An Introduction to Geosynthetics Material

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***Abstract*— This paper focuses on geosynthetics products, their applications and design methodologies required for reinforcing soil and environmental protection work. From decades Geosynthetics are widely used construction materials for geotechnical and environmental applications in most parts of the world. Because they constitute manufactured materials, new products and applications are developed on a routine basis to provide solutions to routine and critical problems alike. Results from recent research and from monitoring of instrumented structures throughout the years have led to new design methods for different applications of geosynthetics.**

Keywords— ***Wovens, Non-Wovens, Knitted, Biogradable, Nets, grids, Membranes***

I. INTRODUCTION

Historically, major developments in structural engineering have only been possible because of parallel developments in the technology of construction materials. Larger and more elaborate structures became possible as we went from using wood to building stone to concrete to reinforced concrete and most recently to prestressed reinforced concrete. The development of steel enabled the construction of longer span bridges and taller buildings than were possible using wrought iron or other traditional construction materials. Because the materials of geotechnical engineering are soil and rock, it is difficult to think of similar parallel developments in geotechnical construction and earthen materials in our field. Compaction and other soil improvement techniques occurred largely because of developments in construction equipment by manufacturers and contractors. Geosynthetics have been increasingly used in geotechnical and environmental engineering for the last 4 decades. Over the years, these products have helped designers and contractors to solve several types of engineering problems where the use of conventional construction materials would be restricted or considerably more expensive. There is a significant number of geosynthetic types and geosynthetic applications in geotechnical and environmental engineering. Due to space limitations, this paper will examine the advances on the use of these materials in reinforcement and in environmental protection. Polymeric reinforcement materials are a subset of a much larger recent development in civil engineering materials: geosynthetics. Geosynthetics are planar products manufactured from polymeric materials (the synthetic) used with soil, rock, or other geotechnical-related material (the geo) as part of a civil engineering project or system. There are few developments that have had such a rapid growth and strong influence on so many aspects of civil engineering practice as geosynthetics. In 1970, there were only five or six geosynthetics available, while today more than 600 different geosynthetic products are sold throughout the world. The size of the market, both in terms of square meters produced and their value, is indicative of their influence. In many cases, the use of a geosynthetic can significantly increase the safety factor, improve performance, and reduce costs in comparison with conventional design and construction alternates. The first part of this paper is an introduction to geosynthetic materials; included are brief descriptions of their types and manufacture, functions and applications, properties and tests, design, selection, and specifications. The second part deals with the use of geosynthetics for soil reinforcement, with specific applications to embankments on soft foundations, steep slopes, and retaining walls and abutments.

Common types of geosynthetics used for soil reinforcement include geotextiles (particularly woven geotextiles), geogrids and geocells. Geotextiles are continuous sheets of woven, nonwoven, knitted or stitch-bonded fibers or yarns. The sheets are flexible and permeable and generally have the appearance of a fabric. Geogrids have a uniformly distributed array of apertures between their longitudinal and transverse elements. These apertures allow direct contact between soil particles on either side of the sheet. Geocells are relatively thick, three-dimensional networks constructed from strips of polymeric sheet. The strips are joined together to form interconnected cells that are infilled with soil and sometimes concrete. In some cases 0.5 m to 1 m wide strips of polyolefin geogrids have been linked together with vertical polymeric rods used to form deep geocell layers called geomattresses.

II. TYPES OF GEOSYNTHETIC

There are many geosynthetics materials available which can be used for different purposes. Few of the geosynthetics materials are as follows:

A. *Geotextiles* : Geotextiles are defined as “any permeable textile used with foundation soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure, or system”. They are typically the most used geosynthetic material for agriculture purposes. These are fabric or cloth-like materials that are classified based on the method used to place the threads or yarns in the fabric: either woven or non-woven. Geotextiles typically come in rolls up to approximately 5.6m (18 ft) wide and 50 to 150m (160 to 500 ft) long [2].

Fig. 1 Example of an geotextile material

i) *Woven*: These cloth-like fabrics are formed by the uniform and regular interweaving of threads or yarns in two directions as shown in Figure 1, below. These products have a regular visible construction pattern, and where present, have distinct and measurable openings. Woven geotextiles are typically used for soil separation, reinforcement, load distribution, filtration, and drainage. They can have high tensile strength and relative low strain or limited elongation under load (typically up to 15%) [9].

Fig. 2 Example of an woven geotextile material

ii)*Non-Woven*: These felt-like fabrics are formed by a random placement of threads in a mat and bonded by heat-bonding, resin-bonding or needle punching. These products do not have any visible thread pattern. Non-woven geotextiles are typically used for soil separation, stabilization, load distribution, and drainage but not for soil reinforcement such as in retaining walls. They have a relatively high strain and stretch considerably under load (about 50%).

Fig. 1 Example of an non woven geotextile material

2).Geogrids and geomesh

Geo-Grids are open grid-like materials of integrally connected polymers. . They are planar polymeric material consisting of regular open network of connected tensile elements with square or rectangular openings. The linkage between the tensile elements can be extrusion, bonding or interlacing. They are used primarily for soil reinforcement. Their strength can be greater than the more common geotextiles. Geogrids have a low strain and stretch only about 2 to 5%. These products protect the soil surface from water and wind erosion while accelerating vegetative development.

Fig. 4 Example of geogrid material

Geogrids are primarily used for reinforcement; they are formed by a regular network of tensile elements with apertures of sufficient size to interlock with surrounding fill material.

3).Geomembranes

Geomembranes are low- permeability geosynthetics used as fluid barriers.

4).Geocomposite

Geotextiles and related products such as nets and grids can be combined with geomembranes and other synthetics to take advantage of the best attributes of each component. These products are called geocomposites, and they may be composites of geotextile-geonets, geotextile-geogrids, geotextile- geomembranes, geomembrane-geonets, geotextile-polymeric cores, and even three- dimensional polymeric cell structures. There is almost no limit to the variety of geocomposites that are possible and useful. The general generic term encompassing all these materials is geosynthetic.

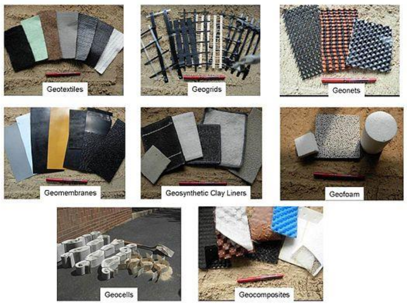

Fig. 5 Example of different types of geotextile material

III. MANUFACTURING OF GEOSYNTHETIC MATERIAL

Most geosynthetics are made from synthetic polymers such as polypropylene, polyester, polyethylene, polyamide, PVC, etc. These materials are highly resistant to biological and chemical degradation. Natural fibers such as cotton, jute, bamboo, etc., could be used as geotextiles and geogrids, especially for temporary applications, but with few exceptions they have not been promoted or researched as widely as polymeric geosynthetics. In manufacturing geotextiles, elements such as fibers or yarns are combined into planar textile structures. The fibers can be continuous filaments, which are very long thin strands of a polymer, or staple fibers, which are short filaments, typically 20 to 100 mm long. The fibers may also be produced by slitting an extruded plastic sheet or film to form thin flat tapes. In both filaments and slit films, the extrusion or drawing process elongates the polymers in the direction of the draw and increases the fiber strength. Geotextile type is determined by the method used to combine the filaments or tapes into the planar textile structure. The vast majority of geotextiles are either woven or nonwoven. Woven geotextiles are made of monofilament, multifilament, or fibrillated yarns, or of slit films and tapes. Although the weaving process is very old, nonwoven textile manufacture is a modem industrial development. Synthetic polymer fibers or filaments are continuously extruded and spun, blown or otherwise laid onto a moving belt. Then the mass of filaments or fibers are either needlepunched, in which the filaments are mechanically entangled by a series of small needles, or heat bonded, in which the fibers are welded together by heat and/or pressure at their points of contact in the nonwoven mass. Stiff geogrids with integral junctions are manufactured by extruding and orienting sheets of polyolefins. Flexible geogrids are made of polyester yarns joined at the crossover points by knitting or weaving, and coated with a polymer. For additional details on the composition, materials, and manufacturing of geosynthetics, see Koerner (1998).

1).Needlepunched, non-wovens geotextiles

Needlepunching is a mechanical process which, rather than using heat, fixes the fibres relative to each other by entanglement. Reciprocating banks of barbed needles compact loose fibre into a labyrinth of interconnected fibres.

The use of continuous filament fibres creates geotextiles with the separation/filtration functions. Using staple, crimped fibres enables the production of thick geotextiles that are suitable for heavy-duty filtration/protection and they also provide the additional function of protection.

Heat-bonded, non-wovens geotextiles

Continuous filament fibres are extruded from spinnerets to form a swirling pattern of fibres across a web. The web passes through a pair of heated rolls or an oven, where the fibres are bonded together to form a uniplanar geotextile. This method generates low-cost products that are used in sub-base/subgrade separation.

2).Geogrids

Three processes are: The first heats and stretches polymer that has been pre-punched with a regular pattern of holes. The second comprises bundles of polymer fibres in a mesh pattern that are coated with bitumen or a PVC (polyvinyl chloride). The third takes sheathed bundles of fibres that are then welded.

3).Woven and knitted geotextiles

Manufactured by weaving or knitting yarns of drawn polymer. These yarns may be flat tape, mono-filament, multi-filament, and fibrilatted (flat tape slit and twisted). The yarn type dictates the properties of the finished geotextile.

4).Geonets

Polymer mesh which is extruded in a tubular form & slit in the machine direction to create a sheet. Essentially a layer of rods overlaying a second layer at an angle. A third layer can be introduced to increase thickness and, thus, flow capacity.

5).Geomembranes

Continuous filament fibres are extruded from spinnerets to form a swirling pattern of fibres across a web. The web passes through a pair of heated rolls or an oven, where the fibres are bonded together to form a uniplanar geotextile. This method generates low-cost products that are used in sub-base/subgrade separation. Polymer sheet that is extruded flat or as a tube to be slit in the machine direction. The textured (roughened) versions are for use on slopes where higher levels of interface friction angles are required.

6).Geocomposites

Heat and/or adhesives are used to create single components by bonding barriers, drains, filters, protectors and reinforcement in different combinations. The objective is to produce materials which are multi-functional and are faster to install than the individual components. Interface friction becomes an issue when geosynthetics are placed on slopes and bonded materials address this potential problem.

IV. FUNCTIONS AND APPLICATIONS

1. Filtration
2. Drainage
3. Separation
4. Reinforcement
5. Fluid barrier, and
6. Protection

Geosynthetics are strong, durable and flexible materials. They do not crack or separate from the soil even if the soil settles and are superior to concrete or metallic material. Geosynthetics are very versatile and can perform many functions and some individual materials can simultaneously perform two or more functions. The applications of the geosynthetics materials in various fields are considered really important. Some of the applications of geosynthetics are discussed as under:

1). Separation

Porous geosynthetics when sandwiched between two soil types with vastly different particle sizes perform the function of keeping them separate and prevent the mixing of particles. For example, when road pavements are constructed, a base course material that is often gravel sized is placed directly on the subgrade soil. If the subgrade is soft clay, the gravel will tend to penetrate into subgrade soil under traffic load resulting in a mixed soil [3]. The performance of the base course deteriorates with time due to mixing. This can be prevented by placing geosynthetics at the interface between the subgrade and the base course. It prevents mixing and results in improved pavement performance.

2) Filtration Porous geosynthetics, when located in between two soil layers, one fine grained and the other coarse grained, through which water is flowing, perform the function of a transition filter [6]. They allow water to pass through them without passage of fine particle of soil along with the water. Geosynthetics can be used in place of transition filters of soil, if suitable soil is not available near the construction site.

3). Drainage

Porous geosynthetics with high in-plane permeability perform the functions of drains where these are placed within a soil mass to intercept seeping water and carry it rapidly along the in-plane direction without migration of fine particles.

4). Reinforcement Geosynthetics with high tensile strength perform the function of reinforcement in a soil mass when these are placed in single or multi layers to improve the engineering behaviour of the soil mass. Soil by itself behaves well under compression but is poor in tension and the performance of the soil is enhanced by the tension carrying capacity of geosynthetics. This improves the bearing capacity of soft soil, enhances stability of steep slopes and reduce earth pressure behind retaining structures.

5). Hydraulic Barriers

Geosynthetics that are impermeable in the cross-plane and in-plane directions perform the function of hydraulic barriers when placed in a soil mass by preventing seepage of water through the soil mass. Seepage of water from canals can be controlled by placing a geomembrane at the base and along the sides of the canal.

6). Surface Erosion Control

Geosynthetics can be used for temporary or permanent erosion control measures along side slopes. Temporary erosion control geosynthetics comprise of natural biodegradable fibers such as jute . They are spread on the slope in the form of grids or mats and they prevent erosion until vegetative growth occurs and later degrade. Permanent erosion control geosynthetics are porous synthetic polymeric products that furnish erosion control, aid vegetative growth and become entangled with the vegetation to provide reinforcement to the root system.

7). Protection

Geosynthetics are used to prevent an under laying layer from damage that may occur due to presence of angular material such as gravel and stones above the layer.

V.GEOSYNTHETICS PROPERTIES AND TESTS

Introduction Because of the wide variety of products available, with different polymers, filaments, weaving patterns or bonding mechanisms, thickness, mass, etc., geosynthetics have a considerable range of physical and mechanical properties. A further complicating factor is the variability of some properties, even within the same manufactured lot or roll; also, some differences may be due to the test procedures themselves. Thus, determination of the design properties is not necessarily easy, although geosynthetic testing has progressed significantly in the past 20 yr. Standard procedures for testing geosynthetics have been developed by ASTM and other standards development organizations throughout the world, particularly in Europe, Japan, and Australia. The design properties required for a design will depend on the specific application and the associated function(s) the geosynthetic is supposed to provide. Geosynthetic properties can be classified as (1) general, (2) index, and (3) performance properties. See Holtz et al. (1997) for a listing of the various properties under these categories, while Koerner and Hsuan (2001) describe test methods for the various geosynthetics properties, including those appropriate for geomembranes and other products used for waste containment.

1) General and Index Properties and Tests

General properties include the polymer, mass per unit area, thickness, roll dimensions and weight, specific gravity, etc. Index tests do not give an actual design property in most cases, but they do provide a qualitative assessment of the property of interest. When determined using standard test procedures, index test values can be used for product comparison, specifications, quality control purposes, and as an indicator of how the product might survive the construction process. These latter properties are called constructability or survivability properties. Index tests include uniaxial mechanical strength (grab tensile; load-strain; creep, tear, and seam strength); multiaxial rupture strength (puncture, burst, and cutting resistance; flexibility); endurance or durability tests (abrasion resistance; UV stability; chemical and biological resistance; wet-dry and temperature stability); and hydraulic index tests (apparent opening size, percent open area; pore size distribution; porosity; permeability and permittivity; transmissivity).

2) Performance Properties and Tests

Performance properties require testing the geosynthetic and the soil together in order to obtain a direct assessment of the property of interest. Because performance tests should be conducted under design specific conditions and with soil samples from the site, these tests must be performed under the direction of the design engineer. Performance tests are not normally used in specifications; rather, geosynthetics should be preselected for performance testing based on index values, or performance test results should be correlated to index values for use in specifications. Examples of performance tests include in-soil stress-strain, creep, friction/adhesion, and dynamic tests; puncture; chemical resistance; and filtration or clogging resistance tests.

3)Other properties for consideration

Whilst most geosynthetics are manufactured from polymers, which are relatively inert materials, some are more susceptible to chemical, biological or mechanical damage than others. Durability must be considered for both installation and in service. To quote a leading consultant "a layer of cling film has a lower permeability than a metre of compacted clay". Areas to consider are:

*i)UV resistance :*The performance of most polymers is degraded, to different extents, by ultra violet light (UV). The polymer bonds breakdown and this can result in a loss in properties. If geosynthetics are to be exposed for more than 30 days in the UK, it is recommended that they should contain a well-dispersed UV inhibitor that protects the polymer chains. Carbon black is the most cost-effective agent for these purposes. Specifications should therefore include an accurate description of the type of UV protection and the concentration by weight - 1% is typical. This should be the concentration of the carbon black and not the weight of carbon black dispersion that is added to the polymer. Carbon black comprises very fine particles that are difficult to handle. It is normal to mix the particles with a carrier to make a dispersion that is easier to handle. So, 2.5% by weight of the dispersion could be added but this equates to 1% carbon black.

ii)Chemical and biological resistance : Some geosynthetics are used in aggressive environments such as in the containment of landfills and contaminated land. As the rate of chemical attack relates directly to the surface area available it is important for Engineers to request proof of stability with the specific chemicals present. This information, generated by the polymer manufacturers, should be available from the geosynthetic manufacturer. In some instances it may be necessary to carry out a specific immersion test at elevated temperatures using the actual mix of chemicals.

iii)Fire resistance : Geosynthetics are used in applications where they are accessible by the public (e.g. rock face cladding) and in applications such as tunnel linings, where flammability can be a consideration. There are specific tests to measure flammability. There are inflammable polymers and others that can by made inflammable, to varying degrees, by the inclusion of additives.

iv)Mechanical damage resistanc: The rigours of installation can often be more demanding than the ultimate in-service requirements. Site damage tests can be specified such as rock drop tests for coastal applications. Laboratory tests have been developed to closely simulate in-service conditions. One of these is the Cylinder test that evaluates the performance of geotextile protector, liner and drainage aggregate combinations.

v)Toxicity: Geosynthetics are frequently used where surface or ground water regulations apply. Evidence must be provided to confirm that no materials will migrate or be extracted from the geosynthetic. Alternatively, that the nature or the levels of any extracts do no present a risk to the environment.

VI. CONCLUSIONS

This paper presented recent advances in geosynthetic products, on the utilization of these materials in reinforced soil structures and in environmental applications. Therefore, the expectation is that innovations in products, types and properties will continue to take place, adding to the already vast range of applications of these materials.This type of structure can be cost- effective not only under static loading but also in regions where significant seismic activities are expected. New construction methodologies have also broaden the applications of geosynthetic reinforced soil retaining wall, which include new facing units and that reduces the construction time, costs and allow better aesthetic conditions for the final structure. This method is a significant advance on existing design approaches and will allow the construction of cheaper structures. The use of geosynthetics has also led to major advances in environmental applications.

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