ACTA SCIENTIFIC AGRICULTURE (ISSN: 2581-365X)

Volume 3 Issue 5 May 2019

Review Article

# Studies on the Characteristics of the Type of Geotextiles

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**Received:** February 15, 2019; **Published:** April 18, 2019

## Abstract

The development of earth science and wider need for more resistant materials in civil engineering projects have pushed engineers and researchers to use artificial and more durable materials named "geosynthetic". This material is made of rubber and plastic and due to its wide application in various projects and the speed of its implementation and its suitable price, its production and consumption is growing rapidly. Therefore, the importance of research on the behavior, characteristics and the application of this new product increases day by day. Geosynthetics are categorized according to their properties and characteristics. In this research, one of the categories under the title "Geotextiles" and its types and basic applications are studied. Geotextiles are commonly referred to as fabric filters. The results of studying the properties of any woven and unwoven geotextile shows that these materials have different characteristics such as fast performance, easy use, low weight, high tensile strength, low cost, long lasting, less environmental degradation, uniformity In its implementation and its other features. According to the mentioned features it can be concluded that geotextiles can be used as an alternative to traditional methods in drainage and separation of soil texture.

**Keywords:** Nonwovens; Flexible; Geotextile; Fiber Reinforced; Mechanical Properties; Low Cost

## Introduction

One of the most important humans concerns up to now has been the consolidation and Reinforcement of the soil and increasing the performance and efficiency of structures. So, in the ancient centuries tree logs, shrubs, rocks, and so on have been used for this purpose.

With developing of durable and reliable artificial materials over the past 50 years, there has been an effective progress in the world of industry, and the introduction of a special type of these materials that are called geosynthetics has had a considerable impact on engineering progress.

The most important member of this group are geotextile stretch fibers and geomembranes which play an important role in various fields of engineering and soil mechanics and even in road construction by upgrading soil cover on safe structures. As it increases the vulnerability of the structure against explosions and makes it safe and impervious versus water flowing as well [6].

In the 1970s there were no more than 5 or 6 geotextile types. But today, more than 250 different substances are produced under this name. Geotextile filters have been used for more than 50 years and are currently used extensively in many parts of the world [1]. The present study has tried to use the most famous sources and the most recent researches in the topic to investigate the geotextile characteristics and its types and the basic applications of each one.

Figure 1 shows different usages of geosynthetics in landfill design.

**Figure 1:** Different uses of geosynthetics in landfill design.

## Geotextile history

The usage of geotextiles dates back to thousands of years ago, which controlled soil erosion at the time of ancient Romans and was used when the desired soil was unstable to build the road [3]. The first recorded usage of geotextile was on the road which was undertaken by the Department of South Carolina Highways in 1926. In this project, a heavy cotton geotextile was loaded onto the soil. And then the hot asphalt was applied to the fabric then a thin layer of sand was poured on the asphalt. Research has shown that this fabric has reduced cracking and has prevented the road from breaking down [6].

The usage of geotextile has been successful for the past two decades and it has grown rapidly, due to its excellent performance in structural applications, especially on the roads.

Today, the world is witnessing thousands of projects where geotextile are used and thousands of companies and factories are active in the production and installation of geotextiles throughout Europe, America, Africa and Asia, especially East Asia.

In figure 2 a geotextiles is used to separate the two layers.

**Figure 2:** Separation function of a geotextile placed between road aggregate and soft saturated subgrade. (a)Without geotextile and (b) with geotextile.

The separation property is a feature that, along with properties such as flexibility and porosity, refers to the ability to locate geosynthetics products between two unmatched materials [1].

For example, the main cause of road rupture is the injection of adjacent layers into the pebble and the consequently the decline in the strength of the pebble layer (Figure 2a). When the pebble is placed on the subgrade layer, the underlying layer is mixed by soil and, over time, the traffic and vibration load, injects the Aggregate layer into the soil, causing the layer to move upwards. Also, in wet places, the traffic causes the weak subgrade soil to pump into the pebbles and all of these conditions reduce the effective thickness of the pebble layer; As a result, the protective layer of the road is damaged and the useful life of the road decreases, which can be protected by placing a geotextile on a pebble layer under the subgrade layer.

## Properties and characteristics of natural geotextiles

As mentioned in the previous section, geotextiles are originally used as natural textiles. These textiles are usually used to control soil erosion, mainly due to the above mentioned properties, as the most appropriate temporary solution.

Some types of famous geotextiles are Coirmat (woven from coconut fiber), Jutmesh (woven from china fibers), Green furee (a combination of biodegradable and non-biodegradable fibers), RECP (rolled erison control product), Coirlog (coconut fiber bag tissue), Environmat (spruce wood fiber) [7].

Figure 3 is a sample of natural woven geotextile made from coconut fiber.

**Figure 3:** A sample of natural woven geotextile made from coconut fiber.

## Properties and characteristics of artificial geotextiles

Synthetic fibers were produced, instead of textiles and natural fibers mentioned in recent decades which has properties like granular materials and in terms of mechanical and chemical resistance are at a higher level.

These fibers are made from crude oil derivatives and its main property is the incorruptibility in contrast of soil degradation factors.

Geotextile materials are placed on or in soil to do one of four things:

- Separation/confinement/distribute loads
  - Improve level-grade soil situations such as roads, alleys, lane ways
  - Improve sloped-grade situations such as banks, hillsides, stream access points
- Reinforce soil
  - Soil walls, bridge abutments, box culverts/bridges, and soil arches
- Prevent soil movement while letting water move through the material
  - Such as in drainage systems and back fill around water intakes
- Controlling water pressure allowing flow in the plane of the material
  - Such as on foundation walls to allow water to move down to perimeter drains

With and without a geotextile

Geotextiles act as a separation barrier between fine grain soils and load distributing aggregate fill
Separation

Geotextiles provide a high friction surface between the subgrade and the aggregate helping keep the aggregate in place
Confinement

Geotextiles, with their high tensile strength and modulus, act to reduce localized stress by redistributing traffic loads over a wider area of subgrade
Load Distribution

**Figure 4:** The main Geotextile characteristics.

## Synthetic fiber materials for geotextiles

Due to previous studies, this type of fiber has different types and the most important ones are polymer fibers. Polymer textiles have diverse applications in the building and hydraulic industry. Such as asphalt pavement, road engineering, railing bed, dockside and damping, retaining wall, shore protection, pipeline, drainage and filtering, backside protection, Artificial Grass, tunnel, environmental protection, water and sewage, creating artificial lakes and etc. and small groups of geotextile is made from fibers that are used in controlling soil erosion [6].

**Figure 5a and 5b:** 5a: Non-woven geotextiles, 5b: Woven geotextiles.

Synthetic fibers According to Woven Geotextile or non-woven (non-woven geotextile), have various quality control indicators. For the "woven synthetic fiber group" the elasticity modulus, stress - strain properties, uniaxial or biaxial tensile strength, fine particles non-passing through voids, tear resistance, UV resistance could be mentioned. And for "non-woven synthetic fibers" water absorption and water absorption properties, The absence of fine particulate matter from the pores, the amount of fluid permeability, the durability against impact, the durability against tearing, the amount of absorption of bitumen (in particular applications), thermal durability (in Specific use) can be noted [6].

The effective factors for providing standard filtration in geotextiles is the choice of suitable cavity size and proper formation of the soil filter bridge. Given that the flow of fluid through the geotextiles increases, but if this size is larger than a limit Certainly, it leads to a piping event in the soil in which, along with the flow of fluid, the soil particles also pass through the geotextiles and cause the structure to collapse (Figure 6) [1].

**Figure 6:** Geotextile providing adequate filtration through selection of adequate opening size and formation of soil filter bridge.

Several methods have been proposed for the design of soil layers using geotextile, in which most of the properties of soil particles are compared with the size of the opening of 95% geotextile (defined as O95 in geotextile) [1]. Given that the average use of geotextiles for soil particle maintenance is essential, the geotextile size should be obtained by using the ASTM D4751, which represents the largest open dimensions available for soil to cross.

## Types of polymer fibers used in geotextiles

Polymer fibers have different types such as propylene, polyester, polyethylene, polyamid and other items. Polyethylene is the first and oldest polymer used in the production of geotextiles, which was discovered in 1931 in the ICI laboratory.

After this polymer, polyamide has the highest record. It has been used since 1935. Gradually, polypropylene was also recognized as the primary ingredient in this industry. But polyester was in competition with polypropylene and since 1954 it plays a major role in making geotextiles.

In this research, we have tried to summarize and conclude previous experiments and studies comparing polymer properties in geotextile layers against different types of resistors in table 1. Geotextile fiber groups are divided into different polymers as the following:

| Type of Resistance | Polyester | Polyamide | Polypropylene | Polyethylene |
|---|---|---|---|---|
| Tensile Strength | H | M | L | L |
| Modulus of Elasticity | H | M | L | L |
| Strain | M | M | M | M |
| Creep | L | M | H | H |
| Unit weight of the surface | H | M | L | L |
| Ultraviolet light resistance | H | M | H | H |

**Table 1:** Comparing polymer properties in geotextile layers against different types of resistors (L: Low, M: Medium, H: High).

- Polypropylene (PP) 92% of geotextiles
- Polyester (PET) 5% of geotextiles
- Polyethylene (PE) 2% of geotextiles
- Polyamide (Nylon) 1% of geotextiles.

There are other powerful polymers in the market, but geotextiles are produced at higher volumes (some polymers are not available in large volumes) and are economical (very specific polymers are very expensive). Among the polymers listed in table 1, the cost versus performance of polyester is today more optimal, while polypropylene and polyethylene have more chemical resistance.

Due to previous research, the first standard for geotextile tests under hit loads is conducted by the Federal Waterways Engineering and Research center of Germany [4].

The test apparatus in BAW's guidelines is composed of a box with horizontal dimensions of 80 × 80 cm and depth of 31 cm filled with compacted sand which the geosynthetic on top of it. The geosynthetic is fixed at the periphery of the sand bed. Once woven geotextiles are tested, it is advised to place a thick rubber sheeting on top of the geotextile prior to clamping to provide a better grip and restrain of the geotextile. Above the geotextile, there is a central rammer sleeve in which a 76 kg rammer with specific edge-cut. The drop should be performed at prescribed energy levels. After the drop is made, the geotextile is taken out for visual examinations. According to BAW's recommendation, any visual damage, which reduces the filtration capability of the geosynthetic must be regarded as a damage.

Also, in a comprehensive study, Wang., *et al.* [5] used the results of 784 drop tests using standard block to determine the main parameters for the stability of geotextiles.

The Drop heights in the tests were 0.5 and 2.5m and two woven and three non-woven geotextiles were included in the testing program. The geotextiles were laid on different types of soils with different layer thicknesses and the effects of both horizontal and sloping grounds were considered. They reported that existing index tests such as the CBR test and tensile strength tests do not properly represent an index for the survivability of the geotextile. Instead, the survivability of a geotextile corresponds to the level of energy that a geotextile can absorb under impact loading.

From the group of polymeric fibers, due to the spectacular role of propylene and polyester in geotextile, we have tried to use the DIN and ASTM standard tests as follows, the technical specifications for these two types of fibers, in the unwoven state Which contains 2 samples with different propylene 200 and 400 in normal and heat conditions, and 2 samples with different amounts of polyester 200 and 400 in normal and heat conditions are considered and are defined as follows.

### ASTM D4632 Geotextile Grab Test

His grab test is used for geotextile fabrics to determine the breaking load (grab strength) and elongation (grab elongation). The grab test is a tensile test where the central part of the specimen's width is tested in the grips, establishing the "effective strength" of the fabric. The effective strength is the strength of the material in a specific width, together with the additional strength of adjacent material.

The specimens are cut to 101.6 mm x 203.2 mm (4 in x 8 in), with attention to the fabrication machine direction. The specimen is loaded into the grips leaving a 75 mm (3 in) separation between the jaw faces, and jaw faces must be 25.4 mm x 50.8 mm (1 in x 2 in) with the longer dimension being parallel to the direction of the load. The test speed is 300 mm/min (12 in/min). The required test results are load at break and total elongation.

Geotextile materials tend to have coatings that may make it difficult to test without slippage or jaw breaks. Instron's pneumatic side acting grips provide an easy, repeatable, high throughput gripping solution. Pneumatic grips allow the user to adjust grip clamping pressure, while the performance of manually operated grips will vary depending on the operator.

| | |
|---|---|
| DIN EN 29073/1 | Determination of mass per unit area |
| DIN EN 29073/2 | Determination of thickness |
| DIN EN 29073/3 | Determination of tensile strength and elongation |
| EN 918 | Dynamic perforation test |
| DIN EN ISO12956 | Determination of the characteristic opening size |
| ASTM D4355 | Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus |
| DIN EN ISO12956 | Determination of the characteristic opening size |
| DIN EN ISO11058 | Determination of water permeability characteristics normal to the plane, without load |
| ASTM D 4632 | Standard Test Method for Grab Breaking Load and Elongation of Geotextiles |
| ASTM D 4833 | Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products |

**Table 2:** Tests based on DIN and ASTM standards.

| 400pp | 200pp | Test Method | Unit | Characteristics |
|---|---|---|---|---|
| 400 | 200 | DIN EN 29073/1 | $g/m^2$ | Volume per unit area |
| 4 | 2.6 | DIN EN 29073/2 | mm | Thickness |
| 69 | 50 | DIN EN 29073/3 | KN/m | Maximum elongation |
| 69 | 53.5 | DIN EN 29073/3 | KN/m | Maximum transverse stretch |
| 60 | 60 | DIN EN 29073/3 | % | Maximum elongation |
| 55 | 55 | DIN EN 29073/3 | % | Maximum transverse stretch |
| 5 | 15 | EN 918 | mm | Drop amount for conical hole size |
| 5.3 | 3.8 | DIN EN ISO12956 | KN/m | CBR Strength |
| 80 | 80 | ASTM D4355 | % | Resistance to UV rays in 500 hours |
| 42 | 93 | DIN EN ISO12956 | um | Initial size |
| 2 | 2 | DIN EN ISO11058 | $10^{-3}$ m/s | Water permeability vertically |
| 2263 | 1703 | ASTM D 4632 | N | Expandable force and Tethering |
| 2263 | 1703 | ASTM D 4632 | N | Extensible force elasticity transverse |
| 57 | 65 | ASTM D 4632 | % | Expandable force and Tethering |
| 60 | 70 | ASTM D 4632 | % | Extensible force elasticity transverse |
| 753 | 473 | ASTM D 7833 | N | Index of compression and resistance |

**Table 3:** Technical specifications of non-woven heat-sealed geotextile with propylene fiber.

| 400pp | 200pp | Test Method | Unit | Characteristics |
|---|---|---|---|---|
| 400 | 200 | DIN EN 29073/1 | $g/m^2$ | Volume per unit area |
| 4 | 2.6 | DIN EN 29073/2 | mm | Thickness |
| 30 | 13 | DIN EN 29073/3 | KN/m | Maximum elongation |
| 30 | 14.5 | DIN EN 29073/3 | KN/m | Maximum transverse stretch |
| 54 | 53 | DIN EN 29073/3 | % | Maximum elongation |
| 51 | 51 | DIN EN 29073/3 | % | Maximum transverse stretch |
| 6 | 17 | EN 918 | mm | Drop amount for conical hole size |
| 4.1 | 2.5 | DIN EN ISO12956 | KN/m | CBR Strength |
| 70 | 70 | ASTM D4355 | % | Resistance to UV rays in 500 hours |
| 42 | 90 | DIN EN ISO12956 | um | Initial size |
| 2 | 2 | DIN EN ISO11058 | $10^{-3}$ m/s | Water permeability vertically |
| 1395 | 835 | ASTM D 4632 | N | Expandable force and Tethering |
| 1395 | 835 | ASTM D 4632 | N | Extensible force elasticity transverse |
| 44 | 50 | ASTM D 4632 | % | Expandable force and Tethering |
| 45 | 52 | ASTM D 4632 | % | Extensible force elasticity transverse |
| 685 | 381 | ASTM D 4833 | N | Index of compression and resistance |

**Table 4:** Specifications of non-woven geotextile with propylene.

| 400pp | 200pp | Test Method | Unit | Characteristics |
|---|---|---|---|---|
| 400 | 200 | DIN EN 29073/1 | $g/m^2$ | Volume per unit area |
| 4 | 2.6 | DIN EN 29073/2 | mm | Thickness |
| 66 | 47 | DIN EN 29073/3 | KN/m | Maximum elongation |
| 66 | 55.5 | DIN EN 29073/3 | KN/m | Maximum transverse stretch |
| 60 | 60 | DIN EN 29073/3 | % | Maximum elongation |
| 55 | 55 | DIN EN 29073/3 | % | Maximum transverse stretch |
| 8 | 18 | EN 918 | mm | Drop amount for conical hole size |
| 5 | 3.5 | DIN EN ISO12956 | KN/m | CBR Strength |
| 42 | 93 | DIN EN ISO12956 | um | Initial size |
| 2.4 | 2.4 | DIN EN ISO11058 | $10^{-3}$ m/s | Water permeability vertically |
| 2260 | 1700 | ASTM D 4632 | N | Expandable force and Tethering |
| 2260 | 1700 | ASTM D 4632 | N | Extensible force elasticity transverse |
| 54 | 62 | ASTM D 4632 | % | Expandable force and Tethering |
| 57 | 67 | ASTM D 4632 | % | Extensible force elasticity transverse |
| 750 | 470 | ASTM D 4833 | N | Index of compression and resistance |

**Table 5:** Technical specifications of non-woven heat-sealed geotextile with polyester fiber

| 400pp | 200pp | Test Method | Unit | Characteristics |
|---|---|---|---|---|
| 400 | 200 | DIN EN 29073/1 | $g/m^2$ | Volume per unit area |
| 4 | 2.6 | DIN EN 29073/2 | mm | Thickness |
| 26 | 11 | DIN EN 29073/3 | KN/m | Maximum elongation |
| 26 | 10.5 | DIN EN 29073/3 | KN/m | Maximum transverse stretch |
| 55 | 55 | DIN EN 29073/3 | % | Maximum elongation |
| 50 | 50 | DIN EN 29073/3 | % | Maximum transverse stretch |
| 9 | 20 | EN 918 | mm | Drop amount for conical hole size |
| 4.1 | 2.5 | DIN EN ISO12956 | KN/m | CBR Strength |
| 42 | 93 | DIN EN ISO12956 | um | Initial size |
| 2.4 | 2.4 | DIN EN ISO11058 | $10^{-3}$ m/s | Water permeability vertically |
| 1380 | 820 | ASTM D 4632 | N | Expandable force and Tethering |
| 1380 | 820 | ASTM D 4632 | N | Extensible force elasticity transverse |
| 43 | 52 | ASTM D 4632 | % | Expandable force and Tethering |
| 47 | 56 | ASTM D 4632 | % | Extensible force elasticity transverse |
| 720 | 370 | ASTM D 4833 | N | Index of compression and resistance |

**Table 6:** Technical specifications of non-woven geotextile with polyester fiber.

Figure 7: Geotextile grab test machine.

## Conclusion

According to results the followings could be concluded:

- In terms of heat, non-woven propylene fibers and non-woven polyester fibers can tolerate longer longitudinal and transverse elongation, and in general, non-woven propylene fibers have greater dimensional stability than non-woven polyester fibers in thermal conditions (Figure 8 and 9).
- As the thickness of the propylene increases, the puncture resistance also increases. Also, this value shows a higher resistance to puncture in heat-bonded conditions (Figure 10).
- By increasing the volume per unit area, the amount of drop for the conical hole size, which is measured according to the EN918 standard, is reduced by the filtration property (Figure 11).

**Figure 8:** Comparing the longitudinal and transverse elongation due to Volume per unit area.

**Figure 9:** Comparing the maximum transverse due to Volume per unit area.

**Figure 10:** Comparing the CBR strength (puncture) due to thickness.

**Figure 11:** Comparing the amount of drop for the conical hole size due to volume per unit

- Also, according to the experiments, heat-bounded propylene and heat-bounded polyester it can be concluded that in propylene the water permeability is less vertical and the perforation resistance is lower, but the elasticity and flexibility are higher so in heat-bounded propylene the non-woven produced fiber can form inside the mold easier.
- On the other hand, higher strength and higher erosion resistance of polyester are also used in cases where the fibers are more exposed to erosion.
- Due to its properties, geotextiles have been used as a suitable substitute for grading filters and have played an effective role in drainage, filtration, separation, and weaponry.

- By comparing the properties of polymeric fibers, it can be concluded that the thickness of the geotextile layer is much smaller than the grain aggregate layer, and this is economically and operationally important.

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**Volume 3 Issue 5 May 2019**