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**Design using geosynthetics —**  
**Part 4:**  
**Drainage**

*Design pour géosynthétiques —*  
*Partie 4: Drainage*



Reference number  
ISO/TR 18228-4:2022(E)

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

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](http://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<sup>[10]</sup>.



# 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 ( $\mu\text{m}$ )                          |
| $k_n$       | coefficient of permeability normal to the plane ( $\text{m/s}$ )                         |
| $q_n$       | flux ( $\text{l/m}^2\cdot\text{s}$ )                                                     |
| $v$ -index  | velocity index ( $\text{mm/s}$ )                                                         |
| $\psi$      | permittivity ( $\text{s}^{-1}$ )                                                         |
| $\vartheta$ | transmissivity ( $\text{m}^3/\text{s/m}$ or $\text{l/s/m}$ )                             |
| GCD         | acronym used for draining geocomposites                                                  |
| $dQ/dt$     | volumetric flow rate of water through the soil ( $\text{m}^3/\text{s}$ or $\text{l/s}$ ) |
| $A$         | bulk cross-sectional area through which the flow occurs ( $\text{m}^2$ )                 |
| $h$         | hydraulic head ( $\text{m}$ )                                                            |

|           |                                                                                                                                                                                       |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $l$       | distance travelled by the bulk water flow (m)                                                                                                                                         |
| $dh/dl$   | hydraulic gradient (dimensionless)                                                                                                                                                    |
| $K$       | hydraulic conductivity or permeability of the soil (m/s)                                                                                                                              |
| $q$       | equal to $(dQ/dt)$ , volumetric flow rate ( $m^3/s$ or $l/s$ )                                                                                                                        |
| $i$       | equal to $(dh/dl)$ , 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 ( $l/s \cdot m$ ). |
| $k_p$     | 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 ( $m^3/s/m^2$ )                                                                                                                                        |
| $\beta$   | slope angle (deg or $^\circ$ )                                                                                                                                                        |
| $q_D$     | 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 ( $mm \cdot h^{-n}$ )                                                                                                                             |
| $n$       | exponent of the pluviometric curve (-)                                                                                                                                                |
| $F_{SQ}$  | 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 ( $\text{m}^3/\text{s}/\text{m}$ or $\text{l}/\text{s}/\text{m}$ ) |
| $B$                     | width of geocomposite specimen in the flow rate test (m)                                                                                                                   |
| $q_m$                   | measured flow rate for a geocomposite specimen of width $B$ ( $\text{l}/\text{s}$ or $\text{m}^3/\text{s}$ )                                                               |
| $p$                     | applied pressure (kPa)                                                                                                                                                     |
| $\gamma$                | saturated unit weight of the soil or material placed on the geocomposite ( $\text{kN}/\text{m}^3$ )                                                                        |
| $H$                     | thickness of the soil or the material placed on the geocomposite (m)                                                                                                       |
| $w_s$                   | distributed surcharge on the ground surface (kPa)                                                                                                                          |
| $H_1$                   | depth of the lowest point of the geocomposite below the ground surface (m)                                                                                                 |
| $K_a$                   | coefficient of active pressure of the soil (dimensionless)                                                                                                                 |
| $\varphi$               | friction angle of the soil (deg or $^\circ$ )                                                                                                                              |
| $t, t_{\text{GCD}}$     | geocomposite thickness (m)                                                                                                                                                 |
| $L_{\text{sp}}$         | distance between geotextile support points (m)                                                                                                                             |
| $Q_{i1}$                | specific flow rate for the $i_1$ gradient ( $\text{l}/\text{s}/\text{m}$ or $\text{m}^2/\text{s}$ )                                                                        |
| $Q_{i0}$                | specific flow rate for the $i_0$ gradient ( $\text{l}/\text{s}/\text{m}$ or $\text{m}^2/\text{s}$ )                                                                        |
| $i_1$                   | 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 ( $\text{m}^3/\text{s}$ )                                                                                                                |
| $A_g$                   | cross-sectional area of the geocomposite ( $\text{m}^2$ )                                                                                                                  |
| $\chi$                  | parameter depending on the roughness of the flow surface ( $\text{m}^{1/2} / \text{s}$ )                                                                                   |
| $R$                     | hydraulic radius of the flow conduit (m)                                                                                                                                   |
| $C$                     | parameter as a function of geometry and roughness of the flow surface                                                                                                      |
| $\sigma_n$              | pressure applied in lab tests (kPa)                                                                                                                                        |
| $i_1, i_2$              | hydraulic gradients applied in lab tests (dimensionless)                                                                                                                   |
| $i_0$                   | actual hydraulic gradient (dimensionless)                                                                                                                                  |
| $Q(\sigma_n, i)$        | flow rate evaluated for the values $\sigma_n, i$ ( $\text{l}/\text{s}/\text{m}$ or $\text{m}^2/\text{s}$ )                                                                 |
| $Q_{i0}(\sigma_n, i_0)$ | flow rate evaluated for the values $\sigma_n, i_0$ ( $\text{l}/\text{s}/\text{m}$ or $\text{m}^2/\text{s}$ )                                                               |
| $Q_{20}, Q_T$           | specific flow rates at $20\text{ }^\circ\text{C}$ and $T\text{ }^\circ\text{C}$                                                                                            |
| $\mu_{20}, \mu_T$       | viscosity of water at $20\text{ }^\circ\text{C}$ and $T\text{ }^\circ\text{C}$                                                                                             |
| $T$                     | actual temperature of water ( $^\circ\text{C}$ )                                                                                                                           |
| $C_T$                   | correction factor for temperature and viscosity (dimensionless)                                                                                                            |

|                  |                                                                                                                                                                                          |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $Q_a$            | available long term flow rate for the geocomposite (l/s/m or m <sup>2</sup> /s)                                                                                                          |
| $Q_L$            | short term flow rate obtained from laboratory tests with the appropriate boundary conditions (l/s/m or m <sup>2</sup> /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)    |
| $R_{F,cr-Q}$     | 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 <sup>3</sup> /s/m <sup>2</sup> )                                                                                                                           |
| $j$              | 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 <sup>3</sup> /s/m or l/s/m) |
| $Q_{Darcy}$      | flow rate in the granular soil layer according to Darcy's law (m <sup>3</sup> /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 <sup>3</sup> /s/m <sup>2</sup> )                                                                      |
| $j^*$            | 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 <sup>3</sup> /s/m)                       |
| $Q_{GL}$         | flow rate afforded by the granular drainage layer (m <sup>3</sup> /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 <sup>2</sup> )                                                                               |
| $\rho$           | density of the fluid (N s <sup>2</sup> /m <sup>4</sup> or kg/m <sup>3</sup> )                                                                                                            |
| $\mu$            | dynamic viscosity of the fluid (N / m <sup>2</sup> s)                                                                                                                                    |
| $C$              | Hazen's empirical coefficient for intrinsic permeability (dimensionless)                                                                                                                 |
| $C^*$            | Hazen's empirical coefficient for permeability (m <sup>-1</sup> s <sup>-1</sup> )                                                                                                        |

|                                    |                                                                                                                                            |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| $C_U$                              | 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 <sup>2</sup>                                                                                        |
| $\gamma_w$                         | unit weight of water for the given temperature (kN/m <sup>3</sup> )                                                                        |
| $n$                                | soil porosity = void volume / total volume (dimensionless)                                                                                 |
| $R_{F,in(R/R)} \text{ short term}$ | Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Rigid boundaries at short term (dimensionless) |
| $R_{F,in(R/S)} \text{ short term}$ | Reduction Factor for the intrusion of filter geotextiles into the draining core for Soft / Soft boundaries at short term (dimensionless)   |
| $R_{F,in(S/S)} \text{ short term}$ | Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Soft boundaries at short term (dimensionless)  |
| $R_{F,in(R/R)} \text{ long term}$  | Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Rigid boundaries at long term (dimensionless)  |
| $R_{F,in(R/S)} \text{ long term}$  | Reduction Factor for the intrusion of filter geotextiles into the draining core for Soft / Soft boundaries at long term (dimensionless)    |
| $R_{F,in(S/S)} \text{ long term}$  | Reduction Factor for the intrusion of filter geotextiles into the draining core for Rigid / Soft boundaries at long term (dimensionless)   |
| $Q_L (R/R) \text{ short term}$     | Specific flow rate for Rigid / Rigid boundaries at short term (m <sup>3</sup> /s/m or l/s/m)                                               |
| $Q_L (R/S) \text{ short term}$     | Specific flow rate for Rigid / Soft boundaries at short term (m <sup>3</sup> /s/m or l/s/m)                                                |
| $Q_L (S/S) \text{ short term}$     | Specific flow rate for Soft / Soft boundaries at short term (m <sup>3</sup> /s/m or l/s/m)                                                 |
| $Q_L (R/R) \text{ long term}$      | Specific flow rate for Rigid / Rigid boundaries at long term (m <sup>3</sup> /s/m or l/s/m)                                                |
| $Q_L (R/S) \text{ long term}$      | Specific flow rate for Rigid / Soft boundaries at long term (m <sup>3</sup> /s/m or l/s/m)                                                 |
| $Q_L (S/S) \text{ long term}$      | Specific flow rate for Soft / Soft boundaries at long term (m <sup>3</sup> /s/m or l/s/m)                                                  |
| $R_{F,cr,th}$                      | Reduction Factor for thickness (dimensionless)                                                                                             |
| $t_{\text{virgin}}$                | thickness of the geocomposite core before load application (m);                                                                            |
| $t_{\text{cr}}$                    | thickness measured at long term (1 year, 10 years, ... 100 years) in compressive creep tests (m)                                           |
| $q(\sigma_n, i, \text{long term})$ | long term available flow rate for applied pressure $\sigma_n$ and hydraulic gradient $i$ (m <sup>3</sup> /s/m or l/s/m);                   |
| $q(\sigma_n, i)$                   | short term available flow rate for applied pressure $\sigma_n$ and hydraulic gradient $i$ (m <sup>3</sup> /s/m or l/s/m);                  |
| $x(\sigma_n, 0)$                   | short term thickness of geocomposite for applied pressure $\sigma_n$ (m);                                                                  |
| $x(\sigma_n, t)$                   | long term thickness of geocomposite for applied pressure $\sigma_n$ (m);                                                                   |
| $F$                                | Reduction Factor for thickness (dimensionless)                                                                                             |
| $\alpha$                           | Reduction Factor for the long term effect of compressive creep and geotextile intrusion (dimensionless)                                    |

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

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](#).

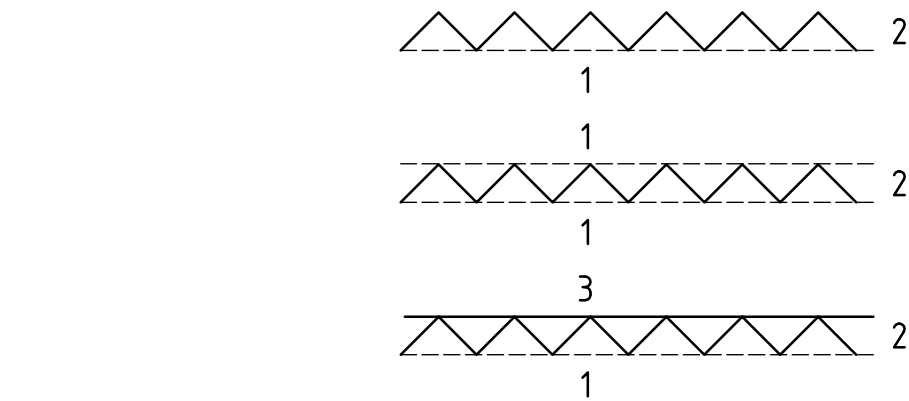
Some geocomposites available on the market include discrete draining elements, such as small diameter pipes, instead of a continuous draining core ([Figure 2](#)). In this type of geocomposite, the geotextiles act as a filter and also contribute to carrying the water flow. In general, the water flow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

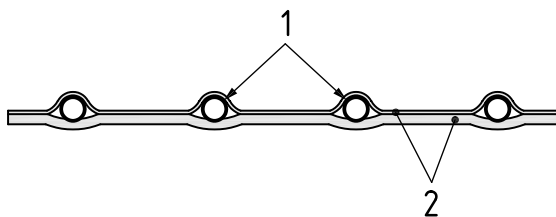
The design of a drainage system with geosynthetics is based on the evaluation of the drainage capacity available under actual operating conditions and on the flow rate required by the project.

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.



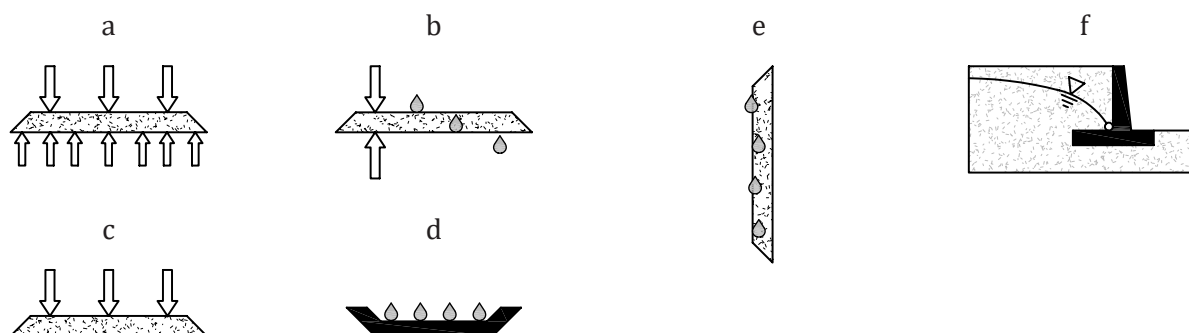
- Key
- 1 geotextile
  - 2 draining core
  - 3 geomembrane

**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**

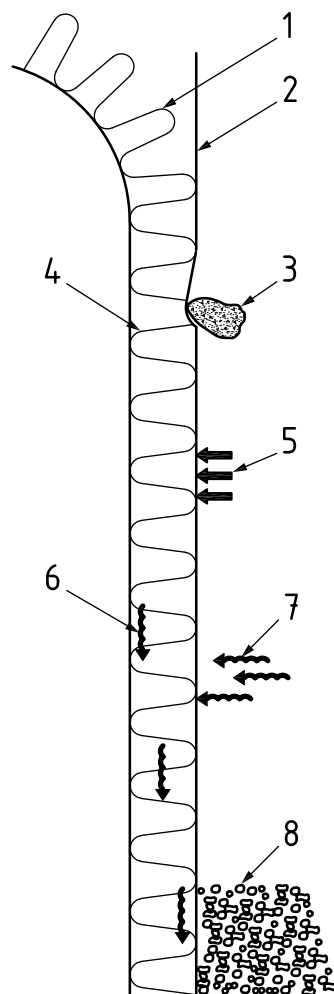
- 1 discrete draining elements
- 2 geotextile

**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

- Moderate deformability over time
- Potential clogging both on the surface and internally and blinding risk on the heat-bonded surface and limited blinding on the other face
- Continuous fibres heat-bonded nonwoven:
  - Lowest thickness
  - Very low compressibility
  - Slightly deformable over time
  - Blinding risks

### 6.3 Drainage cores

The drainage cores are characterized by a three-dimensional structure with a high void ratio, and they differ according to the mode of manufacture and the type of polymer.

The main types of drainage cores can be grouped into the following categories:

- **Geomats:** made from a set of filaments which are tangled and welded at the contact points; the profile of the core can be different (cuspatated, channelled, etc.) according to the required thickness and resistance to compression. These profiles are usually made of polyamide (PA) or polypropylene (PP).
- **Geonets:** made by the extrusion of two or three sets of parallel strands. Geonets are typically made of high-density polyethylene (HDPE).
- **Geospacers:** cuspatated foils produced from extruded laminates, which are profiled during production into wave-shaped or truncated cuspatate cone profiles, on one or both faces. They are typically made of polypropylene (PP) or high-density polyethylene (HDPE).

It is important for all forms and grades of geosynthetic drains that their strength and long-term creep and drainage performance is demonstrated to be appropriate for the loadings and design life envisaged.

Since geosynthetic drains may exhibit high resistance to compression in the short term but may be prone to sudden collapse if the loads are maintained for a long time, it is also important to check if the draining core behaves as compressible or collapsible for the project conditions of applied load, slope and design life.

### 6.4 Definitions and acronyms for the various products

ISO 10318-1 provides definitions and acronyms for many of the various products presently available on the market. In the present document the acronym GCD is used for draining geocomposites.

## 7 Properties relevant to design

Geosynthetics testing standards relevant to design for drainage are listed under further reading at the end of this document.

## 8 Darcy's law

The unidirectional movement of water through the soil is represented by Darcy's law.

Information on the movement of water in the ground is provided in [Annex A](#).

## 9 Subsurface drainage structures

The uncontrolled movement of groundwater can be deleterious to geotechnical structures by:

- reducing or eliminating cohesion in soils;
- originating pore water pressures that reduce effective stresses, thereby lowering shear strength;
- producing horizontally inclined forces which increase the moments acting on them;
- lubricating failure planes;
- supplying water which leads to liquefaction during earthquakes; or
- promoting the uncontrolled movement of soil particles (piping).

The design engineer would normally be aware of all these risks and either account for this presence of water within their calculations (resulting in a conservative and expensive solution) or provide a technique to control it.

Subsurface drainage is the technique to control the flow of groundwater, through interception and/or deviation.

An effective subsurface drainage system will:

- reduce pore water pressures and thus increase effective stresses, thereby increasing shear strength;
- reduce horizontal forces, and thus reduce overturning moments and the possibility of failure;
- prevent the lubrication of failure planes;
- prevent the uncontrolled movement of soil particles (piping).

An essential feature of the successful use of subsurface drainage is that the groundwater can be removed in a controlled manner (i.e. without causing undue disturbance to surrounding areas). This is particularly important where its removal causes movements or subsidence in surrounding areas. In order for a subsurface drainage system to be effective, due consideration would normally be given to the positioning of the drain and to the materials selected.

All of the three following criteria apply

- a) The drainage system may intercept the zone of seepage which can be the cause of the problem. The proper placement and configuration of the subsurface drainage system are important.
- b) The seepage water can enter the subsurface drainage system with minimal resistance whilst at the same time cause minimal disturbance (piping) at the drain/soil interface. To facilitate this, filters are positioned around the outside perimeter of the subsurface drains.
- c) The subsurface drainage system can remove the required amount of groundwater from the soil in the required time interval. The dimensions of the drains, the selection of appropriate drainage media, and the configuration of the drainage system all contribute to its ability to perform satisfactorily.

## 10 Geosynthetic properties

When considering drainage projects, the hydraulic properties of the geosynthetics are the most important.

ISO 10318-1 defines the hydraulic properties of geosynthetics listed in [Table 1](#).

**Table 1 — Relevant hydraulic properties of geosynthetics defined in ISO 10318-1**

|                                                       |
|-------------------------------------------------------|
| Characteristic opening size $O_{90}$                  |
| Permeability                                          |
| Coefficient of permeability normal to the plane $k_n$ |
| Flux $q_n$                                            |
| Velocity index (v-index)                              |
| Permittivity $\psi$                                   |
| In-plane flow capacity $q_p$                          |
| Transmissivity $\theta$                               |
| Coefficient of permeability in the plane $k_p$        |

## 11 Geotextile filter performance and filter criteria

For designing the geotextile filters of drainage geocomposites see ISO/TR 18228-3.

## 12 Geocomposite drainage systems design

### 12.1 General

The design of a geocomposite drainage system may be carried out as follows:

- a) Identify/set all the design conditions, including (but not limited to):
  - Type of project (landfill bottom or capping, vertical wall, etc.)
  - Types of soil involved (stones, gravel, clay, etc.) and their grading curves
  - Environment (aggressive for landfill bottom, medium for landfill capping, ordinary for walls or roof gardens, etc.)
  - Chemical and physical properties of the materials in contact with the geocomposite (pH, chemical and biological content, hardness, stiffness, etc.) and of the liquid to be drained (pH, chemical and biological content, density, viscosity, turbidity, etc.)
- b) Set the boundary conditions, that is the type of materials in contact with the two faces of the geocomposite;
- c) Calculate the maximum applied pressure, the hydraulic gradient and the design input flow rate for the geocomposite;
- d) Select one or more geocomposites and, for each of them, calculate the available flow rate for the design conditions of materials in contact with the two faces, maximum applied pressure, and hydraulic gradient;
- e) Compare the available flow rate with the design input flow rate and consider only the geocomposites for which the former is larger than the latter;
- f) Make the final selection of the geocomposite;
- g) Provide design specifications and details, in particular the method for fixing the geocomposites on the supporting surface and the connections/overlaps between geocomposite rolls and between the geocomposites and other elements of the drainage system (manholes, perforated pipes, etc.).

## 12.2 Calculation of input flow rate

### 12.2.1 General

The calculation of the input flow rate is project specific, therefore it is possible to provide indications only for the most common and simple cases.

### 12.2.2 Rainfall on sloping surface

The input flow from rainfall onto a sloping surface is of interest in many common situations: landfill bottom and side slopes (before capping), landfill capping, roads, railways, airports, roof gardens and deck pavements.

In all these cases there is a common calculation scheme applicable, as shown in [Figure 5](#).

With reference to this scheme, the rainfall per unit area is given by [Formula \(1\)](#):

$$q_r = P / A_h \quad (1)$$

where

$P$  is the rainfall flow rate ( $\text{m}^3/\text{s}$ );

$A_h$  is the horizontal area ( $\text{m}^2$ );

$q_r$  is the rainfall per unit horizontal area ( $\text{m}^3/\text{s}/\text{m}^2$ ).

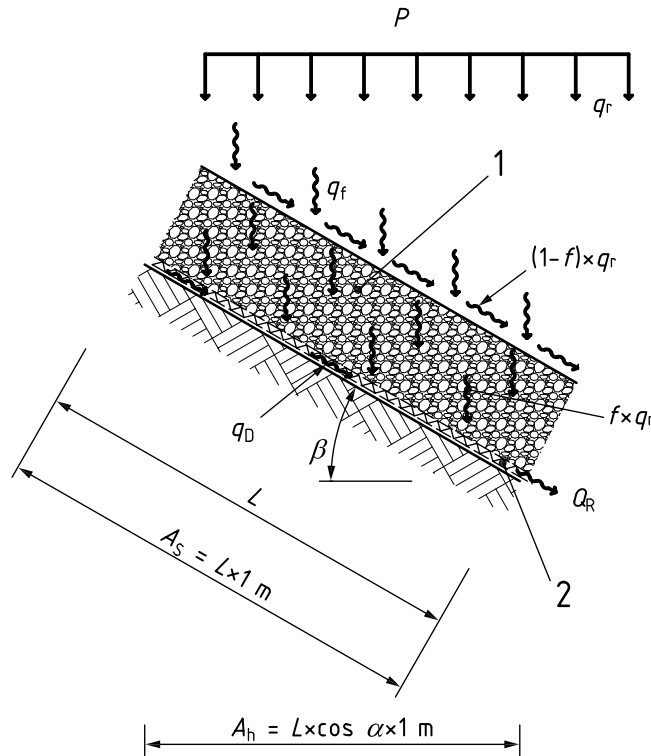
Since the actual surface is sloping, the effective rainfall per unit sloping area is given in [Formula \(2\)](#):

$$q_s = q_r \cdot \cos \beta \quad (2)$$

where

$q_s$  is the rainfall per unit sloping area ( $\text{m}^3/\text{s}/\text{m}^2$ );

$\beta$  is the slope angle (deg).



**Key**

- 1 soil or waste or no cover material
- 2 geocomposite

**Figure 5 — Scheme for the calculation of the input flow rate in case of rainfall on sloping surface**

Not all the rainfall reaches the drainage system, since a part of it becomes runoff; therefore, the input rainfall is given by [Formula \(3\)](#):

$$q_D = f \cdot q_r = f \cdot q_r \cdot \cos \beta \quad (3)$$

where

$f$  is the coefficient of infiltration;

$q_D$  is the rainfall per unit sloping area entering the drainage system ( $\text{m}^3/\text{s}/\text{m}^2$ ).

The input rainfall collects along the slope to produce the flow rate [Formula \(4\)](#):

$$Q_R = q_D \cdot L = f \cdot q_r \cdot L_h \quad (4)$$

where

$L$  is the length of the slope (m);

$L_h$  is the horizontal length of the slope (m);

$Q_R$  is the input flow rate per unit width of slope due to rainfall ( $\text{m}^3/\text{s}/\text{m}$ ).

The rainfall per unit area  $q_r$  can be calculated knowing the rainfall intensity  $j$ . According to the principles of hydrology it is possible to compute  $j$  by the formula of the pluviometric curve relative to the specific hydrologic region, which is usually written in the form given in [Formula \(5\)](#):

$$h_r = a \cdot t^n \quad (5)$$

Therefore [Formula \(6\)](#) gives:

$$j = h_r / t = a \cdot t^{n-1} \quad (6)$$

where

- $h_r$  is the height of rainfall (mm);
- $t$  is the duration of the rainfall (h);
- $j$  is the rainfall intensity (mm/h);
- $a$  is the parameter of the pluviometric curve (mm/h<sup>n</sup>);
- $n$  is the exponent of the pluviometric curve (dimensionless).

Finally, to pass from  $j$ (mm/h) to  $q_r$ (m<sup>3</sup>/s/m<sup>2</sup> = m/s), [Formula \(7\)](#) applies:

$$q_r = j \cdot 2,777 \cdot 10^7 \quad (7)$$

Hence the input flow rate due to rainfall is given in [Formula \(8\)](#):

$$Q_R = 2,777 \cdot 10^7 \cdot a \cdot t^{n-1} \cdot L \cdot f \cdot \cos \beta \quad (8)$$

or [Formula \(9\)](#):

$$Q_R = 2,777 \cdot 10^7 \cdot j \cdot L \cdot f \cdot \cos \beta \quad (9)$$

It is evident that the rainfall intensity depends on the rainfall duration being considered and hence such parameters may be carefully selected based on the type of application and/or on hydrologic considerations.

Only the most intense rainfalls, occurring during storm events, are meaningful for the geocomposite drainage system design, while the long duration rain events with low intensity do not produce high water flows. Additionally, very intense yet very short rainfall events might not produce the highest input flow rates for the geocomposite, since the soil absorbs the rain and delays the filtration flow to a great extent.

Therefore, a general rule is to consider rainfall durations of 0,5 h to 1 h.

When the hydrologic parameters of the pluviometric curve are not available, [Formula \(9\)](#) is used and the rainfall intensity  $j$  for the duration of 1 h may be estimated or provided by local authorities/agencies.

There are many situations where an additional input flow in the geocomposite needs to be considered, for example, if there is an upstream slope that produces runoff, a pipe discharging water on the ground surface just upstream of the geocomposite or if there is a higher roof that discharges the water on the roof garden below.

In all these cases the additional surficial flow rate per unit width of slope,  $Q_S$ , may be evaluated and added to the rainfall generated flow rate  $Q_R$ .