2.0 GEOSYNTHETICS IN SUBSURFACE DRAINAGE SYSTEMS

2.1 BACKGROUND

One major area of geotextile use is as filters in drain applications such as trench and interception drains, blanket drains, pavement edge drains, structure drains, and beneath permeable roadway bases. The *filter* restricts movement of soil particles as water flows into the *drain* structure and is collected and/or transported downstream. Geocomposites consisting of a drainage core surrounded by a geotextile filter are often used as the drain itself in these applications. Geotextiles are also used as filters beneath hard armor erosion control systems, and this application will be discussed in Chapter 3.

Because of their comparable performance, improved economy, consistent properties, and ease of placement, geotextiles have been used successfully to replace graded granular filters in almost all drainage applications. Thus, they must perform the same functions as graded granular filters:

- to allow water to flow through the filter into the drain, and to continue doing this throughout the life of the project; and
- to retain the soil particles in place and prevent their migration (*piping*) through the filter (if some soil particles do move, they must be able to pass through the filter without blinding or clogging the downstream media during the life of the project).

Geotextiles, like graded granular filters, require proper engineering design or they may not perform as desired. Unless flow requirements, piping resistance, clogging resistance and constructability requirements (defined later) are properly specified, the geotextile/soil filtration system may not perform properly. In addition, construction must be monitored to ensure that materials are installed correctly.

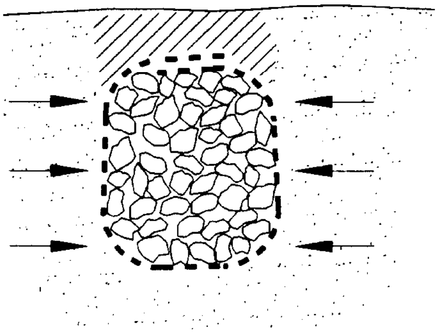
In most drainage and filtration applications, geotextile use can be justified over conventional graded granular filter material use because of cost advantages from:

- the use of less-costly drainage aggregate;
- the possible use of smaller-sized drains;
- the possible elimination of collector pipes;
- expedient construction;
- lower risk of contamination and segregation of drainage aggregate during construction;
- reduced excavation.

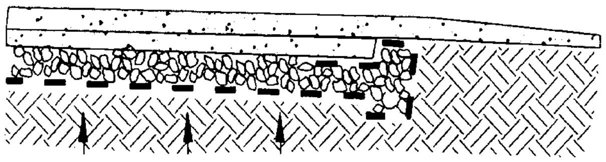
2.2 APPLICATIONS

Properly designed geotextiles can be used as a replacement for, or in conjunction with, conventional graded granular filters in almost any drainage application. Properly designed geocomposites can be used as a replacement for granular drains in many applications (*e.g.*, pavement edge drains). Below are a few examples of drainage applications.

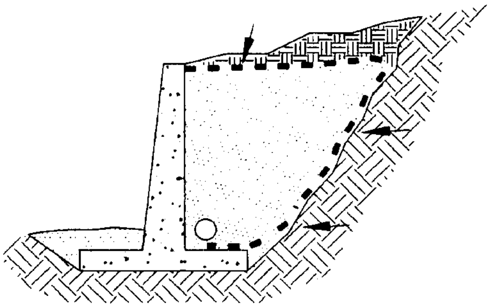
- Filters around trench drains and edge drains -- to prevent soil from migrating into the drainage aggregate or system, while allowing water to exit from the soil.



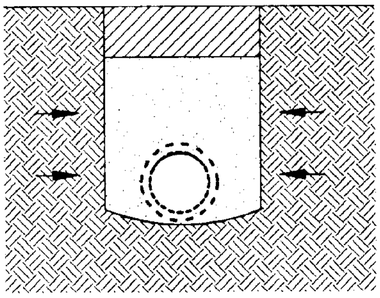
- Filters beneath pavement permeable bases, blanket drains and base courses. Prefabricated geocomposite drains and geotextile-wrapped trenches are used in pavement edge drain construction.



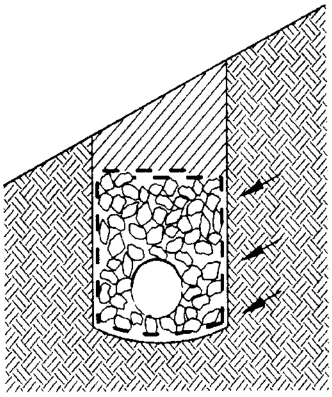
- Drains for structures such as retaining walls and bridge abutments. They separate the drainage aggregate or system from the backfill soil, while allowing free drainage of ground and infiltration water. Geocomposite drains are especially useful in this application.



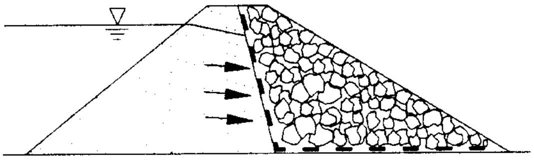
- Geotextile wraps for slotted or jointed drain and well pipes -- to prevent filter aggregate from entering the pipe, while allowing the free flow of water into the pipe.



- Interceptor, toe drains, and surface drains -- to aid in the stabilization of slopes by allowing excess pore pressures within the slope to dissipate, and by preventing surface erosion. Again, geocomposites have been successfully used in this application.



- Chimney and toe drains for earth dams and levees -- to provide seepage control.



In each of these applications, flow is through the geotextile -- that is, perpendicular to the plane of the fabric. In other applications, such as vertical drains in soft foundation soils, lateral drains below slabs and behind retaining walls, and gas transfer media, flow may occur both perpendicular to and transversely in the plane of the geotextile. In many of these applications, geocomposite drains may be appropriate. Design with geocomposite systems is covered in Section 2.11.

All geosynthetic designs should begin with a criticality and severity assessment of the project conditions (see Table 2-1) for a particular application. Although first developed by Carroll (1983) for drainage and filtration applications, the concept of critical-severe projects -- and, thus, the level of engineering responsibility required -- will be applied to other geosynthetic applications throughout this manual.

TABLE 2-1
GUIDELINES FOR EVALUATING THE CRITICAL NATURE OR SEVERITY OF DRAINAGE AND EROSION CONTROL APPLICATIONS
(after Carroll, 1983)

A. Critical Nature of the Project		
Item	Critical	Less Critical
1. Risk of loss of life and/or structural damage due to drain failure:	High	None
2. Repair costs versus installation costs of drain:	>>>	= or <
3. Evidence of drain clogging before potential catastrophic failure:	None	Yes
B. Severity of the Conditions		
Item	Severe	Less Severe
1. Soil to be drained:	Gap-graded, pipable, or dispersible	Well-graded or uniform
2. Hydraulic gradient:	High	Low
3. Flow conditions:	Dynamic, cyclic, or pulsating	Steady state

A few words about the condition of the soil to be drained (Table 2-1) are in order. First, gap-graded, well-graded and uniform soils are illustrated in Figure 2-1. Certain gap-graded and broadly graded soils may be *internally unstable*; that is, they can experience piping or internal erosion. On the other hand, a soil is *internally stable* if it is self-filtering and if its own fine particles do not move through the pores of its coarser fraction (LaFluer, et al., 1993). Criteria for deciding whether a soil is internally unstable will be given in the next section.

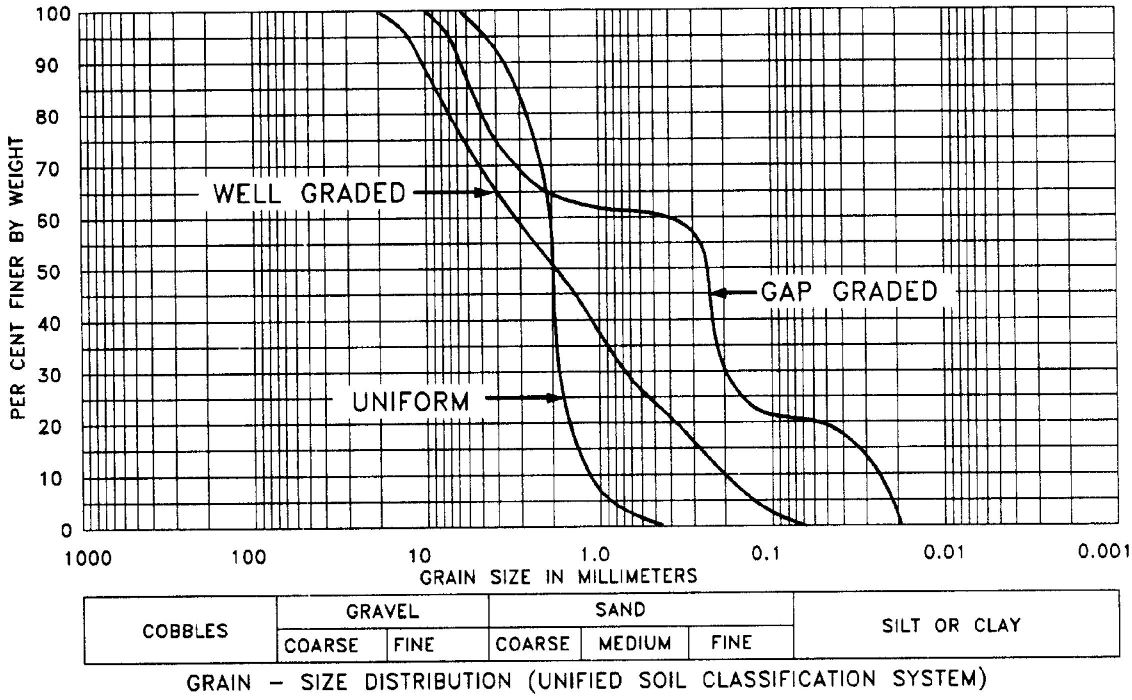


Figure 2-1 Soil descriptions.

Dispersible soils are fine-grained natural soils which deflocculate in the presence of water and, therefore, are highly susceptible to erosion and piping (Sherard, et al., 1972). See also Sherard and Decker (1977) for more information on dispersible soils.

2.3 GEOTEXTILE FILTER DESIGN

Designing with geotextiles for filtration is essentially the same as designing graded granular filters. A geotextile is similar to a soil in that it has voids (pores) and particles (filaments and fibers). However, because of the shape and arrangement of the filaments and the compressibility of the structure with geotextiles, the geometric relationships between filaments and voids is more complex than in soils. In geotextiles, pore size is measured directly, rather than using particle size as an estimate of pore size, as is done with soils. Since pore size can be directly measured, relatively simple relationships between the pore sizes and particle sizes of the soil to be retained can be developed. Three simple filtration concepts are used in the design process:

1. If the size of the largest pore in the geotextile filter is smaller than the larger particles of soil, the soil will be retained by the filter. As with graded granular filters, the larger

particles of soil will form a filter bridge over the hole, which in turn, filters smaller particles of soil, which then retain the soil and prevent piping (Figure 2-2).

2. If the smaller openings in the geotextile are sufficiently large enough to allow smaller particles of soil to pass through the filter, then the geotextile will not *blind* or *clog* (see Figure 2-3).
3. A large number of openings should be present in the geotextile so proper flow can be maintained even if some of the openings later become plugged.

These simple concepts and analogies with soil filter design criteria are used to establish design criteria for geotextiles. Specifically, these criteria state:

- the geotextile must retain the soil (retention criterion), while
- allowing water to pass (permeability criterion), throughout
- the life of the structure (clogging resistance criterion).

To perform effectively, the geotextile must also survive the installation process (survivability criterion).

After a detailed study of research carried out both in North America and in Europe on conventional and geotextile filters, Christopher and Holtz (1985) developed the following design procedure for geotextile filters for drainage (this chapter) and permanent erosion control applications (Chapter 3). The level of design required depends on the critical nature of the project and the severity of the hydraulic and soil conditions (Table 2-1). Especially for critical projects, consideration of the risks and the consequences of geotextile filter failure require great care in selecting the appropriate geotextile. For such projects, and for severe hydraulic conditions, conservative designs are recommended. **Geotextile selection should not be based on cost alone.** The cost of the geotextile is usually minor in comparison to the other components and the construction costs of a drainage system. Also, do not try to save money by eliminating laboratory soil-geotextile performance testing when such testing is required by the design procedure.

A recent National Cooperative Highway Research Program (NCHRP) study (Koerner et al., 1994) of the performance of geotextile drainage systems indicated that the FHWA design criteria developed by Christopher and Holtz (1985) were an excellent prediction of filter performance, particularly for granular soils (<50% passing a 0.075 mm sieve).

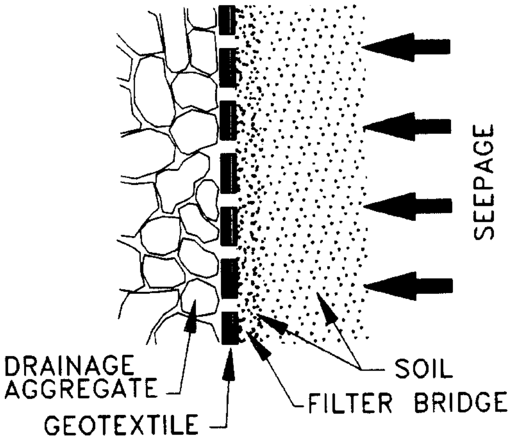


Figure 2-2 Filter bridge formation.

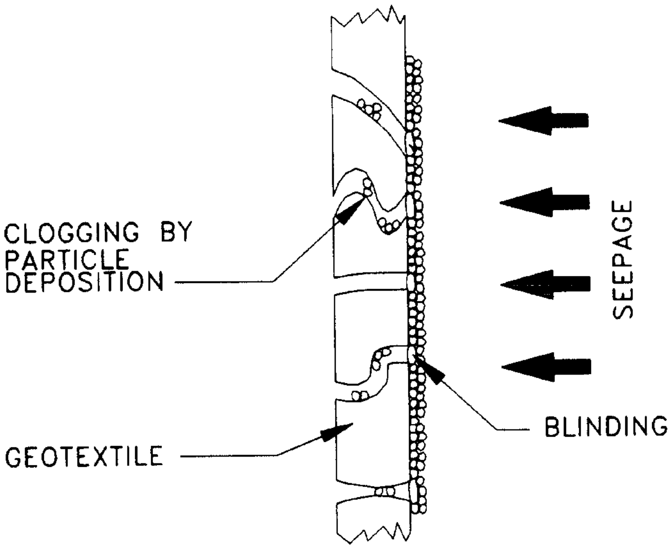


Figure 2-3 Definitions of clogging and blinding (Bell and Hicks, 1980).

2.3-1 Retention Criteria

2.3-1.a Steady State Flow Conditions

$$\text{AOS or } O_{95(\text{geotextile})} \leq B\, D_{85\,(\text{soil})} \qquad [2 - 1]$$

where:

AOS = apparent opening size (see Table 1-3) (mm);
O_{95} = opening size in the geotextile for which 95% are smaller (mm);
AOS ≈ O_{95};
B = a coefficient (dimensionless); and
D_{85} = soil particle size for which 85% are smaller (mm).

The coefficient B ranges from 0.5 to 2 and is a function of the type of soil to be filtered, its density, the uniformity coefficient C_u if the soil is granular, the type of geotextile (woven or nonwoven), and the flow conditions.

For *sands, gravelly sands, silty sands,* and *clayey sands* (with less than 50% passing the 0.075 mm sieve per the Unified Soil Classification System), B is a function of the uniformity coefficient, C_u. Therefore, for

$$C_u \leq 2 \text{ or } \geq 8: \qquad B = 1 \qquad [2 - 2a]$$

$$2 \leq C_u \leq 4: \qquad B = 0.5\, C_u \qquad [2 - 2b]$$

$$4 < C_u < 8 \qquad B = 8/C_u \qquad [2 - 2c]$$

where:

C_u = D_{60}/D_{10}.

Sandy soils which are not uniform (Figure 2-1) tend to bridge across the openings; thus, the larger pores may actually be up to twice as large ($B \leq 2$) as the larger soil particles because, quite simply, two particles cannot pass through the same hole at the same time. Therefore, use of the criterion $B = 1$ would be quite conservative for retention, and such a criterion has been used by, for example, the Corps of Engineers.

If the protected soil contains any fines, use only the portion passing the 4.75 mm sieve for selecting the geotextile (*i.e.*, scalp off the +4.75 mm material).

For *silts and clays* (with more than 50% passing the 0.075 mm sieve), B is a function of the type of geotextile:

for *wovens*, $B = 1;\ O_{95} \leq D_{85}$ [2 - 3]

for *nonwovens*, $B = 1.8;\ O_{95} \leq 1.8\ D_{85}$ [2 - 4]

and *for both*, AOS or $O_{95} \leq 0.3$ mm [2 - 5]

Due to their random pore characteristics and, in some types, their felt-like nature, nonwovens will generally retain finer particles than a woven geotextile of the same AOS. Therefore, the use of $B = 1$ will be even more conservative for nonwovens.

In absence of detailed design, the AASHTO M 288 Standard Specification for Geotextiles (1997) provides the following recommended maximum AOS values in relation to percent of situ soil passing the 0.075 mm sieve: (i) 0.43 mm for less than 15% passing; (ii) 0.25 mm for 15 to 50% passing; and (iii) 0.22 mm for more than 50% passing. However, for cohesive soils with a plasticity index greater than 7, the maximum AOS size is 0.30 mm. These default AOS values are based upon the predominant particle sizes of the in situ soil. The engineer may require performance testing based on engineering design for drainage systems in problematic soil environments. Site specific testing should be performed especially if one or more of the following problematic soil environments are encountered: unstable or highly erodible soils such as non-cohesive silts; gap graded soils; alternating sand/silt laminated soils; dispersive clays; and/or rock flour.

2.3-1.b Dynamic Flow Conditions

If the geotextile is not properly weighted down and in *intimate contact* with the soil to be protected, or if dynamic, cyclic, or pulsating loading conditions produce high localized hydraulic gradients, then soil particles can move behind the geotextile. Thus, the use of $B = 1$ is not conservative, because the bridging network will not develop and the geotextile will be required to retain even finer particles. When retention is the primary criteria, B should be reduced to 0.5; or:

$$O_{95} \leq 0.5\ D_{85} \qquad [2\ \text{-}6]$$

Dynamic flow conditions can occur in pavement drainage applications. For reversing inflow-outflow or high-gradient situations, it is best to maintain sufficient weight or load on the filter to prevent particle movement. Dynamic flow conditions with erosion control systems are discussed in Chapter 3.

2.3-1.c Stable versus Unstable Soils

The above retention criteria assumes that the soil to be filtered is internally stable -- it will not pipe internally. If unstable soil conditions are encountered, performance tests should be conducted to select suitable geotextiles. According to Kenney and Lau (1985, 1986) and LaFluer, et al. (1989), broadly graded ($C_u > 20$) soils with concave upward grain size distributions tend to be internally unstable. The Kenney and Lau (1985, 1986) procedure utilizes a mass fraction analysis. Research by Skempton and Brogan (1994) verified the Kenney and Lau (1985, 1986) procedure.

2.3-2 Permeability/Permittivity Criteria

Permeability requirements:

-- for *less critical applications* and *less severe conditions*:

$$k_{geotextile} \geq k_{soil} \qquad [2 - 7a]$$

-- and, for *critical applications* and *severe conditions*:

$$k_{geotextile} \geq 10\ k_{soil} \qquad [2 - 7b]$$

Permittivity requirements:

$$\psi \geq 0.5\ \text{sec}^{-1} \text{ for } < 15\% \text{ passing } 0.075 \text{ mm} \qquad [2 - 8a]$$

$$\psi \geq 0.2\ \text{sec}^{-1} \text{ for } 15 \text{ to } 50\% \text{ passing } 0.075 \text{ mm} \qquad [2 - 8b]$$

$$\psi \geq 0.1\ \text{sec}^{-1} \text{ for } > 50\% \text{ passing } 0.075 \text{ mm} \qquad [2 - 8c]$$

In these equations:

k = Darcy coefficient of permeability (m/s); and

ψ = geotextile permittivity, which is equal to $k_{geotextile}/t_{geotextile}$ (1/s) and is a function of the hydraulic head.

For actual flow capacity, the permeability criteria for noncritical applications is conservative, since an equal quantity of flow through a relatively thin geotextile takes significantly less time than through a thick granular filter. Even so, some pores in the geotextile may become blocked or plugged with time. Therefore, for critical or severe applications, Equation 2-7b is recommended to provide an additional level of conservatism. Equation 2-7a may be used where flow reduction is judged not to be a problem, such as in clean, medium to coarse sands and gravels.

The AASHTO M 288 Standard Specification for Geotextiles (1997) presents recommended minimum permittivity values in relation to percent of situ soil passing the 0.075 mm sieve. The