PROPERTIES OF GEOTEXTILES
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1.0 Introduction

Geotextiles can be simply defined as "a textile material used in a soil (geo)environment" and include woven and non-woven polymeric materials and natural materials, such as jute, manufactured using textile processes.

Polymers
Geotextiles are usually made from one of the four synthetic polymers: polyamide, polyester, polyethylene, and polypropylene or natural materials.

Polyamide: also known as Nylon 6 and Nylon 6.6. The production process and the material properties are influenced by the use of various additives such as (a) viscosity stabilisers which control the degree of polymerisation during processing; b) ageing inhibitors which protect the polymer against ageing due to light or thermo-oxidation; and c) colouring, i.e. carbon black, which also has the advantage of increasing the stability of polyamides.

Polyester: additives used in the production of polyester are a) catalysts which increase the speed of polymerisation; b) phosphatic compounds which reduce thermal degradation during processing in the molten stage; and c) ageing inhibitors (including carbon black) which increase the U.V.-resistance.

Polyethylene: two main groups of polyethylene can be identified:

i) low density polyethylene (density 920-930 kg/m$^3$)
ii) high density polyethylene (density 940-960 kg/m$^3$)

Low density polyethylene is produced at high pressures (up to 300 MN/m$^2$), whereas high density polyethylenes are produced at low pressures (4MN/m$^2$) and low temperatures. The processes for the production of high density polyethylene are initiated by special catalysts. The physical properties of polyethylene are mainly determined by its crystallinity. Crystallisation can occur better when the degree of branching is lower. The branching accounts for the differences in physical properties between the different grades of polyethylene. Due to its lower degree of branching high density polyethylene is more rigid, stronger, tougher and has a better chemical resistance than the low density types. Better end-use properties are achieved using additives which improve thermal stabilisation and resistance to oxidation and UV attack. The addition of carbon blacks (about 2%) can result in an optimum improvement.

Polypropylene: The polymerisation of propylene monomers in the presence of specific catalyst produces the crystalline thermoplastic polypropylene. It is very susceptible to oxidation and additives are required to protect against ageing. Other additives are also used to improve thermal stabilisation, UV resistance and underwater resistance.

Natural materials, such as jute, cotton, rayons etc., are used to manufacture bio-degradable geotextiles for temporary or specific applications.
Types of Geotextile

Woven Geotextiles:
These are developed from synthetic or natural fibres using weaving techniques. The weaving process gives these geotextiles an appearance of two sets of parallel threads interlaced at right angles. "warp" runs along the length of the loom and "weft" runs in the transverse direction across the loom. The yarn used to produce a woven geotextile may be monofilament or multifilament or a combination of each type. However, slit film tapes have recently become the most common form of yarn used in the manufacture of woven geotextiles. The yarn in the warp direction has to withstand the action of the loom's reeds continually pulling and pushing it apart to make way for the shuttle which pulls the weft yarn through. As a consequence it is usual for a slightly stronger yarn to be selected for the warp direction.

Non-woven Geotextiles:
These are formed from filaments or fibres arranged at random and bonded together into a planar structure. The filaments or fibres are first arranged into a loose web, then bonded together.

Thermal Bonding:
These geotextiles are produced by spraying continuous polymer filaments on to a moving belt which is then passed through heated rollers. These rollers compress the layers of loose filaments and cause partial melting of the polymer, leading to thermal bonding of the filament cross-over points. Thermally bonded geotextiles tend to be relatively thin. The random distribution of the filaments results in a wider range of opening sizes than is found in a woven geotextile. The absence of any preformed orientation of the filaments results in a more isotropic strength compared to wovens.

Mechanical Bonding:
These geotextiles are formed by introducing a fibrous web into a machine equipped with groups of specially designed needles. While the web is trapped between plates, the needles punch through it and re-orientate the fibres so that mechanical bonding is achieved among the individual fibres. In some cases, the needles may also vibrate or rotate to speed up the entanglement. This process produces fabrics which have a high density, considerable bulk, and thick.

Chemical Bonding:
This is the least common method for forming non-woven geotextiles. They are produced by spraying polymer filaments on to a moving conveyor and then spraying or impregnating an acrylic resin on to or into the fibrous web. After curing or rolling, strong bonds are formed between the filaments. Often a forced-air drying operation is required to establish the fabrics open pore structure.
2.0 Functions

Four basic functions of geotextile are: Separation, Filtration, Drainage & Reinforcement. These functions may be combined for specific applications, and may be sub-divided into primary and secondary function.

Separation
A geotextile placed between a fine soil and a coarse material to prevents the two materials from mixing. With the introduction of this barrier the dissimilar materials are each able to function properly.

Filtration
A geotextile placed in contact with a soil, it allows water to pass through while preventing the passage of soil particles. Both adequate permeability (permittivity) and soil retention are required simultaneously over the design life of such application.

Drainage
A geotextile collects a liquid and conveys it towards an outlet. All fabrics can provide such a function, but a thin woven fabric obviously has less capacity than a thick needle punched non-woven. However, the capacity of fabrics is limited and geocomposite drains have been developed to provide increased capacity. The flow of water into the drain is controlled by the geotextile which must also perform a filter function to prevent loss of capacity due to soil entry into the drain. This drainage-in-the-plane is termed transmittivity as contrast to permittivity for filtration.

Reinforcement
A geotextile used to improve the mechanical properties of an earth structure by interacting with soil through interface shear.

3.0 Index testing

Index tests on parent materials are used for identification, quality control, comparison of manufacturers' products, some design consideration and specification writing. As the tests are being carried out on polymeric materials it is important that the test conditions are controlled to ensure consistent results. Particularly important are relative humidity and ambient temperature of the testing laboratory, duration of the test and test conditions.

Physical Properties

Mass/Unit Area: The mass per unit area is determined by cutting from a roll a minimum of 10 specimens, each at least 100 mm square, and then weighing the specimens on an accurate balance. This simple test is frequently used for quality control and can help identify the material. It is an important property to measure as fabric cost is directly related to mass/unit area.
Nominal Thickness/Dimensions: The nominal thickness is determined by placing a sample of the geotextile on a plane reference plate and applying a pressure of 2 kN/m² through a circular pressure plate with a cross-sectional area of 2500 mm². A vernier gauge measures the distance between the reference plate and pressure plate. The test is useful for quality control and classification of geotextiles.

Apparent Pore Size Distribution by Dry Sieving: The pore size distribution of the fabric is determined by sieving dry spherical solid glass beads for a specified time at a specified frequency of vibration and then measuring the amount retained by the fabric sample. The test is carried out on a range of sizes of glass beads. The apparent pore size distribution is presented on a graph using scales compatible with soil grading curves. In addition, the apparent opening size ($O_{90}$) is determined, this being the pore size at which 90% of the glass beads are retained on and within the fabric. This test provides information on the pore size distribution which is an important parameter to be used in assessing a geotextile's soil filtration capability.

Percent Open Area Determination for Woven Geotextiles: A small section of the fabric is held within a standard slide cover, inserted into a projector and the magnified image traced on to a sheet of paper. Using a planimeter, the magnified open spaces can be measured and expressed as a percentage of whole area. The test is primarily applicable to monofilament woven fabrics. The test provides information on pore size openings which is important in assessing a geotextile's soil filtration capability.

Mechanical Properties

Tensile Properties Using a Wide Width Strip: A specimen of the geotextile, at least 200 mm wide, is clamped within the compressive jaws of a tensile testing machine which is capable of applying the load at a constant rate of strain. During loading, a load-strain curve is plotted and, from this, the maximum load, breaking load and the secant modulus at any specified strain may be determined.

The tensile strength of geotextiles and related materials is a very important property as virtually all applications rely on it either as the primary or secondary function. This test is useful for quality control and can also be used for design purposes.

Puncture Strength of Geotextiles: A specimen of the fabric is clamped, without tension, over an empty cylinder, and a solid steel rod is pushed through the fabric. A load indicator attached to the rod measures the force required to cause rupture. A CBR(soil) testing apparatus may be modified for this purpose.

This is a common test used for quality control. The results of this test can also be used to assess the fabric's resistance to aggregate penetration, particularly in separation applications.
Soil-Fabric Friction Tests: This is an adaptation of the direct shear test, in that the fabric is firmly fixed to the top half of the shear box and a standard laboratory soil is used in the bottom half. The force required to cause sliding between the fabric and soil is determined for different normal stresses and the shear strength parameters are obtained.

The test is useful for quality control and may be used to compare different geotextiles. It is not a suitable test for assessing the parameters to be used for the analysis for reinforced soil. For reinforced soil applications the proposed fill material should be used in the test.

Hydraulic Properties

Water Permeability of Geotextiles-Permittivity Method: This test measures the quantity of water which can pass through a geotextile (normal to the plane) in an isolated condition. The permeability may be measured either in a constant head or falling head test, although constant head testing is more common due to the high flow rates through geotextiles. Since there are geotextiles of various thicknesses available it is better to evaluate them in terms of permittivity, which relates the quantity of water passing through a geotextile under a given head over a particular cross-sectional area.

This test is useful in classifying geotextiles and for comparing the in-isolation water permeability of geotextiles. However, in drainage and filtration applications, the influence of in-soil confinement should be established prior to selecting a geotextile.

Constant Head Hydraulic Transmissivity: This method may be used to estimate the in-plane permeability of a geotextile or a composite drain. The sample is confined, at varying normal stresses, and the flow under a constant head is measured.

This test is useful for classifying geotextiles and geocomposite drains and will provide information to allow comparisons of in-plane permeability to be made. However, in drainage applications, the influence of in-soil confinement should be established.

4.0 International Testing Standards for Geotextiles

British Standards (BS), European Norm (EN), International Standards Organisation (ISO) and American Society of Testing Materials (ASTM) all provide testing methods for geotextiles and related products. Some of these test methods with respect to the tests discussed in the previous section are given for reference as follows. (cross references for different standards are given in the bracket).

British Standards


American Society of Testing Materials


ASTM D4533: 1991: Trapezoidal tearing strength of geotextiles


ASTM D4632 : 1991: Grab breaking load and elongation of geotextiles


ASTM D5261:1992: Determination of mass per unit area (BSEN965, ISO 9864)

Others

BSEN963: Sampling and preparation of test specimens

BSEN964: Determination of thickness at specified pressures


BSEN30320: Geotextiles - Identification on site (ISO 10320:1991)

BSENISO 10321:1992: Tensile test for joints/seams by wide-width method