24

Geosynthetics

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24.1 Introduction

In only a very few years, geosynthetics (geotextiles, geogrids, and geomembranes) have joined the list of traditional civil engineering construction materials. Often the use of a geosynthetic can significantly increase the safety factor, improve performance, and reduce costs in comparison with conventional construction alternatives. In the case of embankments on extremely soft foundations, geosynthetics can permit construction to take place at sites where conventional construction alternatives would be either impossible or prohibitively expensive.

Two recent conferences dealt specifically with geosynthetics and soil improvement, and their proceedings deserve special mention (see Holtz [1988a] and Borden et al. [1992]).

After an introduction to geosynthetic types and properties, recent developments in the use of geosynthetics for the improvement of soils in foundations and slopes will be summarized. Primary applications are to drainage and erosion control systems, temporary and permanent roadways and railroads, soil reinforcement, and waste containment systems.

There are a number of **geotextile**-related materials, such as webs, mats, nets, grids, and sheets, which may be made of plastic, metal, bamboo, or wood, but so far there is no ASTM (American Society for Testing and Materials) definition for these materials. They are "geotextile-related" because they are used in a similar manner, especially in reinforcement and stabilization situations, to geotextiles.

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*.

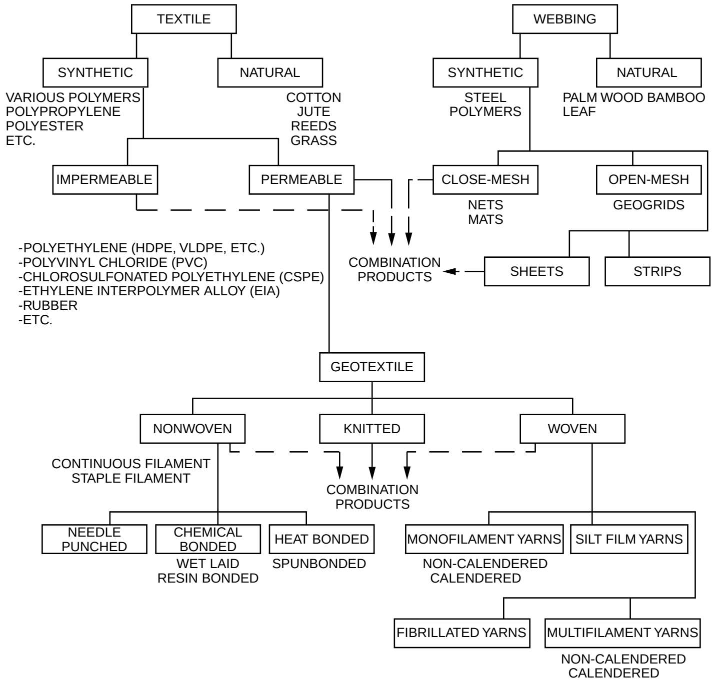

FIGURE 24.1 Classification of geosynthetics. [Adapted (from Rankilor, P. R. 1981. *Membranes in Ground Engineering*. John Wiley & Sons, New York) by Christopher, B. R., and Holtz, R. D. 1989. *Geotextile Design and Construction Guidelines*. U.S. Federal Highway Administration, National Highway Institute, Report No. FHWA-HI-90-001.]

Types and Manufacture

A convenient classification for geosynthetics is given in Fig. 24.1. For details on the composition, materials, and manufacture of geotextiles and related materials, see Koerner and Welsh [1980], Rankilor [1981], Giroud and Carroll [1983], Christopher and Holtz [1985], Veldhuijzen van Zanten [1986], Ingold and Miller [1988], and Koerner [1990a]. Most geosynthetics are made from synthetic polymers such as polypropylene, polyester, polyethylene, polyamide, and PVC. These materials are highly resistant to biological and chemical degradation. Natural fibers such as cotton, jute, and bamboo can be used as geotextiles and geogrids, especially for temporary applications, but they have not been promoted or researched as widely as geotextiles made from synthetic polymeric materials.

Applications and Functions

More than 150 separate applications of geosynthetics have been identified [Koerner, 1990a]. Table 24.1 lists those for geotextiles and related products, and the primary application areas are filtration and drainage, erosion protection and control, roadways and asphalt pavement overlays, and reinforced walls, slopes, and embankments. The primary geotextile functions are filtration, drainage, separation, and reinforcement. In virtually every application, the geotextile also provides one or more secondary functions of filtration, drainage, separation, and reinforcement (see Table 24.1). Geogrids, nets, webs, fascines, and so on are primarily used for roadway stabilization and all types of earth reinforcement. They also have significant applications in waste containment systems when used together with geotextile filters and geomembranes (geocomposites).

Historical and Recent Developments

Giroud [1986] and Fluet [1988] give interesting accounts of the history of geosynthetics. Few developments have had such a rapid growth and strong influence on so many aspects of civil engineering practice.

TABLE 24.1 Representative Applications and Controlling Functions of Geotextiles

Primary Function	Application	Secondary Functions
Separation	Unpaved roads (temporary and permanent)	Filter, drains, reinforcement
	Paved roads (secondary and primary)	Filter, drains
	Construction access roads	Filter, drains, reinforcement
	Working platforms	Filter, drains, reinforcement
	Railroads (new construction)	Filter, drains, reinforcement
	Railroads (rehabilitation)	Filter, drains, reinforcement
	Landfill covers	Drains, reinforcement
	Preloading (stabilization)	Drains, reinforcement
	Marine causeways	Filter, drains, reinforcement
	General fill areas	Filter, drains, reinforcement
	Paved and unpaved parking facilities	Filter, drains, reinforcement
	Cattle corrals	Filter, drains, reinforcement
	Coastal and river protection	Filter, drains, reinforcement
	Sports fields	Filter, drains
Drainage-transmission	Retaining walls	Separation, filter
	Vertical drains	Separation, filter
	Horizontal drains	Reinforcement
	Below membranes (drainage of gas and water)	Reinforcement
	Earth dams	Filter
	Below concrete (decking and slabs)	—
Reinforcement	Pavement overlays	—
	Concrete overlays	—
	Subbase reinforcement in roadways and railways	Filter
	Retaining structures	Drains
	Membrane support	Separation, drains, filter
	Embankment reinforcement	Drains
	Fill reinforcement	Drains
	Foundation support	Drains
	Soil encapsulation	Drains, filter separation
	Net against rockfalls	Drains
	Fabric retention systems	Drains
	Sandbags	—
	Reinforcement of membranes	—
	Load redistribution	Separation
	Bridging nonuniformity soft soil areas	Separation
	Encapsulated hydraulic fills	Separation
	Bridge piles for fill placement	—
Filter	Trench drains	Separation, drains
	Pipe wrapping	Separation, drains
	Base course drains	Separation, drains
	Frost protection	Separation, drainage, reinforcement
	Structural drains	Separation, drains
	Toe drains in dams	Separation, drains
	High embankments	Drains
	Filter below fabric-form	Separation, drains
	Silt fences	Separation, drains
	Silt screens	Separation
	Culvert outlets	Separation
	Reverse filters for erosion control:	
	Seeding and mulching	
	Beneath gabions	
	Ditch amoring	
	Embankment protection, coastal	
	Embankment protection, rivers and streams	
	Embankment protection, lakes	
	Vertical drains (wicks)	Separation

Source: Christopher, B. R., and Holtz, R. D. 1989. *Geotextile Design and Construction Guidelines.*, U.S. Federal Highway Administration, National Highway Institute, Report No. FHWA-HI-90-001.

In 1970, there were only five or six geotextiles available. Today more than 250 different materials are sold in the U.S. as geotextiles and geogrids; worldwide, the number probably exceeds 400. The size of the geotextile market, both in terms of square meters produced and their dollar value, is indicative of their influence. For example, in 1991, more than 300 million square meters of geotextiles and related materials such as geogrids were sold in North America. The worldwide consumption was probably more than twice this amount. The value of these materials is probably close to $500 million. Since the total cost of the construction is at least four or five times the cost of the geosynthetic itself, the impact of these materials on civil engineering construction is very large indeed.

Another important recent development is the rapid growth of the literature on geosynthetics. This literature includes books, conference proceedings, and technical journals devoted to various aspects of geosynthetics. A listing of geosynthetic literature can be found in Holtz and Paulson [1988] and Cazzuffi and Anzani [1992].

Design and Selection

In the early days of geotextiles, selection and specification were primarily by type or brand name. This was satisfactory as long as there were only a few geotextiles on the market and the choices available to the designer were limited. Today, however, with such a wide variety of geosynthetics available, this approach is inappropriate. The recommended approach for designing, selecting, and specifying geosynthetics is no different than what is commonly practiced in any geotechnical engineering design. First, the design should be made *without* geosynthetics to see if they really are needed. If conventional solutions are impractical or uneconomical, design calculations using reasonable engineering estimates of the required geosynthetic properties are carried out. Next, generic or performance type specifications are written so that the most appropriate and economical geosynthetic is selected, consistent with the properties required for its function, constructibility, and endurance. In addition to conventional soils and materials testing, geosynthetic testing will very likely be required. Finally, as with any other construction, design with geosynthetics is not complete until construction has been satisfactorily carried out. Therefore, careful field inspection during construction is essential for a successful project.

Properties and Tests

Because of the wide variety of geosynthetics available (Fig. 24.1), along with their different polymers, filaments, bonding mechanisms, thicknesses, masses, and so on, they have a wide range of physical and mechanical properties. A further complicating factor is the variability of some properties, even within the same manufactured lot or roll. Differences may sometimes be due to the test procedures themselves.

Many of our current geosynthetic tests were developed by the textile and polymer industries, often for quality control of the manufacturing process. Consequently the test values from these tests may not relate well to the civil engineering conditions of a particular application. Furthermore, soil confinement or interaction is not accounted for in most geosynthetics testing. Research is now underway to provide test procedures and soil–geosynthetic interaction properties which are more appropriate for design. Geotextile testing is discussed in detail by Christopher and Holtz [1985] and Koerner [1990a].

Specifications

Good specifications are essential for the success of any civil engineering project, and this is even more critical for projects in which geosynthetics are to be used. Christopher and DiMaggio [1984] provide some guidance on writing generic and performance-based geotextile specifications.

24.2 Filtration, Drainage, and Erosion Control

One of the most important uses for geotextiles is as a filter in drainage and erosion control applications. Drainage examples include trench and French drains, interceptor drains, blanket drains, pavement edge drains, and structural drains, to name just a few. Permanent erosion control applications include coastal and lakeshore revetments, stream and canal banks, cut and fill slope protection, and scour protection. In all these applications, geotextiles are used to replace graded granular filters used in conjunction with the drainage aggregate, perforated pipe, rip rap, and so on. When properly designed, geotextiles can provide comparable performance at less cost, provide consistent filtration characteristics, and they are easier and therefore cheaper to install. Although erosion control technically does not improve the soil, prevention of both external and internal erosion in residual and structured soils is an important design consideration.

Geotextiles can also be used to temporarily control and minimize erosion or transport of sediment from unprotected construction sites. In some cases, geotextiles provide temporary protection after seeding and mulching but before vegetative ground cover can be established. Geotextiles may also be used as armor materials in diversion ditches and at the ends of culverts to prevent erosion. Probably the most common application is for silt fences, which are a substitute for hay bales or brush piles, to remove suspended particles from sediment-laden runoff water.

Filtration Design Concepts

For a geotextile to satisfactorily replace a graded granular filter, it must perform the same functions as a graded granular filter: (1) prevent soil particles from going into suspension; (2) allow soil particles already in suspension to pass the filter (to prevent clogging or blinding); and (3) have a sufficiently high permeability and flow rate so that no back pressure develops in the soil being protected.

How a geotextile filter functions is discussed in detail by Bell et al. [1980, 1982], Rankilor [1981], Christopher and Holtz [1985], and Koerner [1990a]. The factors that control the design and performance of a geotextile filter are (1) physical properties of the geotextile, (2) soil characteristics, (3) hydraulic conditions, and (4) external stress conditions.

After a detailed study of research carried out here and in Europe on both conventional and geotextile filters, Christopher and Holtz [1985] developed a widely used design procedure for geotextile filters for drainage and permanent erosion-control applications. The level of design required depends on the critical nature of the project and the severity of the hydraulic and soil conditions. Especially for critical projects, consideration of the risks involved and the consequences of possible failure of the geotextile filter require great care in selecting the appropriate geotextile. For such projects and for severe hydraulic conditions, very conservative designs are recommended. As the cost of the geotextile is usually a minor part of the total project or system cost, geotextile selection should not be based on the lowest material cost. Also, expenses should not be reduced by eliminating laboratory soil–geotextile performance testing when such testing is recommended by the design procedure.

The three design criteria which must be satisfied are (1) soil retention (piping resistance), (2) permeability, and (3) clogging criteria. For both permeability and clogging, different approaches are recommended for critical/severe applications. Furthermore, laboratory filtration tests must be performed to determine clogging resistance. It is not sufficient to simply rely on retention and permeability to control clogging potential. Finally, mechanical and index property requirements for durability and constructibility are given. Constructibility is sometimes called *survivability*, and it depends on the installation conditions. The best geotextile filter design in the world is useless if the geotextile does not survive the construction operations.

Fischer et al. [1990] have proposed a design procedure based on the pore size distribution of the geotextile filter.

Applications

The more common applications of geotextiles in drainage and erosion control are shown in Figs. 24.2, 24.3, and 24.4. Construction of geotextile filters in these applications is described in detail by Christopher and Holtz [1985, 1989].

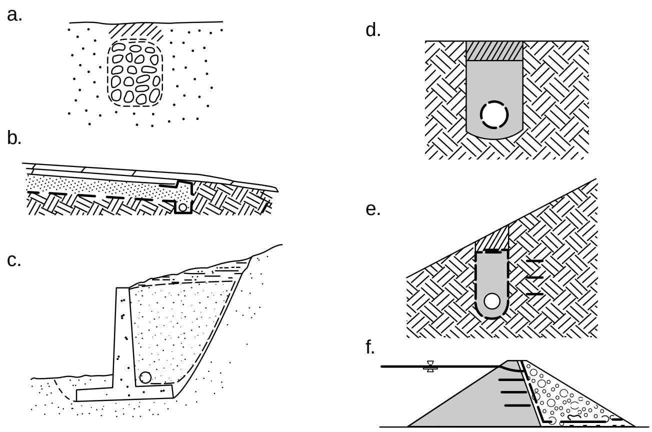

FIGURE 24.2 Drainage applications: (a) trench drains, (b) blanket and pavement edge drains, (c) structural drains, (d) pipe wraps, (e) interceptor drains, and (f) drains in dams. (*Source:* Christopher, B. R., and Holtz, R. D. 1989. *Geotextile Design and Construction Guidelines*. U.S. Federal Highway Administration, National Highway Institute, Report No. FHWA-HI-90-001.)

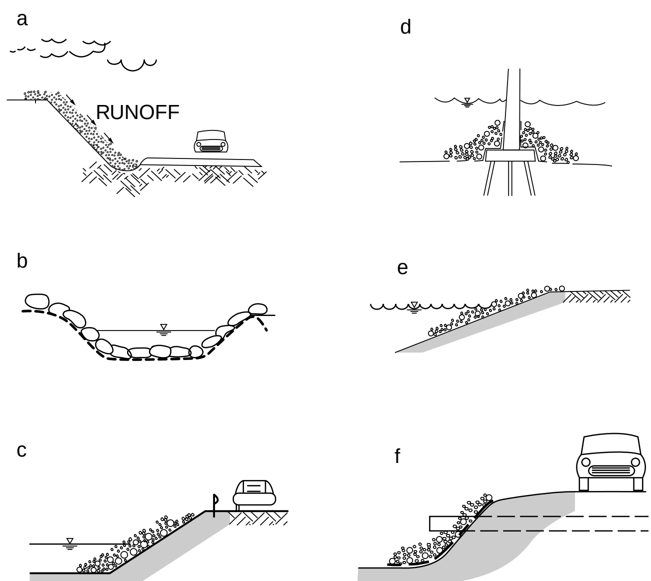

FIGURE 24.3 Permanent erosion control applications: (a) slope protection, (b) diversion ditches, (c) stream and canal banks, (d) scour protection, (e) beaches, and (f) culvert outlets. (*Source:* Christopher, B. R., and Holtz, R. D. 1989, *Geotextile Design and Construction Guidelines*. U.S. Federal Highway Administration, National Highway Institute, Report No. FHWA-HI-90-001.)

Prefabricated Drains

In the last few years, prefabricated geocomposite drainage materials have become available as a substitute for conventional drains with and without geotextiles. Geocomposites are probably most practical for lateral drainage situations [Figs. 24.2(b), (c), and (e)] and in waste containment systems in conjunction with clay or geomembrane liners [Koerner, 1990a]. Another important soil improvement application of

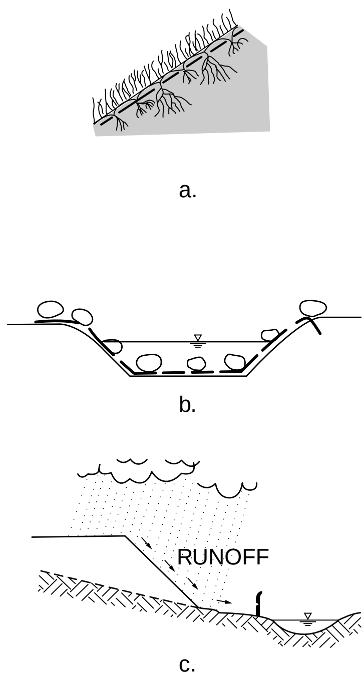

FIGURE 24.4 Temporary erosion control applications: (a) vegetative cover, (b) diversion ditches, and (c) silt fences. (*Source:* Christopher, B. R., and Holtz, R. D. 1989. *Geotextile Design and Construction Guidelines*. U.S. Federal Highway Administration, National Highway Institute, Report No. FHWA-HI-90-001.)

geocomposites is the use of prefabricated vertical ("wick") drains to accelerate the consolidation of soft compressible cohesive soil layers. Because they are much less expensive to install, geocomposite drains have made conventional sand drains obsolete. Design principles and installation techniques are given by Holtz et al. [1991].

24.3 Geosynthetics in Temporary and Permanent Roadways and Railroads

A very important use of geosynthetics is to stabilize roadways and railroads. The primary function of the geosynthetic in these applications is that of separation; secondary functions such as filtration, drainage, and possibly reinforcement may also be more or less present. Recommended references on geotextiles in various aspects of roads and railroads are Steward et al. [1977], Rankilor [1981], Christopher and Holtz [1985, 1989], Fluet [1986], and Koerner [1990a].

In the early days of geotextiles, a number of design procedures were developed to use geotextiles in temporary facilities such as haul roads, contractor staging yards, mine and timber storage and haulage facilities, temporary construction platforms, and so on. Virtually all methods provided design charts which indicated that the use of a geotextile could reduce the thickness of aggregate required for a given subgrade and traffic condition. Unfortunately, most of these design methods permitted some rutting to occur in the subgrade even with the geotextile in place; obviously, rutting is not desirable for permanent facilities. Although the geotextile functions are similar for both temporary and permanent roadways, because of the difference in performance requirements, design methods for temporary roads should *not* be used to design permanent roads. However, as noted by Christopher and Holtz [1985], there still are a number of significant advantages to using geotextiles in permanent roadways.

Geosynthetics in roadways are most cost effective on soft subgrades (CBR values less than 2) with sensitive silty or clayey soils (CH, ML, MH, A-6, A-7, etc.), and at sites with the water table near the ground surface and where there is poor equipment mobility. If such conditions are present in residual and structured soil subgrades, geotextiles should also be effective stabilizers of subgrades on these soils. One important consequence of using geotextiles in roadway construction is that the contractors are required to be more careful during construction to avoid damaging the geotextile. Such care usually results in reduced stress and damage to the subgrade soils, which is especially appropriate for residual and structured soil subgrades.

Although there is strong evidence that the primary function of geotextiles in roadways is separation [Steward et al., 1977], research has suggested a number of possible geosynthetic reinforcement mechanisms [Christopher and Holtz, 1985]. For example, a geogrid placed in the aggregate base course will provide a significant increase in load-carrying capacity [Haas et al., 1988].

Design Approaches

Design of geosynthetics in both temporary and permanent roadways is discussed at length by Christopher and Holtz [1985, 1989] and Koerner [1990a]. Recommended temporary road design methods are discussed by Steward, et al. [1977], Bender and Barenberg [1978], Giroud and Noiray [1981], Haliburton and Barron [1983], Houlsby et al. [1989], and Milligan et al. [1989]. The last two papers are summarized by Jewell [1990].

Because most of the available design methods for permanent roadways lack field or controlled experimental verification, Christopher and Holtz [1991] proposed a simple procedure which assumes that the first aggregate stabilization layer often required to permit construction at very soft, wet sites acts as an unpaved road subjected to only a few passes of construction equipment. The geotextile acts primarily as a separator, and geotextile survivability must be taken into account [Christopher and Holtz, 1985, 1989]. It should be noted that no structural support is attributed to the geotextile in this design procedure. The method does not change the design thickness required for traffic or other design considerations. It only allows aggregate to be saved which would otherwise be consumed in constructing the first stabilization lift.

Detailed guidelines for the construction of roads using geotextiles are given by Christopher and Holtz [1985, 1989].

24.4 Geosynthetics for Reinforcement

One of the most important applications of geosynthetics in geotechnical engineering is soil reinforcement, an important aspect of soil improvement. Applications include reinforcing the base of embankments constructed on very soft foundations, increasing the stability and steepness of slopes, and reducing the earth pressures behind retaining walls and abutments. In the first two applications, geosynthetics permit construction that otherwise would be cost-prohibitive or in some cases impossible. In the case of retaining walls, significant cost savings are possible in comparison with conventional retaining wall construction.

Other reinforcement and stabilization applications in which geosynthetics have also proven to be very effective include large area stabilization and natural slope reinforcement.

Reinforced Embankments

In only a few years, geosynthetic reinforcement has joined the list of the more traditional soil improvement methods for increasing the stability of embankments on very soft foundations. Concepts for using geosynthetics for reinforcement are indicated in Fig. 24.5. Discussion of these concepts as well as detailed design procedures are given by Christopher and Holtz [1985, 1989], Bonaparte et al. [1987], Bonaparte and Christopher [1987], Holtz [1989a, 1989b, 1990], and Humphrey and Rowe [1991]. As our approach is to design against failure, types of unsatisfactory behavior (Fig. 24.6) which are likely to require reinforcement must be assumed so that an appropriate stability analysis may be carried out.

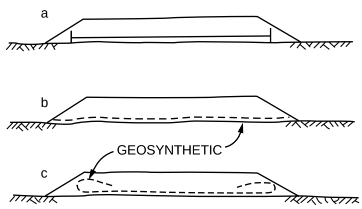

FIGURE 24.5 Concepts for using geosynthetics to reinforce embankments. (*Source:* Holtz, R. D. 1990. Design and construction of geosynthetically reinforced embankments on very soft soils. In *Performance of Reinforced Soil Structures, Proc. Int. Reinforced Soil Conf.* Glasgow, British Geotechnical Society, pp. 391–402.)

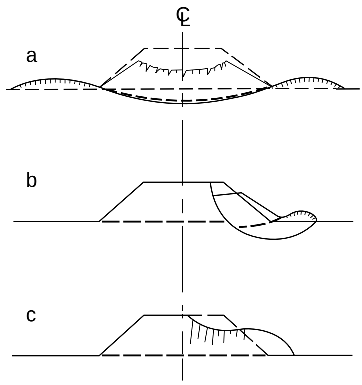

FIGURE 24.6 Unsatisfactory behavior that may occur in reinforced embankments. (*Source:* Christopher, B. R., and Holtz, R. D. 1989. *Geotextile Design and Construction Guidelines.* U.S. Federal Highway Administration, National Highway Institute, Report No. FHWA-HI-90-001.)

The design steps are as follows:

1. Check overall bearing capacity.
2. Check edge bearing capacity or edge slope stability.
3. Conduct a sliding wedge analysis for embankment spreading.
4. Perform an analysis to limit geosynthetic deformations.
5. Determine geosynthetic strength requirements in the longitudinal direction.

Based on these stability calculations, the minimum geosynthetic strengths required for stability at an appropriate factor of safety can be determined. A detailed discussion of geosynthetic properties and specifications is given in the references cited above.

The importance of proper construction procedures for geosynthetic reinforced embankments cannot be overemphasized. A specific construction sequence is usually required in order to avoid failures during construction. Appropriate site preparation, low ground pressure equipment, small initial lift thicknesses, and partially loaded hauling vehicles may be required. Fill placement, spreading, and compaction procedures are also very important. A detailed discussion of construction procedures for reinforced embankments on very soft foundations is given by Christopher and Holtz [1985, 1989].

It should be noted that all geosynthetic seams must be positively joined. For geotextiles, this means sewing; for geogrids, some type of positive clamping arrangement must be used. Careful inspection is essential, as the seams are the "weak link" in the system and seam failures are common in embankments which are improperly constructed.

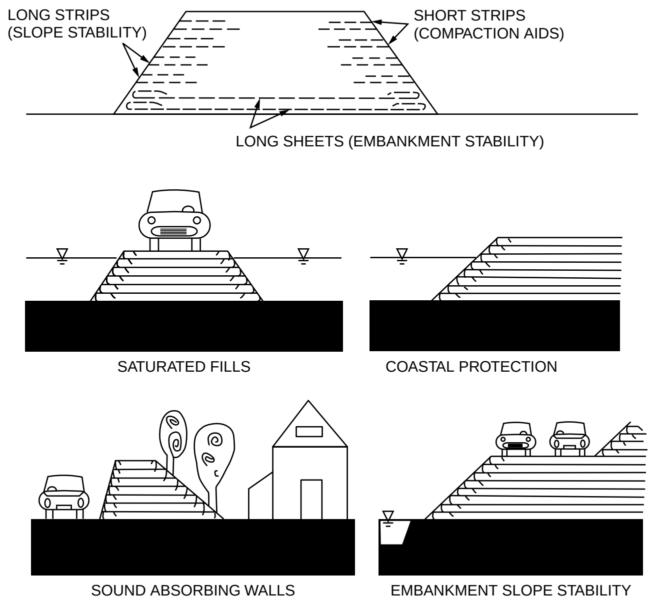

FIGURE 24.7 Examples of multilayer geosynthetic slope reinforcement. (*Source:* Christopher, B. R., and Holtz, R. D. 1985. *Geotextile Engineering Manual*. STS Consultants Ltd., Northbrook, IL; U.S. Federal Highway Administration, Report No. FHWA-TS-86/203.)

Slope Stability

Geosynthetics have been very effectively used many times both here and abroad to stabilize failed slopes. Cost savings result because the slide debris is reused together with geosynthetic reinforcement in the reinstatement of the slope. It is also possible that even though foundation conditions are satisfactory, slopes of a compacted embankment fill may be unstable at the desired slope angle. Costs of fill and right-of-way plus other considerations may require a steeper slope than is stable in compacted soils. Typically, embankment slope reinforcement is placed in layers as the embankment is constructed in lifts (see Fig. 24.7).

Embankment slope stability analyses have been developed by Murray [1982], Jewell et al. [1984], Schneider and Holtz [1986], Schmertmann et al. [1987], Verduin and Holtz [1989], Christopher et al. [1989], and Christopher and Leshchinsky [1991].

Reinforced Retaining Walls and Abutments

Retaining walls are used where a slope is uneconomical or not technically feasible. Retaining walls with reinforced backfills are very cost-effective, especially for higher walls; also, they are more flexible and thus more suitable for poor foundation conditions. The concept was developed in France by H. Vidal in the mid-1960s. His system, called *reinforced earth,* is shown in Fig. 24.8. Steel strips or ties are used to reduce the earth pressure against the wall face ("skin"). The design and construction of Vidal-type reinforced earth walls are now well established, and many thousands have been successfully built throughout the world in the last 25 years.

The use of geotextiles as reinforcing elements started in the early 1970s because of questions about possible corrosion of the metallic strips in reinforced earth. Systems using sheets of geosynthetics rather than steel strips are shown in Fig. 24.9. The most commonly used system is shown in Fig. 24.9(a), in which the geosynthetic provides the facing as well as the reinforcing elements in the wall.

Most designs of geotextile reinforced retaining walls utilize classical earth pressure theory combined with tensile-resistance *tiebacks,* in which the reinforcement extends back beyond the assumed failure

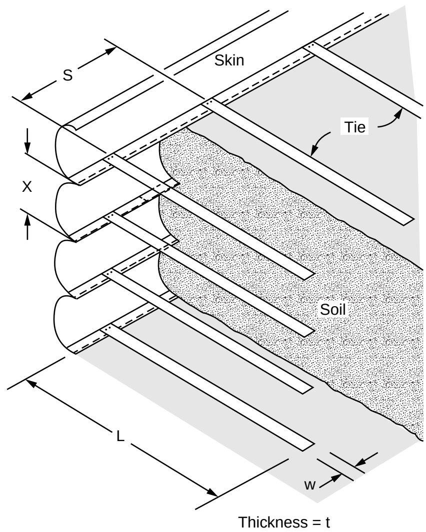

FIGURE 24.8 Components of reinforced earth. (*Source:* Lee, K. L., Adams, B. D., and Vagneron, J. M. J. 1973. Reinforced earth retaining walls. *J. Soil Mech. Found., ASCE.* 99(SM10):745–764.)

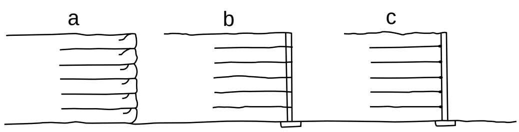

FIGURE 24.9 Reinforced retaining wall systems using geosynthetics: (a) with wraparound geosynthetic facing, (b) with segmented precast concrete or timber panels, and (c) with full height ("propped") precast panels.

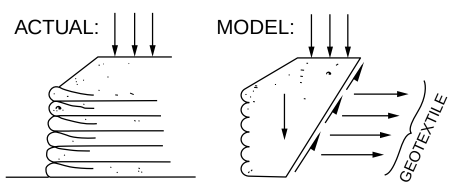

FIGURE 24.10 Actual geosynthetic-reinforced wall compared to its analytical model. (*Source:* Christopher, B. R., and Holtz, R. D. 1985. *Geotextile Engineering Manual.* STS Consultants Ltd., Northbrook, IL; U.S. Federal Highway Administration, Report No. FHWA-TS-86/203.)

plane (see Fig. 24.10). This approach is discussed by Christopher and Holtz [1985, 1989], Bonaparte et al. [1987], Christopher et al. [1989], and Allen and Holtz [1991]. Both internal and external stability must be considered. Failure modes and geosynthetic properties required for design are given in Table 24.2; these are patterned after the failure modes for reinforced earth. Christopher and Holtz [1985, 1989], Bonaparte et al. [1987], and Christopher et al. [1989] discuss how these properties may be obtained by laboratory and other tests.

Typically, sliding of the entire reinforced mass controls the length of the reinforcing elements. Thus Christopher and Holtz [1989] and Christopher et al. [1989] recommend starting with a sliding analysis first (considering surcharges, etc.) and then designing for internal stability before proceeding to check the other components of external stability (bearing capacity, overturning, and slope stability). Surcharges may be considered in the usual manner, and both stiff and flexible facings are possible. For design, K_0 and K_A may be assumed, depending on the rigidity of the facing and the amount of yielding likely to occur during construction.

TABLE 24.2 Failure Modes in Geosynthetically Reinforced Retaining Walls

Geosynthetic Failure Mode	Corresponding Reinforced Earth Failure Mode	Property Required
Geosynthetic rupture	Ties break	Geosynthetic tensile strength
Geosynthetic pullout	Ties pull out	Soil-geosynthetic friction
Creep	Creep	Creep resistance

Source: Christopher, B.R. and Holtz, R.D. 1985. *Geotextile Engineering Manual.* STS Consultants Ltd., Northbrook, IL; U.S. Federal Highway Administration, Report No. FHWA-TS-86/203.

Backfill for geosynthetically reinforced walls should be free draining. This is important for stability considerations and because an impervious permanent facing is often used; thus, drainage outward through the wall face may not be possible. For permanent construction, some type of permanent facing is required because of possible deterioration of the geosynthetic due to ultraviolet radiation. This is the only application in which the geosynthetic is not entirely buried, and consequently, some ultraviolet deterioration and loss of stability, at least locally, is possible. Permanent facings which have been successfully used include shotcrete, sprayed asphalt emulsion, precast concrete elements hung on the wall, segmented precast concrete blocks, and separate timber or precast concrete facades.

Construction procedures for geosynthetic reinforced walls and abutments are quite straightforward. Details are given by Steward et al. [1977] and Christopher and Holtz [1985, 1989].

24.5 Geosynthetics in Waste Containment Systems

Geomembranes and geocomposite drainage systems are commonly used today in the construction and remediation of containment and disposal systems for hazardous, industrial, and domestic wastes. Although not directly part of soil improvement, their importance in environmental geotechnology deserves special mention. Tremendous advances have been made in recent years in geomembrane technology, yet the seams and joints between sheets of geomembrane are still the weak link in these systems. Inspection during construction is crucial; improper installation or damage to the membrane during construction operations may compromise the integrity of the entire containment system. Helpful references on geomembrane technology and related systems include Koerner [1990a, 1990b], Bonaparte [1990], and Rollin and Rigo [1991].

Defining Terms

Geomembrane — Continuous membrane-type liners and barriers composed of asphaltic, polymeric, or a combination of asphaltic and polymeric materials with sufficiently low permeability so as to control fluid migration in a geotechnical engineering-related man-made project, structure, or system.

Geotextile — The American Society for Testing and Materials (ASTM) has defined a *geotextile* 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.

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