes*, 22(5):399-413. Doi: https://doi.org/10.1016/j.geotexmem.2003.12.003

[15]. Rawal, A. & Anandjiwala, R. D. (2007) Comparative Study between Needle punched Nonwoven Geotextile Structures Made from Flax and Polyester Fibres. *Geotextiles and Geomembranes*, 25(1):61–65.Doi: https://doi.org/10.1016/j.geotexmem.2006.08.001

[16]. Ahn, T. B., Cho, S.D.,& Yang, S. C.(2002) Stabilization of soil slope using geosynthetic mulching mat. *Geotextiles and Geomembranes*,20(2):135–146.Doi:https://doi.org/10.1016/S0266-1144(02)00002-X

[17]. Datye, K. R. &Gore, V. N.(1994) Application of natural geotextiles and related products. *Geotextiles and Geomembranes*,13(6-7):371–388.Doi: https://doi.org/10.1016/0266-1144(94)90003-5

[18]. Kaniraj, S. R. & Rao,G. V.(1994) Trends in the use of geotextiles in India,*Geotextiles and Geomembranes*,13(6-7):389–402.Doi:https://doi.org/10.1016/0266-1144(94)90004-

[19]. Lee, S. L., Karunaratne, G. P., Ramaswamy, S. D., Aziz, M. A., & Gupta, N.C. D. (1994)Natural Geosynthetic Drain for Soil Improvement. *Geotextiles and Geomembranes,*13(6-7):457–474.Doi: https://doi.org/10.1016/0266-1144(94)90008-6

[20]. Lekha, K. R., &Kavitha, V.(2006) Coir geotextile reinforced clay dykes for drainage of low-lying areas, *Geotextiles and Geomembranes,*24(1):38–51.Doi: https://doi.org/10.1016/j.geotexmem .2005.05.001

[21]. Rao, G. V., Kumar, J. P. S., &Banerjee, P. K.(2000) Characterization of a braided strip drain with coir and jute yarns, *Geotextiles and Geomembranes,*18(6):367–384.Doi: https://doi.org/10.1016/S0266-1144(00)00006-6

[22]. Sanyal, T., &Chakraborty, K. (1994) Application of a bitumen-coated jute geotextile in bank-protection works in the Hooghly estuary. *Geotextiles and Geomembranes,* 13(2):127–132. Doi: https://doi.org/10.1016/0266-1144(94)90044-2

[23]. Slater, K. (2003). J. Text. I. 94:99–105.

[24]. Tan, S. A., Karunaratne, G. P.,& Muhammad, N.(1993) The measurement of interface friction between a jute geotextile and a clay slurry. *Geotextiles and Geomembranes,*12(4):363–376.Doi: https://doi.org/10.1016/0266-1144(93)90010-L

[25]. Ranganathan, S. R. (1994)Development and potential of jute geotextiles, *Geotextiles and Geomembranes*13(6-7):421–433.Doi: https://doi.org/10.1016/0266-1144(94)90006-X

[26]. Balan, K., & Rao, G. V. (1996)*Erosion control with natural geotextiles*, in *Environmental Geotechnology with Geosynthetics*, G.V. Rao and P.K. Banerjee, eds., The Asian Society forEnvironmental Geotechnology and CBIP, New Delhi, 1996, pp. 317–325.

[27]. Wall, M. J., Frank, G. C., & Stevens, J. R. (1971). *Textile Research Journal*. 41:38–43.

[28]. Barnett, R. B., &Slater, K. (1991). J. Text. I. (82):417–425.

[29]. Ludewig, H. (1971).*Polyester Fibers*. Wiley, New York.

[30]. Corbman, B. P. (1975).*Textile: Fiber to Fabric*. McGraw-Hill, New York.

[31]. Bhatia, S.K., & Smith, J. L. (1996) Geotextile Characterization and Pore-Size Distribution: Part I. A Review of Manufacturing Processes, *Geosynthetics International*, 3(1):85-105.

[32]. Giroud, J. P. (1984)Geotextiles and geomembranes, *Geotextiles and Geomembranes,* 1(1):5–40.Doi: https://doi.org/10.1016/0266-1144(84)90003-7

[33]. Rawal, A., Moyo, D., Soukupova, V., & Anandjiwala, R. D. (2007). J. Ind. Text. (36):207–220.

[34]. Russell, S. J. (2007).*Handbook of Nonwovens*, Woodhead Publishing, Boca Raton, FL.

[35]. Potluri, P., Rawal, A., Rivaldi, M., &Porat, I. (2003). Composites: Part A.(34):481–492.

[36]. Rawal, A., *Generation of an expert system for the optimisation of net extrusion processes*, PhD dissertation. University of Bolton, Bolton, UK, 2002.

[37]. https://en.wikipedia.org/wiki/Geocomposite (access date: 15/10/2017)

[38]. Tao, T., Yan, J., Tao, X., Fu, F., &Zhou, H. (1996) Application of Geotextile/Geomembrane Composite Liner for Infiltration Prevention in Xiaolingtou Rock-Fill Dam, Geosynthetics International, 3(1):125-136. Doi: https://doi.org/10.1680/gein.3.0057

[39]. Das, S. C., Nizam, M. E. H. (2014) Applications of fiber reinforced polymer composites (FRP) in civil engineering.International Journal of Advanced Structures and Geotechnical Engineering,3(3):299-309.

[40]. Das, S.C., Paul, D., Siddiquee, M. A. B., Saha, J., Khan, M. A. &Islam, J. M. M. (2017)Study on the mechanical properties of non-woven glass fiber reinforced polyester composites, *Paper ID: 75, Proceeding of the International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering IC^{4}ME^2-2017, 26-27 January, 2017, University of Rajshahi, Rajshahi, Bangladesh.*

[41]. Das, S. C., Islam, M. T., Khan, M. A., Mamun, M. A. A., Mittro, B. K., Saha, J.,Paul, D., (2017) Fabriaion and mechanical characterization of PALF plain fabric reinforced polyester biocomposites, *Paper ID: 76, pp. 55, Proceeding of the International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering IC^{4}ME^2-2017, 26-27 January, 2017, University of Rajshahi, Rajshahi, Bangladesh.*

[42]. Das, S. C., Paul, D., Islam, J. M. M., Khan, M. A.(2016) Effect of gamma radiation on the mechanical properties of PET felt reinforced polyester composites, *Paper ID: ICMIEE-PI-160337, Proceeding of the International Conference on Mechanical, Industrial & Energy Engineering 2016, 26-27 December, 2016, Khulna, Bangladesh.*

[43]. Das, S. C., Paul, D., Siddiquee, M. A. B., Islam, J. M. M., Khan, M. A. (2016) Experimental investigation and analysis of mechanical behavior of jute fabric reinforced polyester composites, *Paper ID: ICMIEE-TE-160167, Proceeding of the International Conference on Mechanical, Industrial & Energy Engineering 2016, 26-27 December, 2016, Khulna, Bangladesh.*

[44]. Fluet, J. E. (1984) *J. Ind. Text.*, 14:53–64.

[45]. Koerner, R.M. (2005). *Designing with Geosynthetics*. 5th Edition. Upper Saddle River, NJ: Prentice Hall.

[46]. Hwang, G. S., Lu, C. K., Lin, M. F., Hwu, B. L., &Hsing, W. H.(1999) *Text. Res. J.*, 69:565–569.

[47]. Williams, N. D., &Luna, J. (1987) Selection of geotextiles for use with synthetic drainage products. *Geotextile andGeomembranes*, 5(1):45–61.Doi: https://doi.org/10.1016/0266-1144(87)90033-1

[48]. Wang, Y. (2001). J. Ind. Text. 30:289–302.

[49]. Ghosh, T. K. (1998)Puncture resistance of pre-strained geotextiles and its relation to uniaxial tensile strain at failure, Geotextile and Geomembranes, 16(5):293–302.Doi: https://doi.org/10.1016/S0266-1144(98)00011-9

[50]. Adanur, S. &Liao, T. (1998).Computer Simulation of Mechanical Properties of Nonwoven Geotextiles in Soil-Fabric Interaction**.** *Textile Research Journal***,** 68(3):155–162.Doi: https://doi.org/10.1177/004051759806800301

[51]. Liao, T., Adanur, S., &Drean, J. Y. (1997).Predicting the mechanical properties of nonwoven geotextiles with the finite element method. Textile Research Journal. 67(10):753–760. Doi: https://doi.org/10.1177/004051759706701008

[52]. Mogahzy, Y. E. E., Gowayed, Y. & Elton, D. (1994) *Textile Research Journal*. 64:744–755.

[53]. Bueno, B.S., Benjamim, C.V., and Zornberg, J.G. (2005). “Field Performance of a Full-Scale Retaining Wall Reinforced with Non-woven Geotextiles,” Slopes and Retaining StructuresUnder Seismic and Static Conditions. ASCE Geotechnical Special Publication No. 140, Gabr, Bowders, Elton, and Zornberg (Editors), January 2005, Austin, TX (CD-ROM).

[54]. Benjamim, C.V.S., Bueno, B., Zornberg, J.G. (2007). *Field Monitoring Evaluation of Geotextile-Reinforced Soil Retaining Walls*. Geosynthetics International Journal, April, Vol. 14, No.1.

[55]. Holtz, R.D., Christopher, B.R., Berg, R.R. (1998). *Geosynthetic Design and Construction Guidelines*. FHWA Technical Report No. FHWA-HI-95-038, Federal HighwayAdministration, Washington, D.C., updated April 1998, 460pp.

[56]. Ghoshal, A. and Som, N. (1989). ‘Use of geotextiles in a heavy duty fabrication yard - A case study’ In Use of Geosynthetics in India: Experiences and Potential. Report No. 207, Central Board of Irrigation and Power, New Delhi, India, pp. 321-324.

[57]. Tiwari, A. B.,&Rajan, V. S. (1989) Use of geotextiles overlay at Ahmedabad airport-A case study. In use of geosynthetics in India: Experiences and Potential. Report No. 207, Central Board of Irrigation and Power, New Delhi, India, pp. 393-399

[58]. Sarkar, S. S. (1989). ‘Formation, rehabilitation and track bed stabilisation in railways using extruded polymer geogrids. In use of geosynthetics in India - Experiences and Potential. Report No. 209, Central Board of Irrigation and Power, New Delhi, India.

[59]. Iyenger, S. S. (1990). ‘Reinforcements in a submarine clay’. Proceedings of the 4th International Conference on Geotextiles, Geomembrances and Related products, vol. 1, ed. G.D. Hock. Balkenma Publication, The Hague, p. 164.

[60]. http://www.indiantextilejournal.com/articles/FAdetails.asp?id=5752 (Access date: 13/10/2017)

[61]. Grand View Research Forecasts Global Geotextiles Market (https://www.estormwater.com/grand-view-research-forecasts-global-geotextiles-market) (access date: 13/10/2017)

[62]. Website: Global Market Insights. https://www.gminsights.com/industry-analysis/geotextile-market (access date: 13/10/2017)

[63]. http://www.grandviewresearch.com/industry-analysis/geotextiles-industry(access date: 13/10/2017)

[64]. https://globenewswire.com/news-release/2015/08/06/758603/10145077/en/Geotextiles-Market-Revenue-Is-Expected-To-Grow-To-8-24-Billion-by-2020-Report-By-Grand-View-Research-Inc.html(access date: 13/10/2017)

[65]. https://www.futuremarketinsights.com/reports/geosynthetics-market(access date: 13/10/2017)