

## GEOTEXTILES

The American Society for Testing and Materials Committee D35 on Geosynthetics defines a *geosynthetic* as a planar product, manufactured from polymer material, used with soil, rock, earth, or other geotechnical engineering-related material, as an integral part of a “man-made” project, structure, or system. A *geotextile*, a subset of geosynthetics, is defined as any permeable textile material used with foundation soil, rock, earth, or any other geotechnical engineering-related material, as an integral part of a “man-made” project, structure, or system.

There are several different processes and polymers used in the manufacture of geotextiles which affect their appearance and physical properties. Geotextiles are produced in various weights and thicknesses, which also determine their physical properties and ultimately the performance of the material when installed on a project (see also High performance fibers).

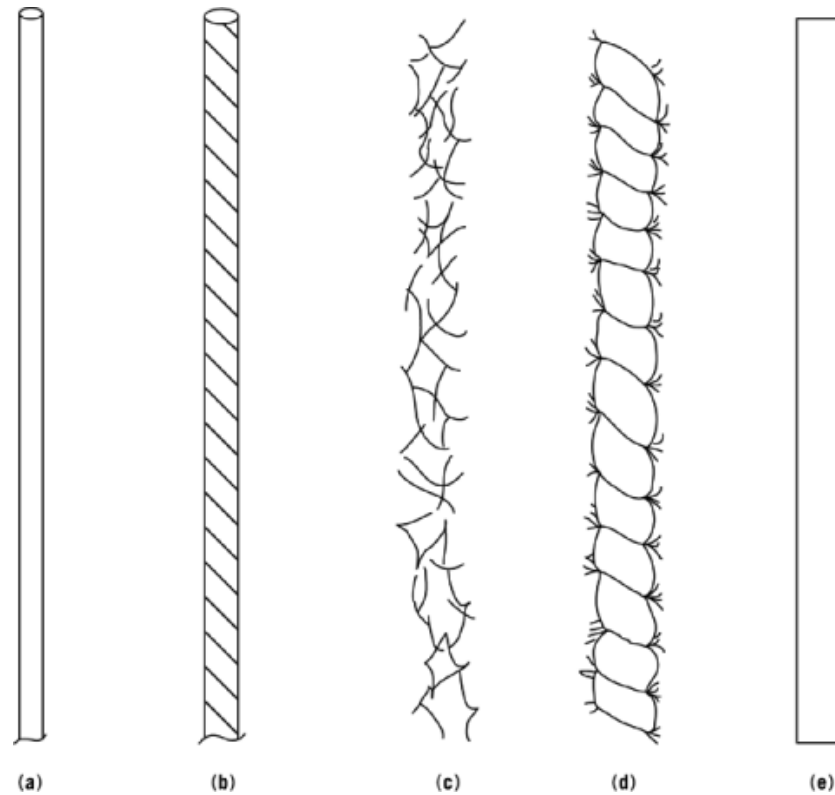
When first used in civil engineering projects, the materials now known as geotextiles were called filter fabrics, civil engineering fabrics, or construction fabrics. Their primary use in the early- to mid-1960s was as erosion control materials, and as an alternative for granular soil filters. Since the late 1970s, the use of these materials has expanded almost limitlessly. The varied uses of geotextiles include drainage, dissimilar materials separation, erosion control, environmental protection, highway pavement rehabilitation, and as component materials of geocomposites used in a variety of applications. Within each of these categories of use there exist numerous types of installations using the geotextiles.

### 1. Manufacturing Process

Polymers used in the manufacturing process in decreasing order of use include polypropylene, polyester, polyamide (nylon), polyethylene, and others to a much lesser extent (1). The fibers used in manufacturing the geotextiles are made by melt-spinning, ie, melting the polymer material and forcing it through a spinneret. Hardening of the fiber filaments is accomplished for the geotextile materials mostly through a process of simultaneous stretching and cooling of the fibers. The stretching of the fibers produces a more orderly arrangement of the molecules in the fibers, resulting in increased strength of the fiber (see Fibers, survey). Monofilament fibers are further processed to form the various types of yarns used in the manufacturing of geotextiles. Multifilament yarn is formed by several monofilaments being twisted together to form the yarn. Staple fibers are formed from a rope-like bundle of monofilaments being crimped and cut into 2.5- to 10-cm (1- to 4-in.) lengths. Staple yarns are formed from these staple fibers by twisting into longer fibers (yarns). Another type of material used in geotextiles is called slit film. A continuous flat sheet of the polymer is cut into fibers by slitting with knives, or through the use of air jets. The resulting ribbons are slit-film fibers. Figure 1 shows the types of fibrous components in geotextiles.

Geotextiles may be woven, nonwoven, or knitted. All types, woven, nonwoven, or knitted, are susceptible to degradation owing to the effects of ultraviolet light and water. Thus stabilizing agents are added to the base polymeric material to lessen the effects of exposure to ultraviolet light and water.

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**Fig. 1.** Schematic drawings of five types of geotextile fibers: (a) monofilament, (b) multifilament, (c) staple fibers, (d) staple yarn, and (e) slit film.

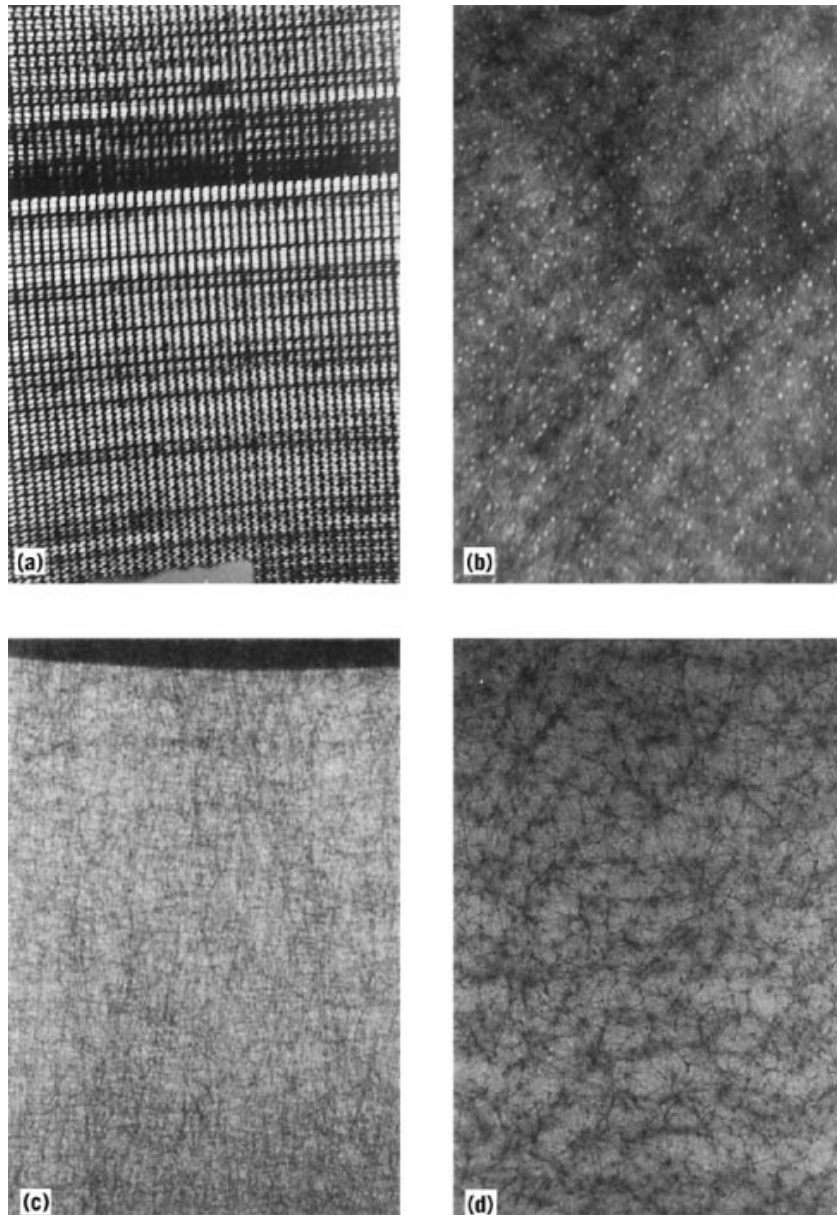
Woven and nonwoven geotextiles are the most common types presently in use in geotechnical engineering. A woven geotextile is formed through the conventional textile weaving process resulting in a screen-like or mesh material with various sizes of mesh openings, depending on the tightness of the weave.

### 1.1. Nonwoven Geotextiles

There are two basic manufacturing processes by which a nonwoven geotextile is produced: a one-stage or continuous process where the fibers are spun and bonded in one continuous process, and a two-stage process where fibers are laid down and then bonded (see Nonwoven fabrics). The most common types of bonding processes are the spun-bonded process, melt- or heat-bonded, resin-bonded, and needle-punched (Fig. 2). Each of the processes results in a geotextile that may have vastly different characteristics than one formed otherwise. Depending on the end use of the material, this may affect the choice of the geotextile to be used on a specific project.

#### 1.1.1. Spun-Bonded Fabrics

In this continuous process, one or more polymers are fed into an extruder, through the spinneret onto a continuous moving conveyor. As a result, a continuous web of material is formed. As the polymer(s) are being placed on the conveyor, fiber orientation is achieved by spinneret rotation, varying conveyor speed, or other actions. Bonding of the fabric is achieved through thermal, mechanical, or chemical treatment. Some of the



**Fig. 2.** Photomicrographs of geotextiles made by various methods: (a) woven geotextile, (b) needle-punched, (c) heat-bonded, and (d) resin-bonded.

notable characteristics of a geotextile produced by this means include high performance, low weight materials as a result of the continuous character of the fibers. Product weights generally range between 10 and 200 g/m<sup>2</sup> (0.3 to 6 oz/yd<sup>2</sup>). Product thicknesses range between 0.08 and 0.64 mm (3 to 25 mils).

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### 1.1.2. Melt- or Heat-Bonded Fabrics

In the two-stage melt or heat-bonding process, the fibers, which may be continuous or long staple fibers, are melted together at fiber crossover points. Bonding is achieved by calendering, ie, passing the geotextile between two rotating hot rollers, melting the fibers together at the crossover points. Resulting fabric characteristics depend on whether one or two different polymers are used for the fibers and on the intensity of the heat and roller pressure used in melting the fibers together. Fabric weights generally range between 70 and 400 g/m<sup>2</sup> (2 to 12 oz/yd<sup>2</sup>).

### 1.1.3. Resin-Bonded Fabrics

To achieve this type of bonding, an acrylic resin is either sprayed onto or impregnated into a fibrous web. The resulting structure is allowed to cure or is run through the calendering process, which develops strong bonds between the fibers. Often the fabric undergoes a forced-air drying process which redevelops the open pores of the structure. This type of bonding may not be used as frequently today as it was in the early years of geotextiles.

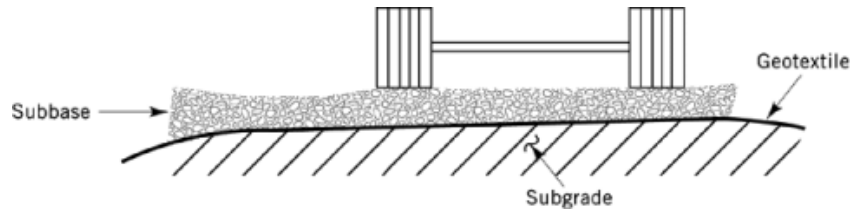
### 1.1.4. Needle-Punched Fabrics

In the two-stage needle-punching process, a fibrous web is placed into a machine which is equipped with a series of specially designed reversed-barbed needles. The web of material is passed between two plates. As the fabric passes between the plates, the needles punch down through the top plate and fabric, reorienting the fibers and resulting in entanglement of the fibers. Fabric weights from this process generally range between 60 and 700 g/m<sup>2</sup> (1.7 to 20 oz/yd<sup>2</sup>). Fabric thickness ranges between 0.4 and 5 mm (15 to 200 mils).

## 2. Physical Properties

The polymer used, the manufacturing process, and additives used in producing the geotextile determine the appearance and physical properties of the product. Properties may be classified as index properties or design and performance properties. Index properties provide a means of material differentiation, quality control in the manufacturing process, and quality assurance for the specifying agency. They generally are determined by relatively simple and quick physical tests that are not performed under the conditions in which the geotextile will be used. That is, they are tested in isolation, without the soil or material in which they are to be placed. Index properties include certain types of strength tests, mass per unit area, thickness, apparent opening size (pore openings), permittivity (volumetric flow rate), and temperature stability.

Design or performance properties define how the geotextile performs under specific installation conditions. Ideally testing is performed under the anticipated installation conditions, but it should not be expected that the manufacturer perform these tests. It is virtually impossible to duplicate every condition under which a geotextile will be placed. The design engineer should determine the specific conditions under which the geotextile will be installed and expected to perform, and select appropriate design and performance tests. There are few standard design and performance tests available. Generally an attempt to interpolate performance requirements based on index properties is made which is very difficult to do and is sometimes misleading. Some design or performance tests that do exist include wide-width strength, filtration efficiency, soil-clogging potential, and biological clogging.



**Fig. 3.** Separation of subbase from subgrade soil by a geotextile.

### 3. Applications

Fabrics perform one or more function in each installation; generally there is one primary function. The five basic primary functions have been identified as separation, stabilization, reinforcement, filtration, and drainage. When the geotextile is impregnated with an impermeable material such as an asphaltic emulsion, it may function as a moisture barrier. Within these basic functions, there are over one hundred different application areas (1–4).

#### 3.1. Separation

In this function, the geotextile serves to separate two dissimilar materials (Fig. 3), eg, two different soils, landfill material and the native soil, stone material and subgrade soil, old and new pavement, foundation soils and various types of walls, or one of many other similar situations. In some instances, it is difficult to distinguish between the separation and stabilization functions because in both situations the geotextile is serving as a separator. However, in stabilization some additional phenomena occur.

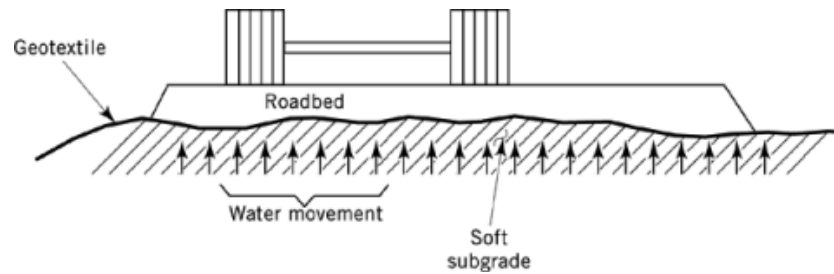
In separation, the primary function of the geotextile is to prevent intrusion of one material into another in order to prevent contamination of either material by the other. In the case of an aggregate being placed over a firm foundation soil, the purpose is to maintain the drainage integrity of the aggregate; wall application is similar. In landfill application, the purpose is to prevent intrusion of waste material into the leachate collector system.

Even though separation may not be the primary function for which the geotextile is installed, in almost every case the geotextile does perform as a separator. For the separation function, the physical properties of concern are primarily strength-related, including wide width, puncture resistance, and tear resistance.

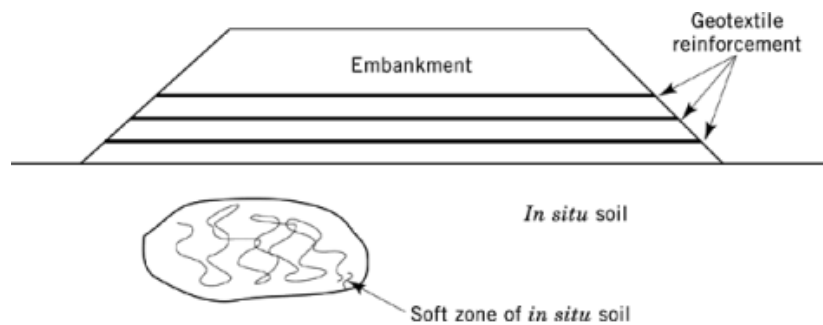
#### 3.2. Stabilization

Figure 4 shows stabilization accompanying separation. In this application, the natural soil on which the geotextile is placed is usually a wet, soft, compressible material, exhibiting very little strength. By acting as a separator, the geotextile allows water from the soft natural soil to pass from this soil into a free-draining construction soil, which in turn allows consolidation of the natural soil to take place. As a result of the consolidation process, there is a strength gain in the natural soil, which then provides an adequate foundation for construction to take place.

The geotextile may also act to bridge over the soft soil in which case drainage of water from the soft, wet soil is not the foremost function served by the geotextile. The geotextile must have sufficient strength to support the construction soil. The area over which the geotextile is spread in this stabilization function is much smaller than the area when it is used in the first-described stabilization application. For stabilization, strength is again of concern, but drainage characteristics must also be considered.



**Fig. 4.** Stabilization of a roadbed by a geotextile.



**Fig. 5.** Reinforced embankment.

### 3.3. Reinforcement

The key difference between stabilization and reinforcement is that stabilization is accomplished by providing for drainage of water from the unstable soil, while in reinforcement the strength characteristics (stress–strain) of the geotextile provide added strength to the whole system. Another difference is that in stabilization the geotextile is placed on or around the area being stabilized and thereby also acts as a separator, whereas in the reinforcement application the geotextile is placed within the material being reinforced (Fig. 5). This is in line with reinforcement concepts in concrete and other materials.

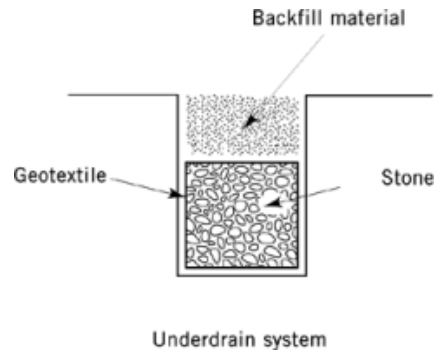
In order for it to perform the reinforcement function, the geotextile must be allowed to deform to develop its strength. When stabilization of a site occurs, there is consolidation of the soil, and with this comes deformation of the geotextile. Due to the deformation of the geotextile, strength is required to ensure that a site failure does not occur, ie, there can be a reinforcement component in the stabilization process.

Areas where geotextiles are used as reinforcement include embankment construction, reinforced soil wall construction, and slope improvement. In reinforcement, the physical properties of importance are primarily related to strength, that is, a combination of the stress–strain characteristics of the material.

### 3.4. Filtration

Here the prime function is to retain soil or other fine materials, while allowing water to pass through. Again, it is seen that more than one function is being performed (Fig. 6). If there were no drainage of water taking place, movement, and therefore retention of the soil, would not be of concern.

Part of the mechanism by which filtration occurs is through the development of a soil filter behind the geotextile. As the water passes through, soil is filtered out and collects behind the geotextile. As buildup takes place, a natural soil filter is developed. If the geotextile is improperly designed for the site, plugging or clogging



**Fig. 6.** Use of a geotextile in filtration.

of the geotextile will take place as a result of this buildup. If the geotextile is plugged or clogged to the point where no water is able to pass through it, excess pore pressure may develop and eventually lead to a failure of the site. It is therefore critical to design an installation so that there is a balance between the soil-retention characteristics and the drainage characteristics of the geotextile-soil system.

Filtration installations include wrapping the trench of a pavement-edge drain system to prevent contamination of the underdrain; placement behind retaining walls and bridge abutments to prevent contamination of the sand blanket placed against the structure to allow dissipation of pore pressures in order to avoid failure of the structure; as silt fences to allow surface runoff from a site while retaining the soil suspended in the runoff; and on earth slopes beneath larger stone or other overlay materials to prevent erosion of the slope as water escapes from the interior of the slope.

### 3.5. Drainage

In the previous sections, drainage was discussed as taking place in a direction perpendicular to the plane of the geotextile. Here, drainage parallel to the plane of the geotextile is described (Fig. 7). The property called transmissivity is defined as flow parallel to the plane of the geotextile. This type of flow can occur to some extent in all geotextiles, but is best achieved in needle-punched nonwoven materials. This class of geotextiles can be manufactured in a range of thicknesses such that this characteristic is optimized.

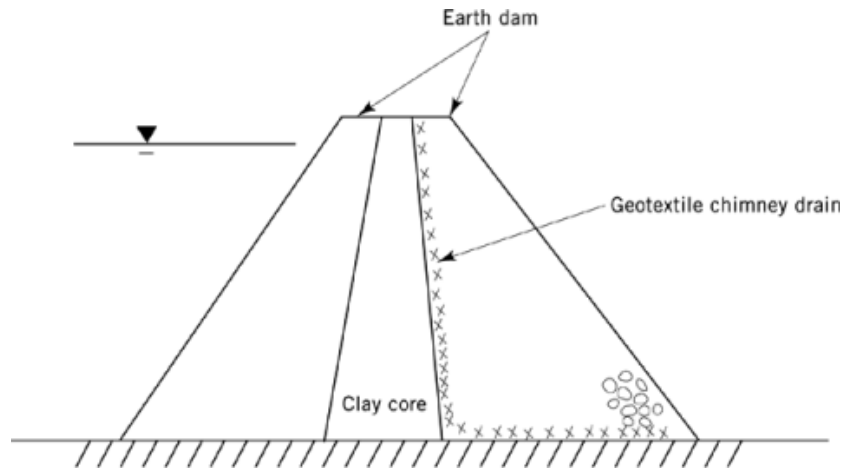
The drainage that is accomplished in this function takes place by one of two mechanisms: gravity or pressure flow. In order for gravity drainage to take place, the geotextile is installed at some incline from the horizontal, up to the point of being vertical. Installations using gravity drainage include chimney drains within earth dams, pore-pressure dissipators behind retaining walls, and for transport of water or air beneath a geomembrane. In pressure flow, fluid is flowing from a point of high pressure to a point of low pressure and the orientation of the geotextile is not critical. It can be placed horizontal, or at a specified incline from the horizontal. This type of drainage occurs when the geotextile is placed as a vertical drain to increase the rate of consolidation of a soil, placed within reinforced earth walls, in earth embankments or dams, and beneath surcharge fills.

The physical property of primary concern in this application is the transmissivity and, depending on the type of installation, the clogging potential and strength properties.

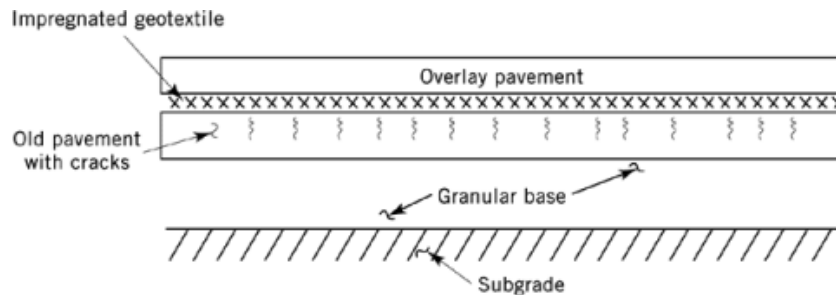
### 3.6. Moisture Barrier

When impregnated with an asphaltic emulsion, geotextiles become impermeable and can then be used as moisture barriers. The primary application for this type of geotextile is in pavement rehabilitation (Fig. 8).

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**Fig. 7.** Drainage parallel to the plane of a geotextile.



**Fig. 8.** Use of a geotextile as a moisture barrier.

One of the primary factors in the deterioration of a pavement structure is the intrusion of surface water into the support structure of the pavement. When rehabilitating a pavement, the installation of a moisture barrier between the old, existing pavement surface and the new overlay surface acts to retard moisture intrusion, thus prolonging the life of the overlay.

In this application, the primary property concern is asphalt absorption and retention. If the geotextile has poor retention capabilities, then the necessary waterproofing cannot be achieved.

### 4. Economic Aspects

Geotextiles are a relatively new concept for solving problems in geotechnical engineering. They have gained wide use as not only an economical solution to these problems, but in many instances as the only viable solution to a complex engineering problem. This is evidenced by the fact that over a seven-year period from 1976 to 1983 sales of geotextiles in North America alone rose from 5 to 115 m<sup>2</sup> (6 to 138 × 10<sup>6</sup>/yd<sup>2</sup>).

The installed price of geotextiles ranges from less than \$1.20/m<sup>2</sup> to over \$12/m<sup>2</sup> (\$1–10/yd<sup>2</sup>), depending on the geotextile and geographic location. The savings compared to what in the past were considered to be conventional solutions to geotechnical problems can range anywhere from a few thousand dollars per project to well over a million dollars, depending on the magnitude of the project.

Use of geotextiles should follow only after careful evaluation of the site conditions and the problems to be solved. In some sites almost any type of geotextile could be installed, survive the installation procedures, and perform as desired. However, there are sites that require a very detailed subsurface exploration program, appropriate soils testing to determine the soil conditions, followed by a detailed design procedure to ensure that the proper geotextile is properly installed. An improperly designed and installed geotextile can result in the desired improvement not being achieved, or in a failure of the site. In some cases a geotextile may not be the appropriate solution.

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