GEOTEXTILE: IT'S APPLICATION TO CIVIL ENGINEEERING – OVERVIEW

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ABSTRACT

Geotextiles, a newly emerging field in the civil engineering and other fields, offer great potential in varied areas of applications globally. Geotextiles play a significant part in modern pavement design and maintenance techniques. The growth in their use worldwide for transportation applications in particular, has been nothing short of phenomenal. Geotextiles are ideal materials for infrastructural works such as roads, harbors and many others. They have a bright future, thanks to their multifunctional characteristics.

The paper provides an overview of various natural as well as synthetic textile fibres used for application as geotextiles

Key words: geotextiles; separators, drainage, filtration, reinforcement, woven and non-woven fabrics

1. INTRODUCTION

Geotextiles were one of the first textile products in human history. Excavations of ancient Egyptian sites show the use of mats made of grass and linen. Geotextiles were used in roadway construction in the days of the Pharaohs to stabilise roadways and their edges. These early geotextiles were made of natural fibres, fabrics or vegetation mixed with soil to improve road quality, particularly when roads were made on unstable soil. Only recently have geotextiles been used and evaluated for modern road construction. Geotextiles today are highly developed products that must comply with numerous standards. To produce tailor-made industrial fabrics, appropriate machinery is needed.

Geotextiles have been used very successfully in road construction for over 30 years. Their primary function is to separate the sub base from the sub grade resulting in stronger road construction. The geotextile perform this function by providing a dense mass of fibres at the interface of the two layers.

Geotextiles have proven to be among the most versatile and cost-effective ground modification materials. Their use has expanded rapidly into nearly all areas of civil, geotechnical, environmental, coastal, and hydraulic engineering. They form the major component of the field of geosynthetics, the others being geogrids, geomembranes and geocomposites. The ASTM (1994) defines geotextiles as permeable textile materials used in contact with soil, rock, earth or any other geotechnical related material as an integral part of civil engineering project, structure, or system.

Geotextiles should fulfill certain requirements like it must permit material exchange between air and soil without which plant growth is impossible, it must be penetrable by roots etc. and it must allow rain water to penetrate the soil from outside and also excess water to drain out of the earth without erosion of the soil. To obtain all these properties in geotextiles, the proper choice of textile fibre is of paramount importance. The different synthetic fibres used in geotextiles are nylon, polyester, polypropylene while some natural fibres like ramie, jute etc. can also be used.

In this paper, the types of fibres suitable for use as geotextiles have been mentioned along with their basic characteristics, functions and applications in various areas.

2. IMPORTANT CHARACTERISTICS OF GEOTEXTILES

The characteristics of geotextiles are broadly classified as:

1. Physical properties:
- **a)** specific gravity
- **b)** weight
- **c)** thickness
- **d)** stiffness
- **e)** density .

2. Mechanical properties:
- **a)** tenacity
- **b)** tensile strength
- **c)** bursting strength
- **d)** drapability
- **e)** compatibility
- **f)** flexibility
- **g)** tearing strength
- **h)** frictional resistance

3. Hydraulic properties:
- **a)** porosity
- **b)** permeability
- **c)** permittivity
- **d)** transitivity
- **e)** turbidity /soil retention
- **f)** filtration length etc.

4. Degradation properties:
- **a)** biodegradation
- **b)** hydrolytic degradation
- **c)** photo degradation
- **d)** chemical degradation
- **e)** mechanical degradation

- **f)** other degradation occurring due to attack of rodent, termite etc.

5. Endurance properties:
   - **a)** elongation
   - **b)** abrasion resistance
   - **c)** clogging length and flow etc.

3. SELECTION OF FIBRE FOR GEOTEXTILES

Different fibres from both natural as well as synthetic category can be used as geotextiles for various applications.

Natural fibres: Natural fibers in the form of paper strips, jute nets, wood shavings or wool mulch are being used as geotextiles. In certain soil reinforcement applications, geotextiles have to serve for more than 100 years. But bio-degradable natural geotextiles are deliberately manufactured to have relatively short period of life. They are generally used for prevention of soil erosion until vegetation can become properly established on the ground surface. The commonly used natural fibres are –

- **Ramie:** These are subtropical bast fibres, which are obtained from their plants 5 to 6 times a year. The fibres have silky luster and have white appearance even in the unbleached condition. They constitute of pure cellulose and possess highest tenacity among all plant fibres.
- **Jute:** This is a versatile vegetable fibre which is biodegradable and has the ability to mix with the soil and serve as a nutrient for vegetation. Their quick biodegradability becomes weakness for their use as a geotextile. However, their life span can be extended even up to 20 years through different treatments and blendings. Thus, it is possible to manufacture designed biodegradable jute geotextile, having specific tenacity, porosity, permeability, transmissibility according to need and location specificity. Soil, soil composition, water, water quality, water flow, landscape etc. physical situation determines the application and choice of what kind of jute geotextiles should be used. In contrast to synthetic geotextiles, though jute geotextileas are less durable but they also have some advantages in certain area to be used particularly in agro-mulching and similar area to where quick consolidation are to take place. For erosion control and rural road considerations, soil protection from natural and seasonal degradation caused by rain, water, monsoon, wind and cold weather are very important parameters. Jute geotextiles, as separator, reinforcing and drainage activities, along with topsoil erosion in shoulder and cracking are used quite satisfactorily. Furthermore, after degradation of jute geotextiles, lignomass is formed, which increases the soil organic content, fertility, texture and also enhance vegetative growth with further consolidation and stability of soil.

Synthetic Fibres: The four main synthetic polymers most widely used as the raw material for geotextiles are – polyester, polyamide, polyethylene and polypropylene. The oldest of these is polyethylene which was discovered in 1931 by ICI. Another group of polymers with a long production history is the polyamide family, the first of which was discovered in 1935. The next oldest of the four main polymer families relevant to geotextile manufacture is polyester, which was announced in 1941. The most recent polymer family relevant to geotextiles to be developed was polypropylene, which was discovered in 1954.

- **Polyamides (PA):** There are two most important types of polyamides, namely Nylon 6 and Nylon 6,6 but they are used very little in geotextiles. The first one an aliphatic polyamide obtained by the polymerization of petroleum derivative ε-caprolactam. The second type is also an aliphatic polyamide obtained by the polymerization of a salt of adipic acid and hexamethylene diamine. These are manufactured in the form of threads which are cut into granules. They have more strength but less moduli than polypropylene and polyester They are also readily prone to hydrolysis.
- **Polyesters (PET):** Polyester is synthesised by polymerizing ethylene glycol with dimethyle terephthalate or with terephthalic acid. The fibre has high strength modulus, creep resistance and general chemical inertness due too which it is more suitable for geotextiles. It is attacked by polar solvent like benzyl alcohol, phenol, and meta-cresol. At pH range of 7 to 10, its life span is about 50 years. It possesses high resistance to ultraviolet radiations. However, the installation should be undertaken with care to avoid unnecessary exposure to light.
- **Polyethylene (PE):** Polyethylene can be produced in a highly crystalline form, which is an extremely important characteristic in fiber forming polymer. Three main groups of polyethylene are – Low density polyethylene (LDPE, density 9.2-9.3 g/cc), Linear low density polyethylene (LLDPE, density 9.20-9.45 g/cc) and High density polyethylene (HDPE, density 9.40-9.6 g/cc).
- **Polypropylene (PP):** Polypropylene is a crystalline thermoplastic produced by polymerizing propylene monomers in the presence of stereo-specific Zeigler-Natta catalytic system. Homo-polymers and co-polymers are two types of polypropylene. Homo polymers are used for fibre and yarn applications whereas co-polymers are used for varied industrial applications. Propylene is mainly available in granular form.

  Both polyethylene and polypropylene fibres are creep prone due to their low glass transition temperature. These polymers are purely hydrocarbons and are chemically inert. They swell by organic solvent and have excellent resistance to diesel and lubricating oils. Soil burial studies have shown that except for low molecular weight component present, neither HDPE nor polyethylene is attacked by micro-organisms.
- **Polyvinyl chloride (PVC):** Polyvinyl chloride is mainly used in geo membranes and as a thermo plastic coating materials. The basic raw materials utilized for production of PVC is vinyl chloride. PVC is available in free- flowing powder form.
- **Ethylene copolymer Bitumen (ECB):** Ethylene copolymer bitumen membrane has been used in civil engineering works as sealing materials. For ECB

production, the raw materials used are ethylene and butyl acrylate (together forming 50-60%) and special bitumen (40-50%).

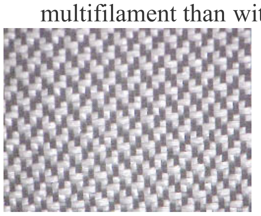
- **Chlorinated Polyethylene (CPE):** Sealing membranes based on chlorinated poly ethylene are generally manufactured from CPE mixed with PVC or sometimes PE. The properties of CPE depend on quality of PE and degree of chlorination.

4. TYPES OF GEOTEXTILES

Geotextiles are a permeable synthetic material made of textile materials. They are usually made from polymers such as polyester or polypropylene. The geotextiles are further prepared in three different categories – woven fabrics, non-woven fabrics and knitted fabrics

- **Woven fabrics:** Large numbers of geosynthetics are of woven type, which can be sub-divided into several categories based upon their method of manufacture. These were the first to be developed from the synthetic fibers. As their name implies, they are manufactured by adopting techniques which are similar to weaving usual clothing textiles. This type has the characteristic appearance of two sets of parallel threads or yarns --.the yarn running along the length is called warp and the one perpendicular is called weft.

  The majority of low to medium strength woven geo synthetics are manufactured from polypropylene which can be in the form of extruded tape, silt film, monofilament or multifilament. Often a combination of yarn types is used in the warp and weft directions to optimize the performance/cost. Higher permeability is obtained with monofilament and multifilament than with flat construction only.



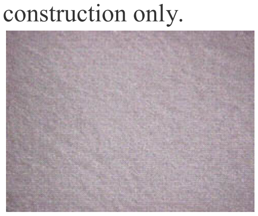


Fig 1. Woven Geotextile **Fig 2.** Non-woven Geotextile

- **Non-woven:** Non woven geo-synthetics can be manufactured from either short staple fibre or continuous filament yarn. The fibers can be bonded together by adopting thermal, chemical or mechanical techniques or a combination of techniques. The type of fibre (staple or continuous) used has very little effect on the properties of the non – woven geo synthetics. Non-woven geotextiles are manufactured through a process of mechanical interlocking or chemical or thermal bonding of fibres/filaments. Thermally bonded non-wovens contain wide range of opening sizes and a typical thickness of about 0.5-1 mm while chemically bonded non-wovens are comparatively thick usually in the order of 3 mm. On the other hand mechanically bonded non-wovens have a typical thickness in the range of 2-5 mm and also tend to be comparatively heavy because a large quantity of polymer filament is required to provide sufficient number of entangled filament cross wires for adequate bonding.

- **Knitted fabrics:** Knitted geosynthetics are manufactured using another process which is adopted from the clothing textiles industry, namely that of knitting. In this process interlocking a series of loops of yarn together is made. An example of a knitted fabric is illustrated in figure. Only a very few knitted types are produced. All of the knitted geosynthetics are formed by using the knitting technique in conjunction with some other method of geosynthetics manufacture, such as weaving.

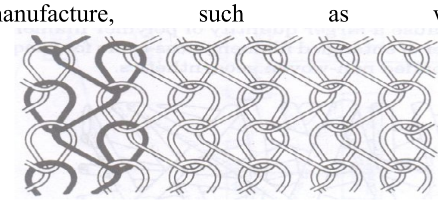


Fig 3. Knitted Geotextile

Apart from these three main types of geotextiles, other geosynthetics used are geonets, geogrids, geo-cells, geo membranes, geo composites, etc. each having its own distinct features and used for special applications.

5. FUNCTIONS OF GEOTEXTILES

Every textile product applied under the soil is a geotextile. The products are used for reinforcement of streets, embankments, ponds, pipelines, and similar applications (Figure 4). Depending on the required function, they are used in open-mesh versions, such as a woven or, rarely, warp-knitted structure, or with a closed fabric surface, such as a non-woven. The mode of operation of a geotextile in any application is defined by six discrete functions: separation, filtration, drainage, reinforcement, sealing and protection. Depending on the application the geotextile performs one or more of these functions simultaneously.

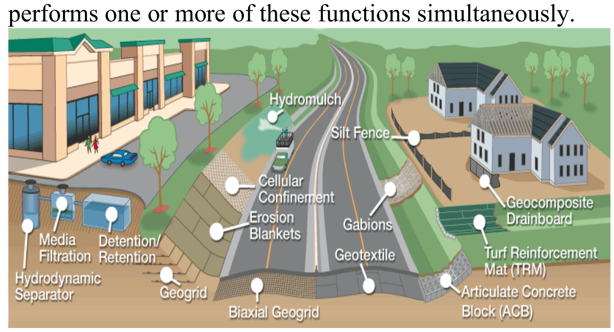


Fig 4. Application areas of Geotextiles

5.1. Separation:

Separation is defined as, "*The introduction of a flexible porous textile placed between dissimilar materials so that the integrity and the functioning of both the materials can remain intact or be improved*". In transportation applications separation refers to the geotextile's role in preventing the intermixing of two adjacent soils. For example, by separating fine subgrade soil from the aggregates of the base course, the geotextile preserves the drainage and the strength characteristics of the aggregate material. The effect of separation is illustrated in figure 5.

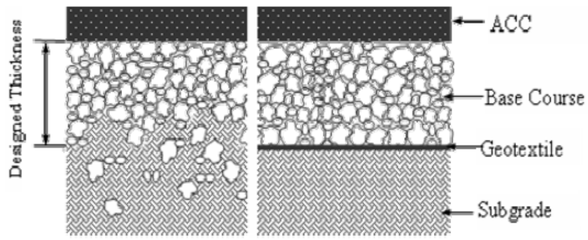


Fig 5. Concept of Separation function

They are used in all classes of roads and similar civil foundation as the base of construction on contaminated layer is the single most cause of premature failure. The use of separator prevents pumping effect created by dynamic load and also helps the passage of water while retaining soil particles. In theses types of geotextiles, thickness and permeability are most important characteristic properties. Some of the applications areas are:

- Between subgrade and stone base in unpaved and paved roads and airfields
- Between subgrade in railroads
- Between land fills and stone base courses
- Between geomembranes and sand drainage layers
- Beneath sidewalks slabs
- Beneath curb areas
- Beneath parking lots
- Beneath sport and athletic fields

5.2. Filtration:

It is defined as "*the equilibrium geotextile-to-soil system that allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration*". In filtration, fabrics can be either woven or non-woven, to permit the passage of water while retaining soil particles. Porosity and permeability are the major properties of geotextiles which involves in filtration action. Application helps the replacement of graded aggregate filters by a geotextiles warping. These applications are also suitable for both horizontal and vertical drains. A common application illustrating the filtration function is the use of a geotextile in a pavement edge drain, as shown in figure 6.

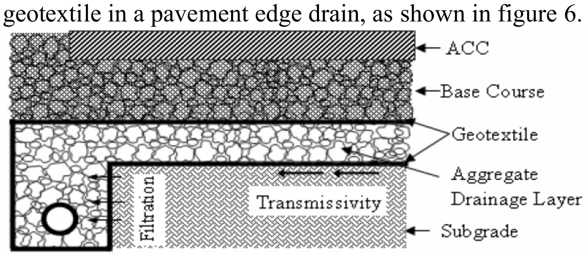


Fig 6. Filtration and Transmissivity functions

5.3. Drainage (Transmissivity):

This refers to the ability of thick nonwoven geotextile whose three-dimensional structure provides an avenue for flow of water through the plane of the geotextile. Figure 6 also illustrates the transmissivity function of geotextile. Here the geotextile promotes a lateral flow thereby dissipating the kinetic energy of the capillary rise of ground water.

5.4. Reinforcement:

This is the synergistic improvement in the total system strength created by the introduction of a geotextile into a soil and developed primarily through the following three mechanisms:

- lateral restraint through interfacial friction between geotextile and soil/aggregate
- forcing the potential bearing surface failure plane to develop at alternate higher shear strength surface
- membrane type of support of the wheel loads.

In this method, the structural stability of the soil is greatly improved by the tensile strength of the geosynthetic material. This concept is similar to that of reinforcing concrete with steel. Since concrete is weak in tension, reinforcing steel is used to strengthen it. Geosynthetic materials function in a similar manner as the reinforcing steel by providing strength that helps to hold the soil in place. Reinforcement provided by geotextiles or geogrids allow embankments and roads to be built over very weak soils and allows for steeper embankments to be built.

5.5. Sealing Function:

A non-woven geotextile performs this function when impregnated with asphalt or other polymeric mixes rendering it relatively impermeable to both cross-plane and in-plane flow. The classic application of a geotextile as a liquid barrier is paved road rehabilitation, as shown in Figure 7. Here the non-woven geotextile is placed on the existing pavement surface following the application of an asphalt tack coat. The geotextile absorbs asphalt to become a waterproofing membrane minimizing vertical flow of water into the pavement structure.

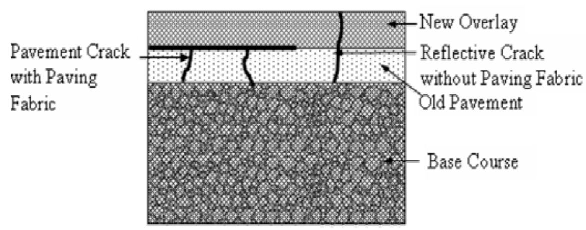


Fig 7. Sealing Function

6. APPLICATIONS OF GEOTEXTILES

Civil engineering works where geotextiles are employed can be classified into the following categories –

6.1 Road Works: The basic principles of incorporating geotextiles into a soil mass are the same as those utilized in the design of reinforced concrete by incorporating steel bars. The fabrics are used to provide tensile strength in the earth mass in locations where shear stress would be generated. Moreover, to allow rapid dewatering of the roadbed, the geotextiles need to preserve its permeability without losing its separating functions. Its filtration characteristics must not be significantly altered by the mechanical loading.

6.2 Railway Works: The development of the railway networks is being greatly boosted by the present state of economy because of their profitability in view of increasing cost of energy and their reliability as a result of the punctuality of trains even in the adverse weather conditions. The woven fabrics or non-wovens are used to separate the soil from the sub-soil without impeding the ground water circulation where ground is unstable.

Enveloping individual layers with fabric prevents the material wandering off sideways due to shocks and vibrations from running trains.

6.3 River Canals and Coastal Works: Geotextiles protect river banks from erosion due to currents or lapping. When used in conjunction with natural or artificial enrockments, they act as a filter. For erosion prevention, geotextile used can be either woven or nonwoven. The woven fabrics are recommended in soils of larger particle size as they usually have larger pore size. Nonwovens are used where soils such as clay silt are formed. Where hydrostatic uplift is expected, these fabrics must be of sufficiently high permeability.

6.4 Drainage: In civil engineering, the need for drainage has long been recognized and has created the need for filters to prevent in-situ soil from being washed into the drainage system. Such wash in soil causes clogging of the drains and potential surface instability of land adjacent to the drains. The use of geotextiles to filter the soil and a more or less single size granular material to transport water is increasingly seen as a technically and commercially viable alternative to the conventional systems. Geotextiles perform the filter mechanism for drainages in earth dams, in roads and highways, in reservoirs, behind retaining walls, deep drainage trenches and agriculture.

6.5 Sports field construction: Geotextiles are widely used in the construction of Caselon playing fields and Astro turf. Caselon playing fields are synthetic grass surfaces constructed of light resistance polypropylene material with porous or nonporous carboxylated latex backing pile as high as 2.0 to 2.5 cm. Astro Turf is a synthetic turf sport surface made of nylon 6,6 pile fibre knitted into a backing of polyester yarn which provides high strength and dimensional stability. The nylon ribbon used for this is of 55 Tex. It is claimed that the surface can be used for 10 hr/day for about 10 years or more. Modern Astro Turf contains polypropylene as the base material.

6.6 Agriculture; It is used for mud control. For the improvement of muddy paths and trails those used by cattle or light traffic, nonwoven fabrics are used and are folded by overlapping to include the pipe or a mass of grit.

7. GEOTEXTILES & THE ENVIRONMENT

Environment and ecological sustainability become one of the prime issues in the modern developmental strategy. Without positive ecological sustainability the technology/product becomes obsolete. Utilization of geotextile in civil engineering is not a new technology. But their modern uses have started with the advancement of synthetic and polymeric products and their ever increasing application in different forms and areas of civil engineering was initiated only a few decades ago. Again uses of natural fibrous materials in the field of bioengineering, erosion control and agro-mulching are also recent practices. In geotechnical uses like fibre drain, separator, filter and reinforcing materials are mostly synthetic and non biodegradable with longer span of life. Woven, non-woven, composite geosynthetics are used in the construction of roads-highways, railways, water-bodies, river banks erosion controls and other areas. On the other hand in soil bioengineering, permanent and self propagating vegetation is required with environmentally desirable and aesthetically pleasing appeal besides being economical and self sustainable. The roots bind the soil and counteract surface erosion for which natural geotextiles are more acceptable due to their better performance. Synthetic geotextiles are made of polymers and plastics. Hydro-carbon, petrochemicals, fossils are the basic raw materials for their production. Thus, all green house gases and effects are some how related with their manufacturing. Moreover, non-destructible nature of these synthetic geotextiles has direct effect on soil, water air and other biotic and a biotic system. These geotextiles may often come in contact with life cycles of animals, fishes, insects, and pests along with various micro organisms and create imbalance in the ecosystem. Thus, synthetic geotextiles may have direct negative impact on climate and ecology as a whole for which extensive research is essential in this area.

8. FUTURE OF GEOTEXTILES

When looking to future generations of geotextiles, an examination of the role of nanotechnology in the functional enhancement of geotextiles is in order. By reducing fiber diameter down to the nanoscale, an enormous increase in specific surface area to the level of 1000 m^2/g is possible. This reduction in dimension and increase in surface area greatly affects the chemical/biological reactivity and electroactivity of polymeric fibers. Because of the extreme fineness of the fibers, there is an overall impact on the geometric and thus the performance properties of the fabric. There is an explosive growth in worldwide research efforts recognizing the potential nanoeffect that will be created when fibers are reduced to nanoscale.

CONCLUSION

Textiles are not only clothing the human body but also our mother land in order to protect her. Extensive awareness should be created among the people about the application of geotextiles. Geotextiles are effective tools in the hands of the civil engineer that have proved to solve a myriad of geotechnical problems. To explore the potential of geotextile more researches are needed in this field.

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