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# Polymeric Synthetic Fabrics to Improve Stability of Ground Structure in Civil Engineering Circumstance

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Han-Yong Jeon

Additional information is available at the end of the chapter

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## Abstract

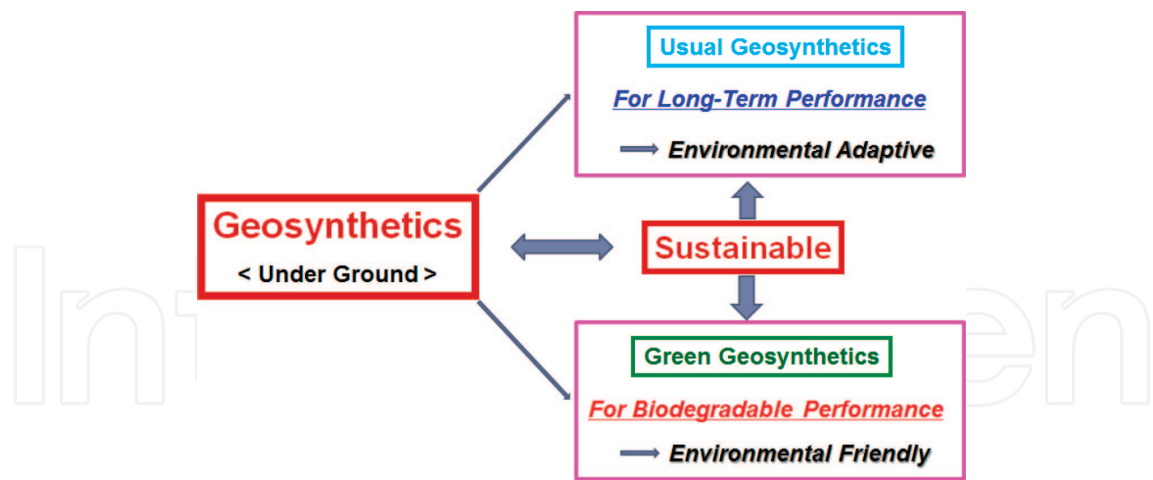
Polymeric synthetic fabrics are continuous sheets of woven, nonwoven, knitted, or stitch-bonded fibers and yarns. The sheets are flexible and permeable and generally have the appearance of a fabric. Among polymeric synthetic fabrics, geosynthetics including geotextiles have special functions of separation, filtration, drainage, reinforcement, and erosion control in civil engineering applications. Also, geosynthetics such as geotextiles and geogrids are used in asphalt pavement reinforcement. An important function of these geotextiles is as cushion layers to prevent puncture of geomembranes (by reducing point contact stresses) from stones in the adjacent soil, waste, or drainage aggregate. Geotextiles, however, are made from a combination of two or more polymeric synthetic fabrics. In this chapter, geotextiles as polymeric synthetic fabrics are introduced not only for improvement but also maintaining stability of ground structure in civil engineering circumstance with their related technologies.

**Keywords:** polymeric synthetic fabrics, geosynthetics, geotextiles, special functions, cushion layers, stability of ground structure

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## 1. Introduction

Geotextile is classified into woven fabric and nonwoven fabric in a morphological form and it performs functions such as reinforcement, separation, filtration, and drainage when applied to civil engineering structures. Generally, due to its structural form, the nonwoven geotextile has a small permeability coefficient and permittivity despite its small apparent opening size (AOS) compared with the woven geotextile style, it has advantages in function. Woven geotextile is applied to reinforce soil structure with poor shape stability in nonwoven geotextile based on excellent mechanical performance, and it also takes charge of filtration and drainage [1, 2].



**Figure 1.** Sustainable geosynthetics.

Geotextile products have the characteristics of so-called tailor-made materials, which are known to function for specific applications. The long-term performance of geotextiles has a close relationship with the stability of the applied structure and practical applications such as continuous new method and new technology [3, 4]. As the demand and necessity to high-performance products gradually increase, composite products, environment-friendly products, environment adaptive products, hybrid, or smart products should be developed. In response to this, the development and advancement of the evaluation method are progressing steadily.

International Geosynthetics Society (IGS) Education Committee established that geotextiles can be classified broadly based on the manufacturing method and geotextiles is a continuous sheet of woven, nonwoven, knitted, or stitch-bonded fibers or yarns. Sheets are flexible and permeable and generally have a cloth-like appearance. Geotextile is used for separation, filtration, drainage, reinforcement, and anti-erosion applications [5].

In general, sustainable geosynthetics mentioned here are classified as “Usual Geosynthetics” and “Green Geosynthetics” based on required performance as shown in **Figure 1**.

In here, “Usual Geosynthetics” refers to the function-oriented long-term maintenance and environment-adaptive products introduced, and “Green Geosynthetics” refers to environment-friendly degradable geosynthetics, respectively.

In this chapter, we will introduce “Sustainable Geotextiles,” which is differentiated from geotextile products to hybrid geocomposites except the traditional geotextile products.

**2. Raw materials for geotextile products**

The geotextile products and the polymeric raw materials are shown in **Table 1**. As the additives, internal fillers, antioxidants, carbon black, emulsions, and plasticizers are used for improving and complementing the physical properties, glass fiber, carbon fiber, aramid fiber,

Polymeric raw materials	Geosynthetic products
Polyethylene (Low, middle and high density)	Geotextiles, Geomembranes, Geogrids, Geopipes, Geonets, Geocomposites
Polypropylene	Geotextiles, Geomembranes, Geogrids, Geocomposites, Prefabricated Board Drain (PBD)
Polyester (High tenacity)	Geotextiles, Geogrids, Prefabricated Board Drain (PBD)
Polyamide	Geotextiles, Geogrids, Geocomposites
Glass fibers, Polyvinyl alcohol(PVA) fibers, Aramid fibers, Carbon fibers etc.	

**Table 1.** Geosynthetic products with polymeric raw materials.

acrylic fiber, asbestos fiber, and low-modulus fibers such as polypropylene, polyamide, polyethylene, and polyester fiber, etc. are generally used to manufacture geosynthetic products.

Otherwise, antioxidants, carbon black, oils, plasticizers, fillers, etc. are added to improve the specific properties of the polymer, and two or more raw materials may be blended to improve specific properties. In the case of the geotextile made of polyethylene resin, radicals are formed due to sunlight, which causes decomposition and causes embrittlement. Hindered amine light stabilizers (HALS) series oxidation stabilizer is added to prevent radical formation by daylight and ultraviolet rays. Weather resistance is also improved. When geosynthetics are applied for a long period of time, durability depends on the characteristics of the polymeric materials used. Therefore, it is highly desirable to analyze the characteristics of geosynthetics to determine their use.

### 3. Fibers used for polymeric synthetic fabrics

#### 3.1. Natural fibers

Natural fibers used in geotextile products are very limited, but they were first used as geotextile products. They were mainly applied in fiber, yarn, and knit form, and their demand increased as nonwoven- and woven-type products were developed. Since geotextiles of natural fibers have the advantage of being eco-friendly materials, the utility of geotextile products has recently begun to reappear. The raw materials of the products also include cotton, jute, coir, straw, and other stem forms of waste assembly, and it is very diverse. However, since it is not used much and cannot be mass-produced compared with synthetic materials, it poses a difficult problem to create demand. Some of them use civil engineering natural fiber products as slope stabilization, erosion control, drainage, etc.

#### 3.2. Synthetic fibers

One of the conditions that geosynthetic products must have is economic advantages, which is a very real problem directly linked to manufacturing costs. Polyolefin, polyester, and so on are

widely used as synthetic polymer fibers, and polyurethane, glass, and carbon-based polymers are applied to very limited fields in order to give a special purpose and function. Demand creation of geosynthetic products using polymer materials can be increased, and new functional products are expected to be developed in parallel with the development of various additives.

### 3.3. Recycled fibers

Since the fiber polymer materials used in the manufacture of geosynthetic products are often used in large quantities, therefore, the cost is low. Therefore, if the performance is similar, the manufacturing cost should be low. In view of this, in the case of nonwoven geotextile, products using already recycled polyester materials are being manufactured and sold, and interest and research on recycled polymeric materials are being actively pursued in terms of environment friendliness. However, in the case of the geosynthetic products manufactured using the recycled polymeric material, the physical properties are deteriorated, and therefore, there is a problem that it needs to be supplemented or improved in the future.

## 4. Manufacturing of polymeric synthetic fabrics as geotextiles

### 4.1. Geotextiles

Geotextile is a planar, permeable, polymeric (synthetic or natural) textile material, which may be nonwoven, knitted, or woven, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications (**Figure 2**).

There are woven geotextiles which are divided into plain weave and twill weave using staple and filament yarns. Yarn used is usually as of 1000–3000 denier. And fabric density is generally in the range of 19–21 plies per inch in the warp and weft direction, and mainly polyester and polypropylene fibers are used, but polypropylene fiber has a weak light resistance. In addition, nonwoven geotextile, in which long fibers or short fibers are randomly arranged and bonded, is manufactured by using a needle punching and thermal bonding



**Figure 2.** Photographs of geotextiles.

process in the case of short fibers and laminated by spunbonding process in the case of long fibers in a weight of about 200–800 g/m<sup>2</sup>.

In general, the constituent fibers form a disorderly entangled structure, so that they have excellent mechanical and mechanical properties, and polypropylene and polyester fibers are mainly used. Normally nonwovens are used for filter and separation functions. A nonwoven is a geotextile in the form of a manufactured sheet, web, or batt of directionally or randomly orientated fibers, filaments, or other elements, mechanically and/or thermally and/or chemically bonded. Nonwovens are used in filtration, drainage, separation, protection, and/or erosion control applications.

Fine soil particles can be captured in between the three-dimensional fiber entanglement of the nonwoven and prevent movement of these into the usually coarse “neighbor” soil. This way the buildup of a filter stable layer is possible. The geotextile filter can be dimensioned with available filter calculations [6, 7].

#### 4.2. Geosynthetic clay liners (GCLs)

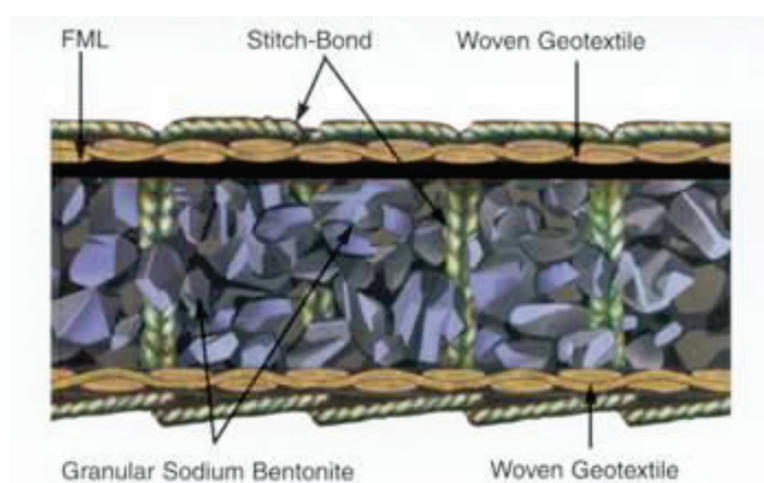
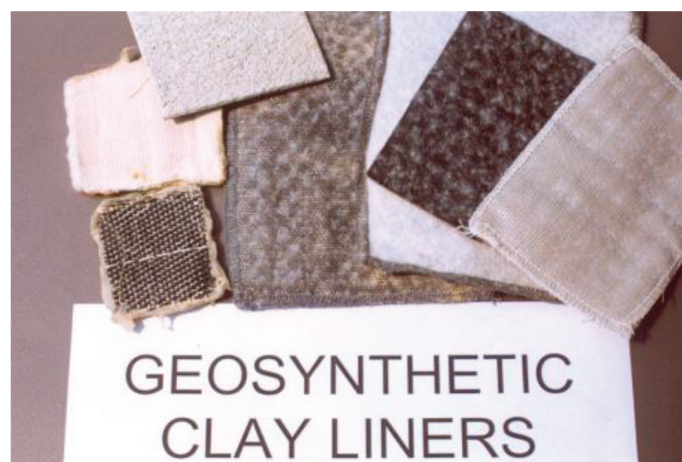
It is a geocomposite produced by bonding bentonite clay to a geotextile or geomembrane or filling bentonite clay between two geotextiles. The geotextile-made geotextile clay pottery often has a needle bent through the bentonite layer to increase internal shear resistance. It is effective as a barrier against liquids or gases when bentonite is hydrated. It is commonly used with geomembranes and is used as filler in landfills (**Figure 3**). GCL is also a factory-manufactured hydraulic barrier consisting of a layer of bentonite or other very-low-permeability materials supported by geotextiles and/or geomembranes, mechanically held together by needling, stitching, or chemical adhesives (**Figure 4**).

#### 4.3. Geotubes and geocontainers

There are many opinions on how to prepare measures to be protected against or prevent catastrophic disasters such as tsunami and Katrina which have recently occurred, but one of the obvious ways of doing this is that it is closely related to advance prevention as well as disaster recovery. To do this, the method is the use of geotextile products. Geotextile containers, which are used instead of building rigid structures such as rocks and concrete in rivers, coasts, and harbors, are used as geotextile containers that are currently being used for this purpose worldwide, and they are used to construct flexible structures, and this technique has been successfully applied [8, 9].

Also, geotextile container is classified as geobags, geotubes, and geocontainers depending on the size and manufacturing method. The geotextile container is made by mechanically or hydraulically filling the soil including dredged soil in the geotextile bag. Generally, a geobag is a small geotextile container with a capacity of 0.3–5.0 m<sup>3</sup>; it is usually used as a sand filling material, and it is finished with a small sewing machine.

Geotubes are manufactured in permeable geotextile and are filled with sand or dredged soil by hydraulic or mechanical methods. The diameter and length of the geotube depend on site conditions and installation possibilities, usually 150–180 m, 4–5 m wide, and 1.5–2 m high.



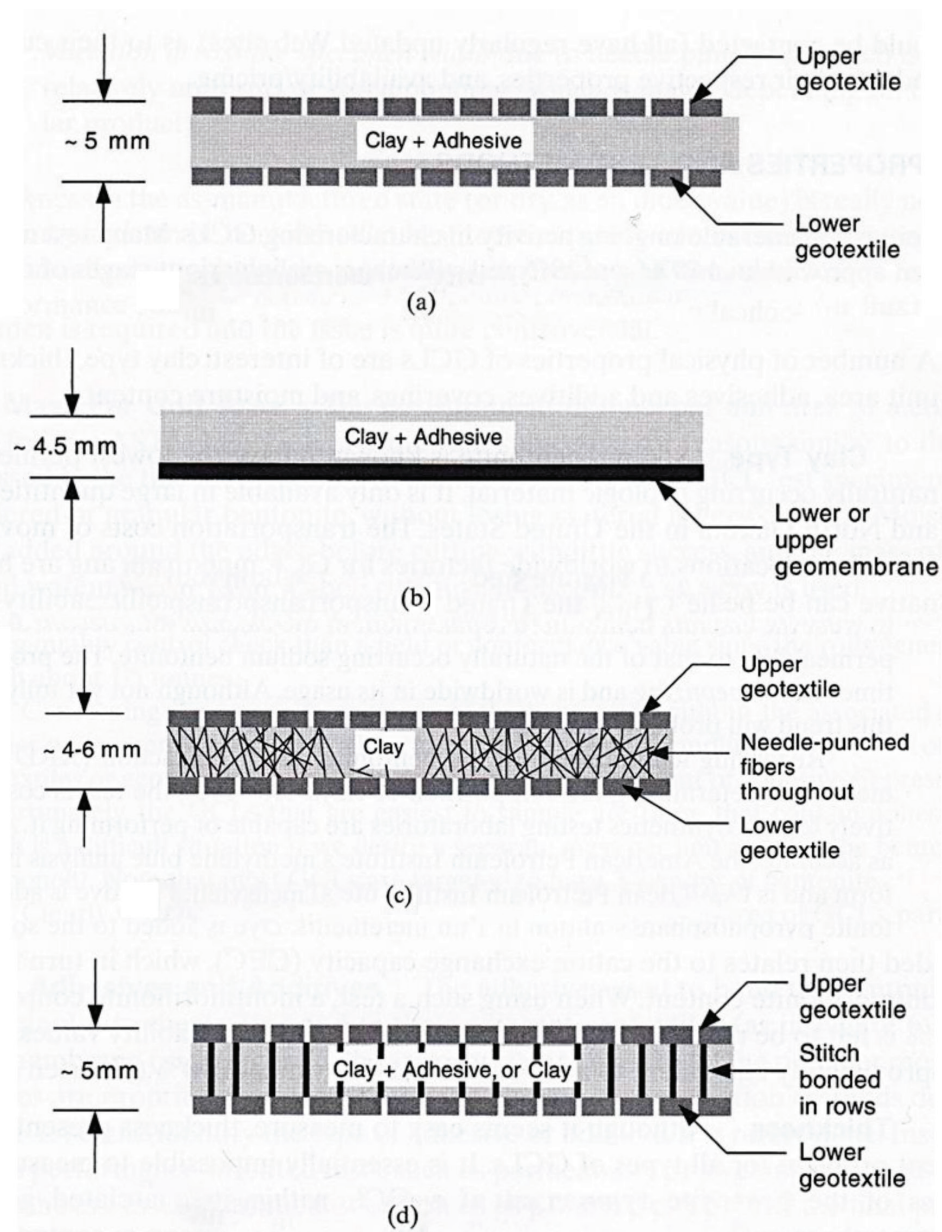
**Figure 3.** Photographs of geosynthetic clay liners.

In order to fill the upper part of the geotube with hydraulic method, the sandy soil should be closer (about 10 m) and the clayey soil as far as possible. Geotube is a massive pillow-shaped structure made in a permeable geotextile style and is filled mechanically with sand or dredged soil by a hopper or clamshell bucket (**Figure 5**).

Since the first attempt of geotube applications was in Brazil in the early 1980s, geotube application technology has been used as a containment embankment for the prevention and isolation of contaminated soil from France in 1986 and has since been used for underwater embankment or coastal protection in the Netherlands and Germany. Now, geotube was widely used for construction work [10].

Geocontainer is constructed by preliminarily sewing the geotextiles of the proper length together and installing it in the split bottom-dump width of the floor (the two ends are sewn together so as to form slender pillow shapes). And then, fill with sand or dredged soil, and seal the suture with a suture at the site (**Figure 6**).

The capacity of the geocontainer can be increased as the barge opening width of the barge becomes larger and is usually about 100–1000 m<sup>3</sup>. When dredged clay is used, geocontainers



**Figure 4.** Cross-sectional sketches of currently available GCLs. (a) Adhesive-bound clay between upper and lower geotextiles, (b) Adhesive-bound clay above or below a geomembrane, (c) Needle-punched clay through upper and lower geotextiles, and (d) Stitch-bonded sketches of currently available GCLs.

can be manufactured by using nonwoven geotextile inside and woven geotextile outside. These geocontainers have many advantages such as shortening the installation period and reducing the construction cost due to the use of site-useable materials and workload and minimizing environmental pollution during construction.

Geocontainer application technology was first developed in the Netherlands and was used in 1986 in Germany for the construction of the flow-inducing dikes in the Rhine River and in 1987 in the Dutch-eroded canal's dikes.

The US Army Engineer Waterway Experiment Station (WES), which has recently been the centerpiece of the Army Engineer's Department and has been planned for Construction

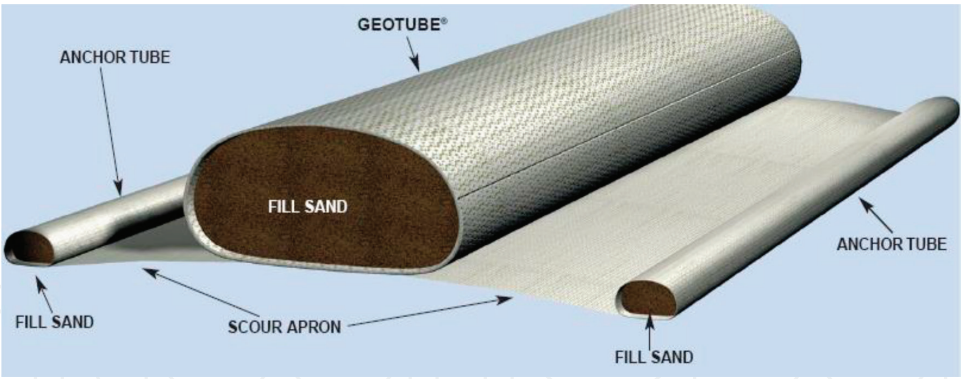


Figure 5. Schematic diagram of geotube.

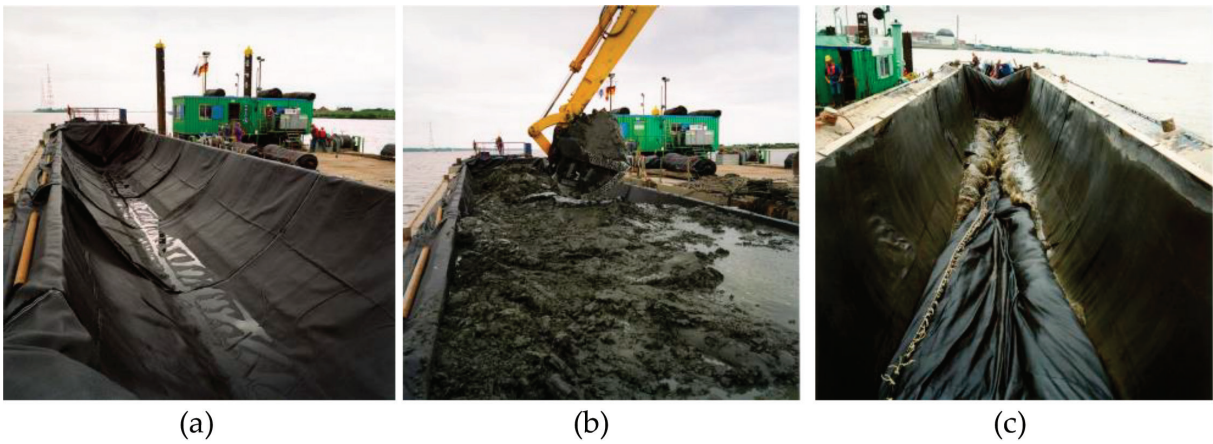


Figure 6. Photographs of geotube application. (a) Spreading, (b) filling soils, and (c) dumping.

Production Advancement Research (CPAR) and has been developing innovative technologies using geotextile for the construction and maintenance of seawalls, rivers, canals, harbors, breakwater, dikes, coastal protection, roads, landfills, and reclaimed land.

## 5. Technical development trend of geosynthetics

Previously, environmental adaptive geosynthetics, which we have described as “Usual Geosynthetics,” have not changed much over the past 20 years, but the paradigm of composite products using extreme strength fibers with the keyword of diversification of applications is being created. In other words, the development demand for divergence-targeted products, which means creation of usage as protection, maintenance, and restoration concept from natural disaster, is growing as megatrend of product development [11–14]. We will introduce the recently introduced fiber-reinforced geosynthetic products based on the concept in Figure 1.

### 5.1. Environmental adaptive geosynthetics

Environmental adaptive geosynthetics introduced as “Usual Geosynthetics” has not changed much over the past 20 years, but the paradigm of composite products using extreme strength fibers with diversification of uses has been created.

On the other hand, most of the synthetic polymeric materials that have been widely used are polyolefin-based and polyester-based ones. However, polyurethane, glass, and carbon-based polymers could be used to manufacture for special purpose and functions. Since the polymer materials used in the manufacture of geosynthetic products are often used in large quantities, therefore, the cost is low. Therefore, if the performance is similar, the manufacturing cost must be low.

In view of this, products using recycled polyester materials have already been manufactured and sold, and interest and research on recycled polymer materials are being actively pursued from the viewpoint of environmental friendliness. However, in the case of the geosynthetic products manufactured using recycled polymeric materials, the physical properties of the recycled polymeric materials are deteriorated, so that they have to be supplemented or improved in the future.

Recently, as the demand of composite-type geosynthetics has increased, functional and special high-performance materials have been used to improve the field application of geosynthetic products and to improve the stability of geotechnical structures from earthquakes, tsunamis, etc., liquid crystal polymer (LCP), polybutylene oxide (PBO), polypropylene sulfide (PPS), and meta- and para-aramid fibers have been used to combine with fusion technology for the production of hybrid geosynthetics.

## 5.2. Environment-friendly geosynthetics

“Green Geosynthetics” refers to products that have sustainable degradable geosynthetics and environmental pollution prevention and restoration functions that do not mean long-term implementation of initial performance in terms of environmental friendliness. In the case of geotextiles, “biodegradability” refers to a phenomenon in which initial performance is gradually lost over time due to decomposition by microorganisms or bacteria in the soil, which is a geotechnical structure. In terms of restoring the polluted environment, it is also a new area of geotextiles that meets the issue.

In order to manufacture “Green Geosynthetics,” a resin which is biodegradable as a raw material should be used separately, and it is closely related to the reduction factor required for long-term use. Therefore, if the green geosynthetics is used as a filter, the production of a geotextile in the form of nanofibers will help improve filtration efficiency.

## 6. Development trend with geotextile-related products

### 6.1. Geotextiles

#### 1. Nonwoven geotextile products

High weight, over 5000 g/m<sup>2</sup>

Smart fusion multifunction product

Filter products for nanofiber applications

Composite products, etc.

## 2. Woven geotextile products

High strength, 30 ton/m or more tensile strength demanded

Creep property improvement product

Low-elongation high-strength yarn use

Smart fusion multifunction product

Composite products, etc.

### 6.2. Geosynthetic clay liners (GCLs)

Differentiated hydraulic function product

Salt water swelling improvement product

Products with improved freeze-thaw stability

Selective-order function products, etc.

### 6.3. Filter and drainage geotextiles

Minimization of penetration by constraint load

Clogging prevention and minimization products

Biodegradable multifunctional products, etc.

### 6.4. Geotubes and geocontainers

High strength, 50 ton/m or more tensile strength demanded

Creep performance improvement products

Permeability and sealing property improvement products

Ultraviolet and salt water stability improvement products, etc.

### 6.5. Miscellaneous

Concrete reinforcement geocomposites

Silt fence products

Seam properties improvement products

Ultraviolet and salt water stability improvement products, etc.

## 7. Functional geotextile-related products

### 7.1. For separation, filtration, and reinforcement functions

In order to improve the separating function of the geotextile for reinforcement, it is possible to improve physical properties and permeability by designing the smoothness of the woven fabric at a high level and to improve the morphological stability by designing the tissue for controlling apparent opening size (AOS) [11–13]. Especially, it is designed to improve the tensile strength of fabric by improving density of weft yarn and double yarn design so as to improve the tensile strength in weft direction (**Figure 7**).

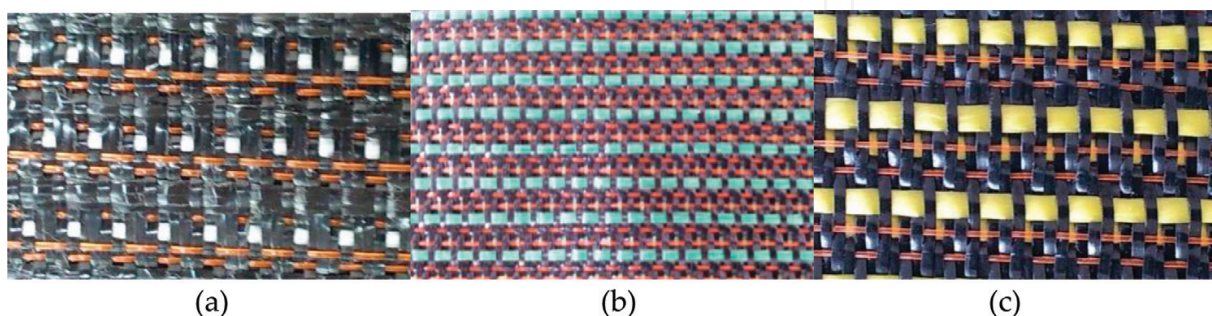
This product has the overall performance (chemical stability, higher tensile property, and water permittivity, etc.) as the geomembrane protection mat in the landfill construction caused by the working vehicle and the aggregate applied to the leachate drainage layer and at the upper part and can be used as a composite product.

### 7.2. Multiaxial geocomposite for reinforcement

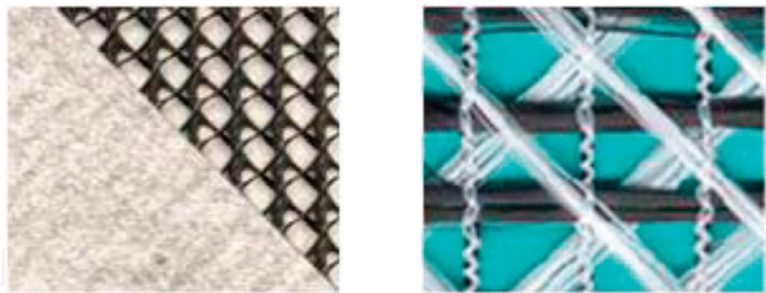
As shown in **Figure 6**, geocomposite fabrication technology and products were developed to enhance the reinforcement function of geosynthetics by applying multiaxial knit fabric and geotextile composite technology by developing not biaxial but multiaxial knit. In addition, a smart monitoring high-performance multiaxial geocomposite technology is being developed in parallel to embed an optical fiber sensor in a multiaxial geocomposite appropriately to monitor the damage of the geocomposite due to stress concentration in real time (**Figure 8**).

### 7.3. Geotextiles for preventing reflective crack

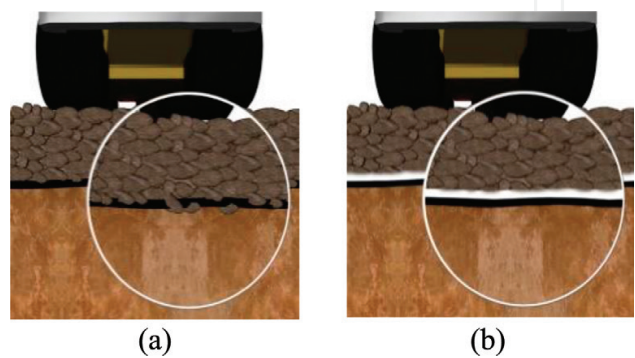
Geotextiles applied on the top of the packed and unpacked road subgrade is considered to be the top layer of the bottom layer consisting of roadbed soil and the top layer consisting of soil or aggregate laid for construction. If the two layers are not properly separated, the particles of the lower layer penetrate the upper part, or the particles of the upper part penetrate the lower layer, causing settlement or cracking of the road. Also, when the bedrock is saturated by rain or other conditions, excess pore water pressure is generated by the traffic volume, so that the bedrock is weak and easily broken. Therefore, proper water discharge must be achieved, and



**Figure 7.** Geotextiles for separation, filtration, and reinforcement. (a) Separation, (b) filtration, and (c) reinforcement.



**Figure 8.** Multiaxial geocomposites for reinforcement.



**Figure 9.** Failure with/without geotextile for pavement protection. (a) Without geotextile and (b) With geotextile.

proper pore size and good permeability coefficient are required because the piping phenomenon is required to prevent the loss of soil along with the flow of water [14, 15].

As shown in **Figure 9**, pavement roads are damaged due to cracks and plastic deformation before the design life due to the surrounding environment and repeated traffic loads, which causes wasted budget for maintenance of road pavement.

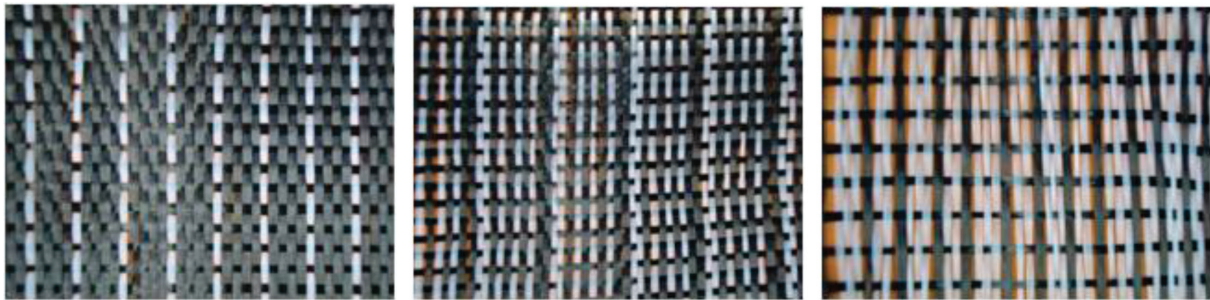
This is due to the weakening of the bearing capacity of the pavement ground or the cracking and growth due to the expansion and contraction of the water inside the packed asphalt or concrete. The role of a geotextile as a localized stress reduction layer could be to prevent or reduce damage to a given surface or layer by vehicle passing load.

Therefore, in order to improve the durability of the pavement, development is underway to improve the performance of asphalt or aggregate as a road pavement material and to reinforce the pavement by adding reinforcement materials such as geosynthetics to traditional pavement materials.

On the other hand, asphalt pavement using geotextiles has a great effect on prevention of fatigue cracks and reflective cracks and additionally has an advantage of blocking water penetration due to road crack by increasing water penetration. Advanced geotextiles have been developed, have improved toughness against repeated fatigue loads, and are resistant to various damage loads that occur during the construction process (**Figure 10**).

#### 7.4. Biodegradable geotextiles

In the case of geosynthetics for slope reinforcement or erosion prevention considering vegetation, biodegradable products are required for the purpose of activating the planting of plants.



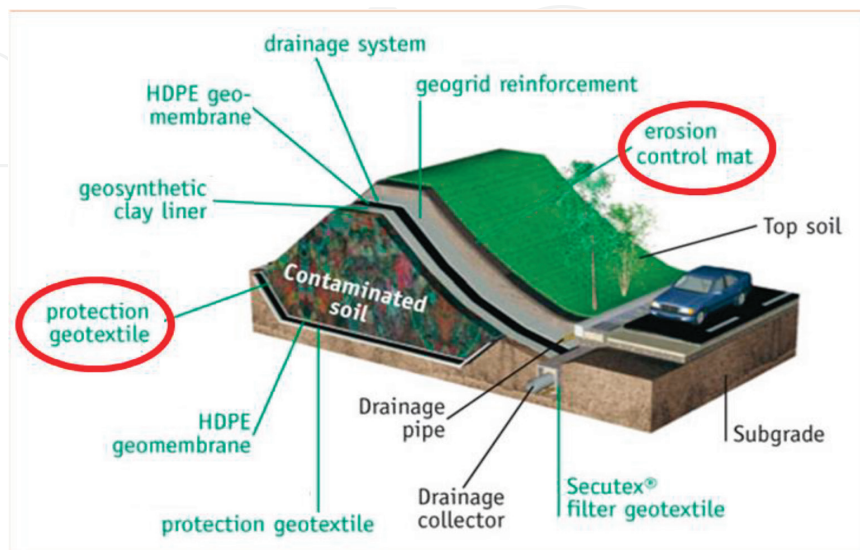
**Figure 10.** Various geotextiles for antireflective crack propagation.

However, as mentioned above, even though it is a product of very important issue in terms of being environmentally friendly, it is easy to enter the market only if the stability of raw material supply and supply and product standardization are solved. Here, only the biodegradable vegetation mats and geocells used for vegetation in river maintenance and slope greening are introduced.

As shown in **Figure 11**, the geotextiles for vegetation mats have a very high initial dependency for the purpose of preventing or stabilizing the erosion. Therefore, biodegradation occurs in the course of the planting process after the vegetation mat construction, thus contributing to the improvement of the stability of the structure.

The synthetic resin system used for slope protection and erosion prevention was originally a product using a mat made of a heat-sealable webbing structure using nylon and a product with a reinforcing material (geogrid) combined with a web structure. And polypropylene staple fibers have been developed in the future, but since they are nondegradable products, it has been pointed out that the residues become an environmental pollution source after completion of the desired slope protection and erosion prevention function.

It is now in the process of restoration of various floods due to increasing weather conditions, eco-friendly construction methods, and landscaping and greening. As the demand for



**Figure 11.** Application examples of geotextiles for erosion control.

products becomes greater, it is possible to apply and expand key technologies for vegetable mats made from biodegradable resins.

8. Nanofiber-used geotextiles

In general, geotextiles can be fabricated with a fiber size of more than 1 denier. However, when the size of a fiber becomes micro fine or nanofiber size, it has a great advantage in restoring the environment from pollution or improving filtration performance (Figure 12).

As shown in Figure 13, the filtering capacity of the geotextile depends on the number of fibers per unit area, the size of the pores, and the compositional structure. Therefore, when nanofibers are used, the smaller the pores constituting the geotextile, the removal rate of the toxic water is improved. However, at present, there is not a variety of techniques for manufacturing nanofibers, and since the manufactured nanofibers are expensive, the practical use of nanofibers is very slow.

In general, regular fibers are widely used to manufacture geotextiles and geogrids, but filtration efficiency of microfiber and nanofiber geotextiles is better than regular fiber-used geotextiles. To consider this, it is expected that nanofiber geosynthetics could be the smart filtration function in geoenvironmental applications by their composition structure as in Figure 3. If the numbers of filled fibers per unit area are increasing, pore size among nanofibers is decreasing. Therefore, the fine particles cannot pass through pores by nanofibers, and the filtration efficiency will be improved. This means that ultrathin geosynthetic filter can be manufactured with high-quality filtration function to absorb the fine impurities and toxic components in water and air media (Figure 14).

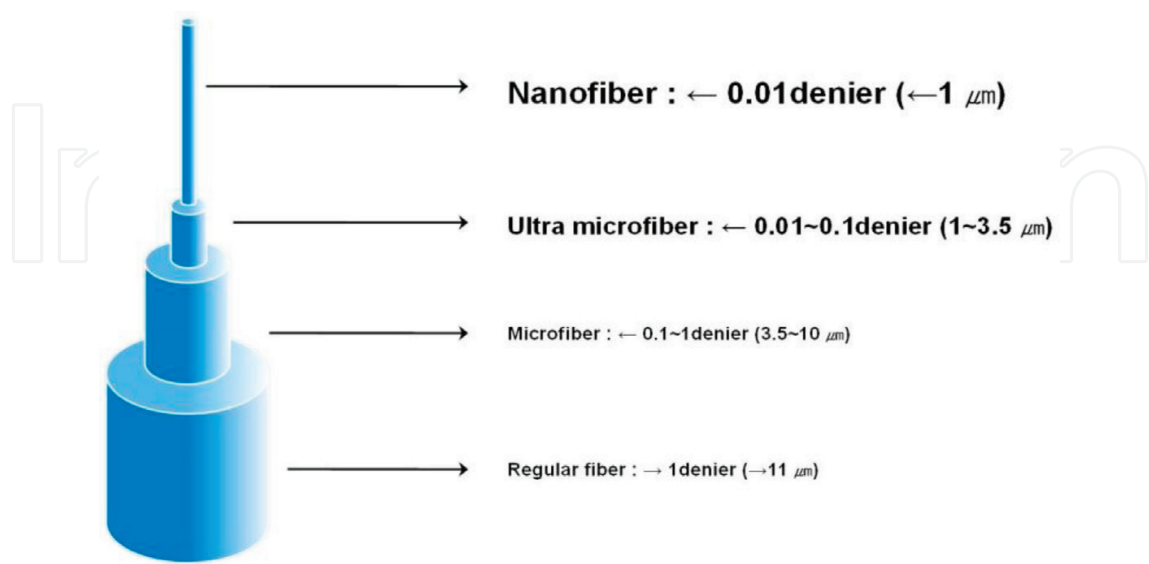


Figure 12. Thickness of fiber for geosynthetic fiber production.

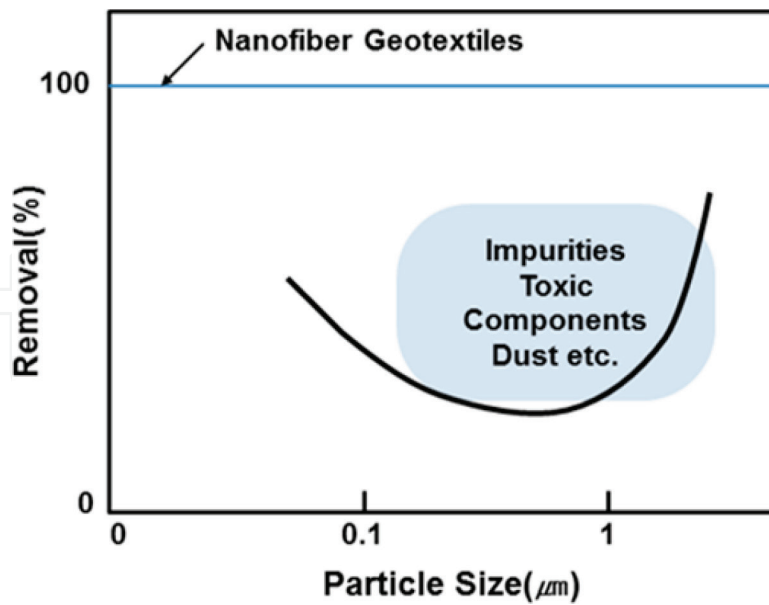


Figure 13. Impurity removal ratio according to geotextile pore size.

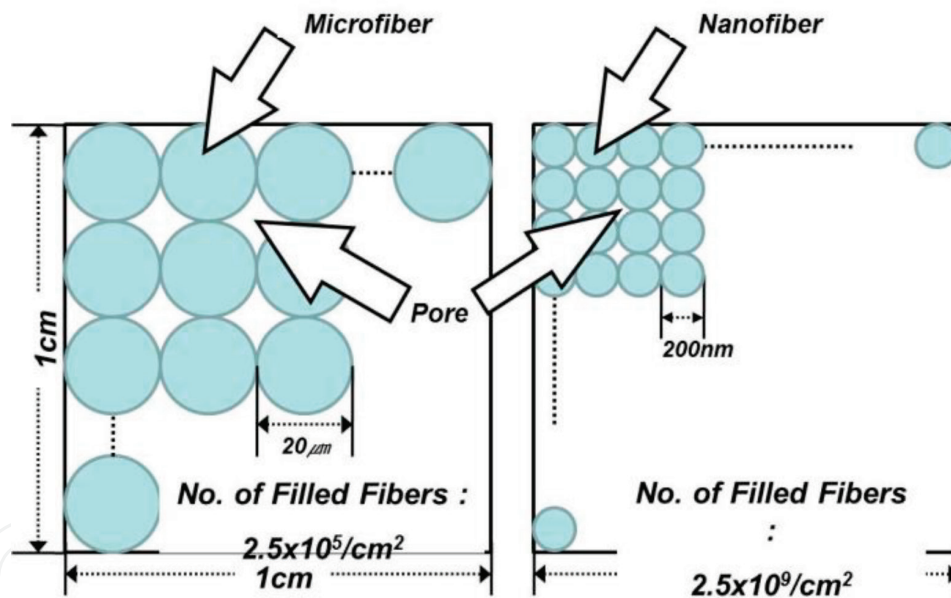
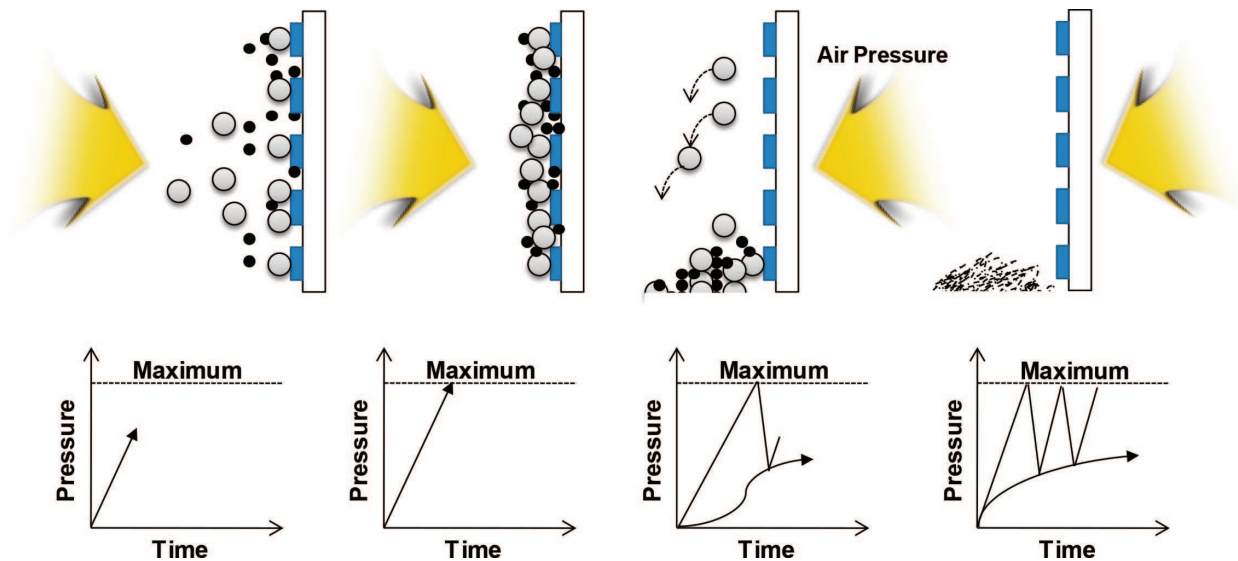


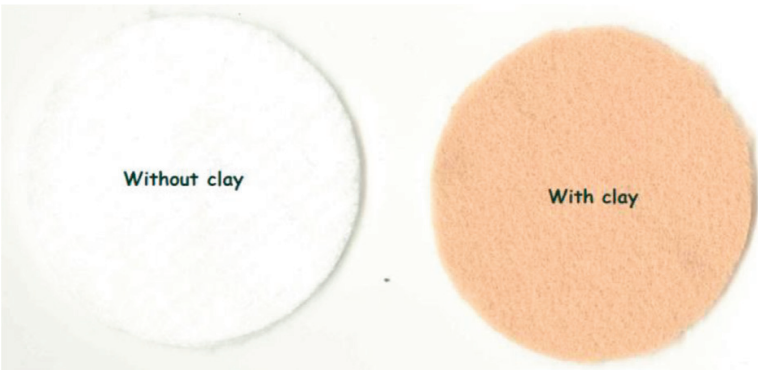
Figure 14. Geotextile filtration ability according to the number of filled fibers.

**Figure 15** shows the separation concept of nanofiber air filter by pressure. To be the best air filter, higher particle collection and dust retention rate should be required.

In order to remove the heavy metals and toxic substances contained in polluted soil, non-woven geotextile is used which is made by mixing nanoparticle clay with polyester fiber (**Figure 16**). Of course, the engineering performance of mixed nonwoven geotextile will vary depending on the composition of clay and particle size, but the strength degradation due to leachate, chemical, and biological degradation of waste landfill is not greater than that of



**Figure 15.** Maintenance of filtration efficiency for nanofiber filter.



**Figure 16.** Nonwoven geotextiles with/without nano-clay.

nonwoven geotextile without clay. Also, AOS is higher than that of the nonwoven geotextile which is not mixed with clay, so that the permeability is improved.

### 9. Conclusion

Looking back at the civil engineering industry, product development and construction technology have been growing remarkably. There is also a growing demand for sustainable civil engineering products to protect, repair, and restore structures after recent floods, tsunامي, and earthquakes. Considering the product characteristics and functions according to the product material and manufacturing method, civil engineering is rapidly growing with advantages of development of convergence composite geosynthetics using polymeric material, new design with geosynthetics.

In addition, it is expected that the utilization of civil engineering products will be further enhanced by various applications of the development and manufacturing methods of geosynthetics. For this, new convergence type composite geotextile-manufacturing technology should be developed not only standardization and reliability of evaluation methods but also design and construction methods and equipment.

## Author details

Han-Yong Jeon

Address all correspondence to: hyjeon@inha.ac.kr

Department of Chemical Engineering, Inha University, Incheon, South Korea

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