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Design using geosynthetics —

Part 4: Drainage

Design pour géosynthétiques —

Partie 4: Drainage

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Foreword

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This document was prepared by Technical Committee ISO/TC 221, *Geosynthetics*.

A list of all parts in the ISO 18228 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 18228 series provides guidance for designs using geosynthetics for soils and below ground structures in contact with natural soils, fills and asphalt. The series contains 10 parts which cover designs using geosynthetics, including guidance for characterization of the materials to be used and other factors affecting the design and performance of the systems which are particular to each part, with ISO/TR 18228-1 providing general guidance relevant to the subsequent parts of the series.

The series is generally written in a limit state format and guidelines are provided in terms of partial material factors and load factors for various applications and design lives, where appropriate.

This document includes information relating to the drainage function. Details of design methodology adopted in a number of regions are provided.

Parts of this document have been adapted from *Comité français des géosynthétiques*, 2014[10].

Design using geosynthetics —

Part 4:
Drainage

1 Scope

This document outlines the criteria for evaluating the available and the required flow rate of geosynthetics in various situations, provides a summary of the available laboratory testing, and lists the safety factors and reduction factors that can be applied to the parameters when designing using geosynthetics for drainage systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10318-1, *Geosynthetics — Part 1: Terms and definitions*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 10318-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Symbols and abbreviations

O_{90}	characteristic opening size of a geosynthetic (µm)
k_n	coefficient of permeability normal to the plane(m/s)
q_n	flux(l/m^2·s)
v-index	velocity index(mm/s)
ψ	permittivity(s^{-1})
ϑ	transmissivity (m^3/s/m or l/s/m)
GCD	acronym used for draining geocomposites
dQ/dt	volumetric flow rate of water through the soil (m^3/s or l/s)
A	bulk cross-sectional area through which the flow occurs (m^2)
h	hydraulic head (m)

l	distance travelled by the bulk water flow (m)
$\mathrm{d}h/\mathrm{d}l$	hydraulic gradient (dimensionless)
K	hydraulic conductivity or permeability of the soil (m/s)
q	equal to ($\mathrm{d}Q/\mathrm{d}t$), volumetric flow rate (m^3/s or l/s)
i	equal to ($\mathrm{d}h/\mathrm{d}l$), hydraulic gradient (dimensionless)
q_p	in-plane flow capacity, equal to the volumetric flow rate of water and/or other liquids per unit width of specimen, at defined gradients in the plane of a product (l/s·m).
k_p	coefficient of permeability in the plane, equal to the ratio between in-plane flow capacity q_p and the product of thickness d and hydraulic gradient i (m/s)
q_r	rainfall per unit horizontal area ($m^3/s/m^2$)
P	rainfall flow rate (m^3/s)
A_h	horizontal area (m^2)
q_s	rainfall per unit sloping area ($m^3/s/m^2$)
β	slope angle (deg or °)
q_D	rainfall per unit area entering the drainage system ($m^3/s/m^2$)
f	coefficient of infiltration (dimensionless)
Q_R	input flow rate due to rainfall (m^3/s/m or l/s/m)
L	length of the slope (m)
L_h	horizontal length of the slope (m)
h_r	height of rainfall (mm)
t	duration of the rainfall (h)
j	rainfall intensity (mm/h)
a	parameter of the pluviometric curve (mm h^{-n})
n	exponent of the pluviometric curve (-)
$F_{S,Q}$	Factor of Safety on input flow rate (dimensionless)
Q_S	input flow rate due to additional surficial flow (m^3/s/m or l/s/m)
Q_D	design input flow rate in the geocomposite (m^3/s/m or l/s/m)
Q_F	total rainfall flow on the catchment zone (m^3/s or l/s)
A_c	horizontal area of the catchment zone (m^2)
B_g	running width of the geocomposite drain (m)
h_{max}	maximum thickness of liquid in the granular liquid collection layer

Q	Specific flow rate = discharge per unit width in the geocomposite, under a specified hydraulic gradient (m^3/s/m or l/s/m)
B	width of geocomposite specimen in the flow rate test (m)
q_m	measured flow rate for a geocomposite specimen of width B (l/s or m^3/s)
p	applied pressure (kPa)
γ	saturated unit weight of the soil or material placed on the geocomposite (kN/m^3)
H	thickness of the soil or the material placed on the geocomposite (m)
w_s	distributed surcharge on the ground surface (kPa)
H_l	depth of the lowest point of the geocomposite below the ground surface (m)
K_a	coefficient of active pressure of the soil (dimensionless)
φ	friction angle of the soil (deg or °)
t, t_{GCD}	geocomposite thickness (m)
L_{sp}	distance between geotextile support points (m)
Q_{i1}	specific flow rate for the i_1 gradient (l/s/m or m^2/s)
Q_{i0}	specific flow rate for the i_0 gradient (l/s/m or m^2/s)
i_1	hydraulic gradient on the diagram, immediately higher than the actual hydraulic gradient (dimensionless)
i_0	actual hydraulic gradient (dimensionless)
Q_v	discharge or volumetric flow rate (m^3/s)
A_g	cross-sectional area of the geocomposite (m^2)
χ	parameter depending on the roughness of the flow surface ($m^{1/2}$ / s)
R	hydraulic radius of the flow conduit (m)
C	parameter as a function of geometry and roughness of the flow surface
σ_n	pressure applied in lab tests (kPa)
i_1, i_2	hydraulic gradients applied in lab tests (dimensionless)
i_o	actual hydraulic gradient (dimensionless)
$Q(\sigma_n, i)$	flow rate evaluated for the values σ_n, i (l/s/m or m^2/s)
$Q_{i0}(\sigma_n, i_0)$	flow rate evaluated for the values σ_n, i_0 (l/s/m or m^2/s)
Q_{20}, Q_T	specific flow rates at 20 °C and T °C
μ_{20}, μ_T	viscosity of water at 20 °C and T °C
T	actual temperature of water (°C)
C_T	correction factor for temperature and viscosity (dimensionless)

Q_a	available long term flow rate for the geocomposite (l/s/m or m^2/s)
Q_L	short term flow rate obtained from laboratory tests with the appropriate boundary conditions (l/s/m or m^2/s)
$R_{F,in}$	Reduction Factor for the intrusion of filter geotextiles into the draining core due to tensile creep of the geotextile, occurring after the short term flow rate test (dimensionless)
$R_{F,cr\text{-}Q}$	Reduction Factor for the compressive creep of the geocomposite (dimensionless)
$R_{F,cc}$	Reduction Factor for chemical clogging of the draining core (dimensionless)
$R_{F,bc}$	Reduction Factor for biological clogging of the draining core (dimensionless)
$R_{F,L}$	Reduction Factor for overall uncertainties on laboratory data and field conditions (dimensionless)
q_h	flow rate of liquid supply ($m^3/s/m^2$)
j	factor of the Giroud theory (dimensionless)
$t_{prescribed}$	prescribed thickness of the granular layer (m)
$F_{S,E}$	Factor of Safety on equivalency (dimensionless)
E	equivalency coefficient (dimensionless)
Q_{GCD}	minimum short term input flow rate for the geocomposite in order to be considered equivalent to the granular layer having thickness larger than h_{max} ($m^3/s/m$ or l/s/m)
Q_{Darcy}	flow rate in the granular soil layer according to Darcy's law ($m^3/s/m$)
K_{lt}	long term permeability of the granular soil layer evaluated in situ at the end of its design life (m/s)
q_h^*	equivalent flow rate of liquid supply in the granular soil layer at equilibrium ($m^3/s/m^2$)
j^*	factor of the Giroud theory related to Q_{Darcy} (dimensionless)
E^*	equivalency coefficient for the thickness $t_{prescribed}$ (dimensionless)
Q_{GCD}^*	short term input flow rate for the geocomposite in order to be considered equivalent to the granular layer having thickness $t_{prescribed}$ ($m^3/s/m$)
Q_{GL}	flow rate afforded by the granular drainage layer ($m^3/s/m$ or l/s/m)
U	Darcy's velocity (m/s)
z	vertical distance in the soil (m)
k	intrinsic permeability of the soil, which depends only on properties of the solid matrix (m^2)
ρ	density of the fluid ($N\ s^2/m^4$ or kg/m^3)
μ	dynamic viscosity of the fluid ($N / m^2\ s$)
C	Hazen's empirical coefficient for intrinsic permeability (dimensionless)
C^*	Hazen's empirical coefficient for permeability ($m^{-1}\ s^{-1}$)

C_U	coefficient of uniformity of the soil = D_{60} / D_{10} (dimensionless)
D_{10}, D_{60}	diameter of soil particles for 10 % and 60 % cumulative passing (m)
g	acceleration due to gravity = 9,81 m/s^2
γ_w	unit weight of water for the given temperature (kN/m^3)
n	soil porosity = void volume / total volume (dimensionless)
$R_{F,in(R/R)\ short\ term}$	Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Rigid boundaries at short term (dimensionless)
$R_{F,in(R/S)\ short\ term}$	Reduction Factor for the intrusion of filter geotextiles into the draining core for Soft / Soft boundaries at short term (dimensionless)
$R_{F,in(S/S)\ short\ term}$	Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Soft boundaries at short term (dimensionless)
$R_{F,in(R/R)\ long\ term}$	Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Rigid boundaries at long term (dimensionless)
$R_{F,in(R/S)\ long\ term}$	Reduction Factor for the intrusion of filter geotextiles into the draining core for Soft / Soft boundaries at long term (dimensionless)
$R_{F,in(S/S)\ long\ term}$	Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Soft boundaries at long term (dimensionless)
$Q_{L\ (R/R)\ short\ term}$	Specific flow rate for Rigid / Rigid boundaries at short term (m^3/s/m or l/s/m)
$Q_{L\ (R/S)\ short\ term}$	Specific flow rate for Rigid / Soft boundaries at short term (m^3/s/m or l/s/m)
$Q_{L\ (S/S)\ short\ term}$	Specific flow rate for Soft / Soft boundaries at short term (m^3/s/m or l/s/m)
$Q_{L\ (R/R)\ long\ term}$	Specific flow rate for Rigid / Rigid boundaries at long term (m^3/s/m or l/s/m)
$Q_{L\ (R/S)\ long\ term}$	Specific flow rate for Rigid / Soft boundaries at long term (m^3/s/m or l/s/m)
$Q_{L\ (S/S)\ long\ term}$	Specific flow rate for Soft / Soft boundaries at long term (m^3/s/m or l/s/m)
$R_{F,cr,th}$	Reduction Factor for thickness (dimensionless)
t_{virgin}	thickness of the geocomposite core before load application (m);
t_{cr}	thickness measured at long term (1 year, 10 years, ... 100 years) in compressive creep tests (m)
$q(\sigma_n, i,$ long term$)$	long term available flow rate for applied pressure σ_n and hydraulic gradient i (m^3/s/m or l/s/m);
$q(\sigma_n, i)$	short term available flow rate for applied pressure σ_n and hydraulic gradient i (m^3/s/m or l/s/m);
$x(\sigma_n, 0)$	short term thickness of geocomposite for applied pressure σ_n (m);
$x(\sigma_n, t)$	long term thickness of geocomposite for applied pressure σ_n (m);
F	Reduction Factor for thickness (dimensionless)
α	Reduction Factor for the long term effect of compressive creep and geotextile intrusion (dimensionless)

$Q_{\text{long term}}$ long term flow rate (m^3/s/m or l/s/m)

4 Concepts

Some types of geosynthetics, particularly geocomposites, can be used as planar drainage medium in subsurface drainage systems.

The design of planar drainage geosynthetics requires hydraulic and geotechnical concepts for defining the design input flow rates, and a detailed method for defining the allowable long-term flow of geosynthetics, based on laboratory testing.

Drainage geosynthetics typically consist of a continuous drainage core (geonet, geomat, geospacer) capable of transporting a fluid along its own plane, and geotextiles and/or geomembranes, coupled to the drainage core, which prevent the drainage core itself from being clogged by the surrounding soil. The components of a draining geocomposite with continuous draining core are filtering geotextiles (on one or both sides), draining core and geomembrane, as shown in Figure 1.

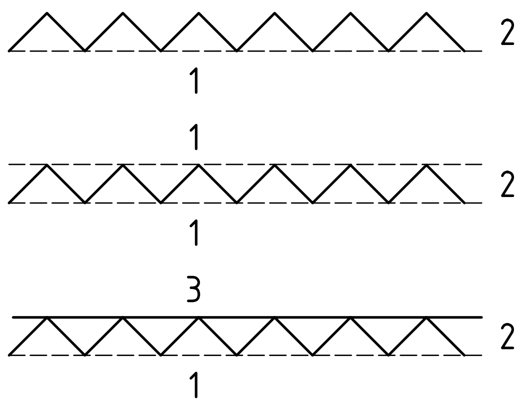
Some geocomposites available on the market include discrete draining elements, such as small diameter pipes, instead of a continuous draining core (Figure 2). In this type of geocomposite, the geotextiles act as a filter and also contribute to carrying the water flow. In general, the water flow capacity provided by geotextiles is very small compared to that provided by the discrete draining elements.

Drainage geosynthetics are widely used in controlled landfills, roads, railways, airports, tunnels and buildings. Drainage systems with geosynthetics are used within a performance envelope between the extreme cases of drainage along a sub-horizontal plane and along a vertical plane; between a hydraulic gradient close to 0 and a hydraulic gradient of 1.

In addition to the hydraulic gradient, the draining capacity of a geocomposite depends on the pressure applied and the materials in contact with the two faces.

The design of a drainage system with geosynthetics is based on the evaluation of the drainage capacity available under actual operating conditions and on the flow rate required by the project.

The drainage capacity can be assessed on the basis of appropriate laboratory tests, while the required flow rate is evaluated on the basis of hydrological and hydraulic considerations.



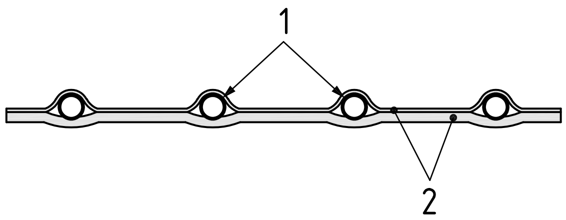
Key

1 geotextile

2 draining core

3 geomembrane

Figure 1 — Components of a draining geocomposite with continuous draining core: 1) Draining core + geotextile; 2) Geotextile + draining core + geotextile; 3) Geotextile + draining core + geomembrane

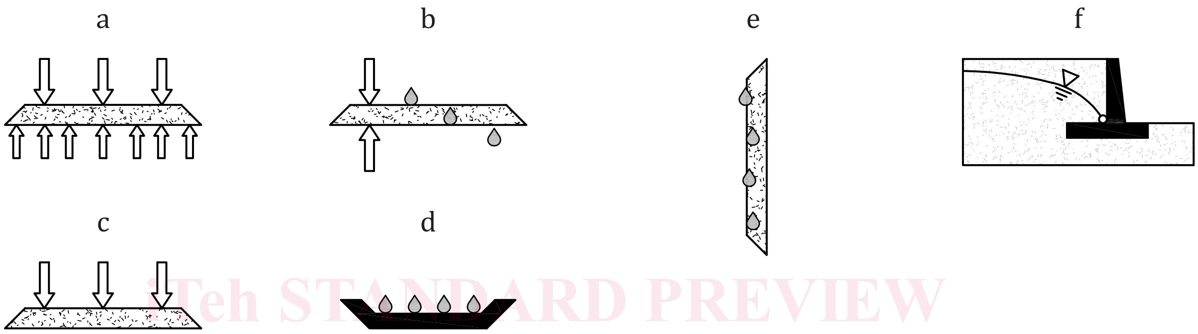


Key

1 discrete draining elements

2 geotextile

Figure 2 — Draining geocomposite with discrete draining elements



Key

a separation function

b filtration function

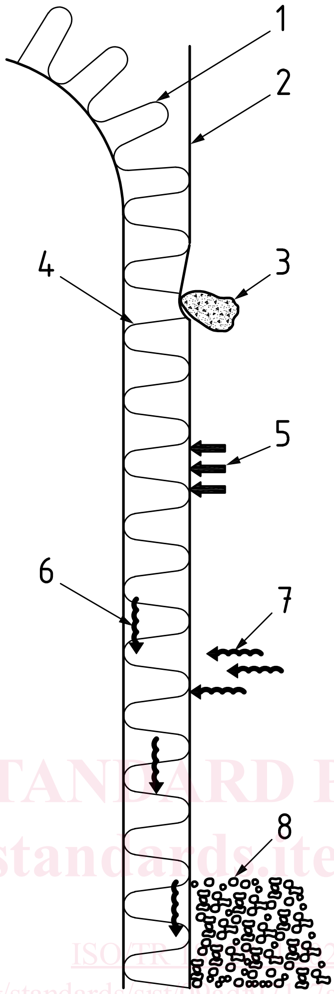
c protection function

d barrier function

e drainage function

f drainage systems applications

Figure 3 — Functions and Applications of drainage geocomposites (Source: ISO 10318-2)



Key

1 plastic core
2 geotextile
3 protects waterproofing from damage
4 distributes pressure
5 retains its drainage capacity even under high earth pressure
6 transports water to the collector drain
7 removes excess water from the soil
8 prevents the collector drain from silting up with fine soil particles

Figure 4 — Principles of the functions afforded by drainage geocomposites

5 Applications

Drainage geocomposites are made from a plastic drainage core that is thermally or otherwise bonded to a geotextile on one or both sides or to a waterproofing layer on one side.

They are capable of providing one or more main functions within the application as a drainage system, shown in Figure 3. The principles of the functions offered by drainage geocomposites are illustrated in Figure 4.

The main applications of planar drainage geocomposites are the following:

— Drainage of concrete walls

— Drainage of reinforced soil structures

— Drainage in road, railway and airport applications

— Horizontal drainage and capillary break layer in embankments made up of fine and cohesive fill

— Drainage trenches

— Leachate collection and gas ventilation in landfill applications (also used as a protection layer against geomembrane puncturing)

— Drainage of rainfall water infiltration in landfill applications

— Drainage in natural and artificial tunnel applications

— Drainage layer in roofing and deck pavement applications

— Drainage of sport fields

6 Materials

6.1 Components of draining geocomposites

The most commonly used drainage geosynthetics are the geocomposites which are produced by laminating one or two geotextiles, with a filter function, onto a drainage element.

— The filtering component can have the following characteristics under operating conditions: adequate permeability to gases and liquids in the direction perpendicular to the filter plane

— retention capacity of the soil particles

The draining component may have the following characteristics under operating conditions:

— adequate permeability to gases and liquids in the direction planar to the drainage structure

— adequate compressive strength and creep resistance for the loads to be applied

6.2 Filter Component of draining geocomposites

The filters are typically made up of nonwoven geotextiles, yet in certain specific applications some types of woven fabrics are occasionally used. The most commonly used nonwoven geotextiles are:

— staple fibres nonwoven, mechanically needled;

— continuous fibres nonwoven, thermally bonded or mechanically needled.

The physico-mechanical properties of nonwoven geotextiles are qualitatively as follows:

— Staple or continuous filament fibres needle-punched (only) nonwoven:

  — Relatively high thickness

  — High compressibility

  — Highly deformable over time

  — Potential clogging both on the surface and internally and limited blinding

— Staple fibres needle-punched and thermocalandered non-woven:

  — Moderate thickness

  — Moderate compressibility

