TECHNICAL REPORT

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Design using geosynthetics —

Part 1: **General**

Conception utilisant des géosynthétiques —

Partie 1: Généralités

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Contents

Page

Foreword

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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).

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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.

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

A list of all parts in the ISO/TR 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/TR 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.

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.

For each of the design considerations, the characteristics of the geosynthetics and the test methods normally used to quantify the properties of the geosynthetics are described. Some regional specific rules and regulations that normally apply to designs using geosynthetics in these regions are also provided.

Design using geosynthetics —

Part 1: General

1 Scope

This document provides general considerations to support the guidance to geotechnical and civil engineers for design using geosynthetics provided in the subsequent parts of the ISO/TR 18228 series.

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

3.1 Terms and definitions

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

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

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

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

3.2 Symbols

For the purposes of this document, the symbols are taken from ISO 10318-2. Table 1, Table 2 and Table 3 provide lists of the lowercase, uppercase and Greek symbols that are typically used throughout the ISO/TR 18228 series. Additional useful symbols may be found in the relevant parts of the series.

Table 1 — Lowercase symbols

Symbol	Meaning
f	Partial factor (with subscripts as noted)
h	Hydraulic head
i	Hydraulic gradient
pH	Value of acidity of an aqueous solution
m	Mass of an element
q	Flow quantity (with subscripts as noted)
r_u	Pore pressure ratio
t	Thickness of a geosynthetic
t_d	Design life
t_t	Test duration

Table 1 *(continued)*

Symbol	Meaning
u	Pore water pressure

Table 2 — Uppercase symbols

Symbol	Meaning
A	Area
C	Hazen empirical coefficient for permeability
C_u	Coefficient of uniformity (D60/D10)
D	Particle grain size, subscript defines percentile
E	Elastic modulus
F_d	Factored design load
F_k	Unfactored characteristic load
H_t	Total height
K	Hydraulic conductivity or coefficient of permeability of the soil
K_a	Coefficient of active earth pressure
K_o	Coefficient of earth pressure at rest
K_p	Coefficient of passive earth pressure
L	Length
N	Normal force
O_{90}	Effective or characteristic opening size in a geotextile, (where 90 % of openings finer than the value)
POA	Percentage open area
Q	Applied pressure
Q_m	Average pressure
R	Reaction
T_{CR}	Extrapolated compressive creep rupture strength at the end of the design life
Z	Section modulus

Table 3 — Greek letter symbols

Symbol	Meaning
α	Inclination of a slope to the horizontal
γ	Unit mass density of soil (with subscripts as noted)
μ	Apparent coefficient of friction
φ	Friction angle of the soil (degree)
σ	Normal stress
σ_h	Horizontal stress on an element of soil
σ_v	Vertical stress on an element of soil
σ'_v	Applied vertical effective stress
Θ	Transmissivity of a geosynthetic
T	Shear stress

4 General design considerations

4.1 Fundamentals

Designs using geosynthetics normally take into account the nature of the soils in contact with the geosynthetic materials. The characteristic properties of the soils can be measured using in situ tests as described in ISO 14688-1, ISO 14688-2, ISO 22476 (all parts) and ISO 22282 (all parts), or with associated laboratory tests from ISO 17892 (all parts) as appropriate for the information required for the designs being made.

Geosynthetics have characteristics which might be suited to specific functions or applications but might be unsuitable for some functions or applications. The individual parts of the ISO/TR 18228 series provide guidance as to which types are suited to each function or application, but the final choice of product for any situation will be the choice of the designer or the project approval authority.

All geosynthetic products delivered to a construction site would normally be clearly marked and labelled as described in ISO 10320.

4.2 Short-term properties

4.2.1 Survivability

4.2.1.1 Mechanical damage

Geosynthetics are predominantly sheet materials which are supplied in rolls or as large folded units. Geosynthetics can be damaged during transport to the construction site, between initial storage on site and the point of laying and during the construction process. To minimize the damage that can arise due to transportation and handling, some geosynthetics might need to be wrapped and pads might be required where appropriate to reduce contact stresses and any resultant damage.

The incorporation of geosynthetics in the construction works involves rolling out or laying the material. Special handling equipment would normally be used when the material units are too heavy for manual handling.

The assessment of survivability would normally consider the nature of the soils and materials in contact with the geosynthetic, and whether construction equipment, wheeled or tracked, will be allowed to run over the geosynthetic.

Any resulting damage from placing fill material (i.e. soil, rock or asphalt) on a geosynthetic would normally be considered in the design by the application of a damage factor. Product specific advice may be obtained from the manufacturer of the geosynthetic as to the damage factor(s) to be used in the particular situation.

4.2.1.2 Weathering

All geosynthetic materials are susceptible to the effects of weathering during periods of exposure; the effects of weathering can be assessed following EN 12224 and EN 12226.

Weathering can be defined as exposure to one or more of the following:

— sunlight (UV radiation/oxidation) (see ISO 13438);

— water (see EN 12447);

— extremes of temperature;

— wind.

Weathering resistance can be built into the geosynthetic or can be inherent as part of the manufacturing process.

Polymers and natural materials used in the manufacture of geosynthetics have varying susceptibility to UV damage. The base polymers can be mixed with additives to enhance the UV resistance. If a geosynthetic is supplied in a protective wrapping, it would normally be kept wrapped or stored as recommended by the manufacturer until needed.

The weathering assessment would normally also consider other processes that can affect geosynthetic performance. Some geosynthetics might be more resistant to the actions of wind and/or flowing water. Selection of a particular geosynthetic would normally consider the method of manufacture and the site conditions.

4.2.1.3 Chemical resistance

Polymer geosynthetics degrade principally due to chemical reactions with the environment. The rate at which this occurs depends significantly on temperature and other conditions. Some key points are:

— Many reactions occur at the polymer surface therefore thicker materials are normally more resistant than thinner materials.

— A change in temperature can lead to a change in the rate of the chemical reaction at the polymer surface.

— Chemical reactions between particles in a solid state are generally slow in comparison to reactions between those involving fluid states.

— The high surface area of fine fibres, as used in the manufacture of geotextiles, will increase the rate of chemical surface attack.

— Chemical reactions can take place in the main chain of the polymer or in the side chains. Rupture of the main chain is more critical because it will directly reduce the strength of the polymer.

4.2.2 Mechanical properties

4.2.2.1 Tensile behaviour

As a short-term property tensile strength is one of the measures used to determine the resistance of the geosynthetic to damage during the construction process. Tensile test method is given in ISO 10319.

4.2.2.2 Impact or penetration damage resistance

Impact or penetration damage can occur when fill or other materials are dropped or placed onto geosynthetics during construction. The laboratory tests described in EN 14574, ISO 12236, ISO 10722 and ISO 13433 measure how easily holes can be made in the product. In some circumstances, full scale site tests might be required when laboratory tests are unable to model the site conditions, including full scale rock dropping tests.

4.2.2.3 Compressive behaviour

Compressive behaviour as measured in ISO 25619-1 and ISO 25619-2, or the ability of three-dimensional products to support loads applied normal to the surface of the material, is usually assessed when the geosynthetic is required to transmit fluids in the plane of the product. Applications such as drains in sports fields, transportation works, structural drainage, landfill drains and gas vents require a three-dimensional core combined with a geotextile filter to ensure that the core remains clear.

4.2.2.4 Abrasion resistance

Abrasion resistance as measured by ISO 13427 is used to check that the geosynthetic does not suffer from damage during construction when subjected to compaction forces on the surface of the product.

4.2.3 Hydraulic properties

4.2.3.1 Filtration and permeability

Filtration is the ability of a geotextile to filter soils so that fine materials do not clog any of the drainage layers, natural sands/gravels or three-dimensional geosynthetic products. The effective opening size, O_{90}, of the geotextile as measured by ISO 12956, is a measure of the pore sizes in the geotextile.

Permeability is a measure of the ability of the geotextile to allow water or other fluids to pass through the product into a drain. The permeability of barriers is measured using tests in EN 14150, EN 16416, ISO 10776, ISO 10772 and ISO 11058.

4.2.3.2 Drainage or flow capacity

Short-term drainage will normally not be critical as any geosynthetic acting as a drain will have its maximum capacity during construction. If the geosynthetic is required to carry additional flows during construction the capacity of the drainage layer would normally be checked. The flow capacity is measured using test in ISO 18325.

4.2.4 Friction properties

4.2.4.1 Direct shear and inclined plane

Friction as measured in either the direct shear (ISO 12957-1) or the inclined plane test (ISO 12957-2) would normally be considered to ensure that fill materials do not slip over the geosynthetic or that the geosynthetic does not slip over the substrata. In some circumstances, interfaces in the construction may be designed to slip to minimize tensile forces in the geosynthetic layers.

4.2.4.2 Pullout resistance

Pullout resistance as measured in a large pull-out test (EN 13738) might need to be considered when anchor lengths of geosynthetics are provided for anchor reinforcement, particularly when the overburden or vertical pressures are less than the permanent loadings.

4.3 Long term properties

4.3.1 Durability

Guidelines for assessing the long-term durability of geosynthetics can be found in ISO/TS 13434:2008.

Assessment of the durability of structures using geosynthetics normally requires a study of the effects of time on the functional properties. The physical structure of the geosynthetic, the nature of the polymer used, the manufacturing process, the physical and chemical environment, the conditions of storage and installation, and the load supported by the geosynthetic are all parameters which govern the durability. A main task of the designer is to understand and assess the evolution of the functional properties over the entire design life. This problem is quite complex due to the combination and interaction of numerous parameters present in the soil environment, and the lack of well-documented experience.

4.3.2 Mechanical damage

The design would normally consider the effects in service of mechanical damage due to dynamic loading. Examples of where dynamic loading results in damage include:

— railways – geosynthetics used in track construction;

— coastal protection – geotextile filters under revetments;

— river banks – geotextile filters, reinforcements and bank protection systems;

— landfills – damage from waste placed in the landfill, thick geotextiles can be used to protect geosynthetic barrier layers; and

— highways – damage from asphalt or other pavement materials when geosynthetics are used to strengthen highway or other pavements.

4.3.3 Weathering

Long-term exposure of geosynthetics is to be avoided. In situations where long-term exposure cannot be prevented, weathering tests can be carried out to determine the effects of exposure. Examples of where geosynthetics are subject to long term weather exposure include:

— geosynthetics on the face of wraparound soil reinforced slopes;

— geosynthetic barriers in service reservoirs;

— geosynthetic barriers on the face of concrete dams as waterproofing; and

— geosynthetic silt fences.

4.3.4 Chemical resistance

Chemical damage is most serious when the polymer chain backbone is broken, leading directly to a loss of mechanical properties and, frequently, to a loss of hydraulic properties. Chemical degradation of polymers occurs through a variety of processes, including oxidation and hydrolysis, depending on the type of polymer and on the acidity or alkalinity of the soil. Acidity and alkalinity are expressed as pH, with neutral soil having a pH of 7, while lower values imply more acidic soils and higher values, more alkaline soils. All chemical reactions occur more rapidly at higher temperatures, as described by the Arrhenius law.

ISO/TS 13434:2008 provides guidance on the primary degradation modes for a wide range of polymers used within the geosynthetics industry. In Europe, a range of screening tests have been developed to allow the most common modes of degradation to be assessed for the majority of typical geosynthetic materials. These tests are included as Annex B of the European Application standards (EN 13361, EN 13362, EN 13491, EN 13492, EN 13493, EN 13249, EN 13250, EN 13251, EN 13252, EN 13253, EN 13254, EN 13255, EN 13256, EN 13257, EN 13258 and EN 15381). Refer to the Bibliography for details.

4.3.5 Mechanical properties

4.3.5.1 Tensile behaviour

The tensile strength of geosynthetics, as measured by ISO 10319, ISO 13426-1 and ISO 13426-2 is a fundamental property when the geosynthetic is required to act as reinforcement. If the geosynthetic is jointed, the strength of the joint is measured using ISO 10321.

Applications such as reinforced steep slopes, walls, basal reinforcement of embankments on soft ground, support over voids and load transfer platforms are examples of situations where tensile strength is fundamental.

When geosynthetics are subject to long term tensile loading they will creep under load and might rupture. The tensile creep and rupture behaviour is measured using the test in ISO 13431. All polymers subjected to loads will creep. Depending on the nature of the polymer and the service loads, the life of the geosynthetic can be predicted. The methods to carry out the evaluations are described in ISO/TR 20432.

4.3.5.2 Compressive behaviour

The compressive strength of three dimensional geosynthetics is an important characteristic if the product is to be installed in a situation where there will be a load on the surface of the product. The loading will induce an immediate change in the thickness, as measured in ISO 25619-2 and hence reduction in the in-plane flow capacity. If the load is maintained, the product thickness will continue to reduce, as measured in ISO 25619-1. As with tensile loading, if the product is loaded with a modest proportion of the short-term crushing load, a rupture or collapse mechanism can develop. The designer would normally select a product that will not suffer from compressive creep rupture or collapse during the design life of the product.

4.3.5.3 Mechanical interlock

Mechanical interlock between the apertures in geogrids and granular materials laid over the geogrid is considered a fundamental mechanism in some design processes for the design of geosynthetics used to stabilize unbound pavements. Other design methods rely on mobilizing frictional resistance between the soils and the geosynthetic. ISO/TR 18228-5[1)] provides further guidance on these concepts.

4.3.6 Hydraulic properties

4.3.6.1 Filtration and permeability

Long-term filtration, measured in ISO 10772 and permeability, measured in ISO 10776 or ISO 11058, are a function of the apparent opening size of the geosynthetic as measured in ISO 12956. For longer term use, the designer would normally consider how the openings in the geosynthetic can become blocked or clogged due to silt migration, or bacterial activity on and in the matrix of the geosynthetic (see References [19] and [18]).

4.3.6.2 Drainage

Designers will normally consider the long-term reduction of drainage capacity due to the changes in thickness or internal clogging of the three-dimensional core by soil particles passing through the filter and/or bacteria multiplying and filling the drainage voids.

4.4 External loadings

4.4.1 Live loading

Many geotechnical structures need to support live loadings in service. The design models would normally include the actions on the structure and any geosynthetics included would normally accommodate the effects of such loadings in the design. Some typical loadings that can be considered include:

— highway traffic and footways;

— railway track loadings from trains;

— wave and ship wash loadings for river and coastal revetments; and

— structural loadings from bridge abutments or bank seats supported on reinforced soil structures.

1) Under preparation.

4.4.2 Permanent applied loading

Geosynthetics are normally subject to permanent loadings which can affect their properties and are normally considered as part of the basic design process. Some typical permanent loadings are:

— normal plane loadings at the base of fills – landfills or as basal reinforcements to embankments on soft ground;

— vertical loads from fills in a reinforced soil structure; and

— lateral soil loadings when used as a drainage layer between a vertical wall and backfill soils.

5 Local design requirements

5.1 General

The descriptions of local requirements given in this clause are not exhaustive and represent the information available at the time this document was prepared. Designers would normally be expected to satisfy themselves of the local requirements in the region in which they are working.

5.2 Europe

The design of geotechnical structures in Europe is generally in accordance with EN 1997-1, Eurocode 7 and the National Application Documents (NADs) applicable to the European State in which the works are to be constructed. Other elements of structural designs would normally be in accordance with the other appropriate parts of the Eurocode suite of standards.

The Eurocodes as currently published are difficult to apply to geosynthetic designs as the partial material factors are not appropriate for geosynthetics. The Eurocodes are being revised. For some areas of the ISO/TR 18228 series, notably the design of reinforced soil structures, changes are expected to be introduced that will allow designs using geosynthetics to be made in accordance with the Eurocode.

5.3 United States of America

The Federal Highways Administration (FHWA) has published documents relating to the design of works incorporating geosynthetics in highway works throughout the USA:

— FHWA-NHI-07-092, *Geosynthetic Design and Construction Guidelines* (2008)[52];

— FHWA- RD-86-171 & 172, *Geocomposite Drains* (1986) (Parts 1 & Part 2)[53];

— FHWA-HI-95-038, *Geosynthetic Design and Construction Guidelines Participant Notebook* (1998)[54];

— FHWA-HRT-11-026, *Geosynthetic Reinforced soil integrated bridge system synthesis report* (2009)[55];

— FHWA-HRT-11-027, *Geosynthetic Reinforced Soil Integrated Bridge System Synthesis Report* (2011)[56];

— FHWA-RD-86-168, *Prefabricated Vertical Drains* (1986) (all volumes)[57];

— FHWA-RD-01-050, *Durability of Geosynthetics for Highway Applications* (2001)[58];

— AASHTO 1993, *Guide for the design of Pavement Structures*[59];

— AASHTO R50-09, *Standard Practice for Geosynthetic Reinforcement of the aggregate base course of flexible pavement structures*[60].

The California Department of Transportation (CALTRANS) has published a geotechnical manual which describes the detailed application of the FHWA-NHI-07-092, *Geotechnical Design and Construction Guidelines*[52] for the design of transportation infrastructure including geosynthetics in California. This is readily available online via a search for *CALTRANS Geotechnical Manual*.

Different states across the USA have their own local standards covering road design and how geosynthetics can be adopted into them. CALTRANS, for example, has different specifications and expected benefits for biaxial and multiaxial geogrids.

5.4 Hong Kong

The Geotechnical Engineering Office has issued a number of design standards and reports which are used in Hong Kong for geotechnical designs incorporating geosynthetics.

5.5 Australia

New South Wales highway authority design specifications are used in the territory and have been adopted elsewhere in Australia. Road design in Australia is typically covered by *AustRoads: Guide to Road design* (available in a number of parts via the AustRoads website). There are local state-based specifications covering products but AustRoads is the design method often used. Other methods covering mechanistic-empirical approaches are also used, for example Circly.

5.6 South Africa

The *South African Pavement Engineering Manual (SAPEM)*[67] is a reference manual for all aspects of pavement engineering. COLTO (Committee of Land Transport Officials) documents published by the South African National Roads Agency (SANRAL): *Standard Specifications for Road and Bridge Works for State Authorities*[68] (Volume 2 Standard Specifications) under development.

5.7 United Kingdom

Within the United Kingdom, highways on the strategic road network and many local roads are designed and detailed using the *Design Manual for Roads and Bridges*[61], and the *Specification for Highway Works*[62]. Included in these documents are requirements for the design and specifications for geosynthetics used to suppress reflective cracking, as reinforcement, separation and drainage aspects of highways and the associated works.

Pavement road layer thickness design in the UK is typically split into two with the foundation designed separately from the surfacing layers. Foundation design has historically been designed using HD25[63] and surfacing by HD26[64]. HD25 has been under review for the last 10 years and published as an Interim Advice Note number 73 (IAN 73) [63]. This is a chart-based design approach with capping and sub-base designs carried out based on ground conditions and target level of support. It is essentially empirical and in its current draft makes an acknowledgement that geosynthetics might be advantageous but is based on previous use or experience. At the time of publication of this document, the draft is however still under review and not yet published. As a result, the previous version of HD25 is still used by authorities where reference is made to it, or observational methods used in older roadways design documents *LR1132*[65], *Road Note 29*[66] for example.

Bibliography

Standards publications

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

[2] ISO 10318-2, *Geosynthetics — Part 2: Symbols and pictograms*

[3] ISO 10319, *Geosynthetics — Wide-width tensile test*

[4] ISO 10320, *Geosynthetics — Identification on site*

[5] ISO 10321, *Geosynthetics — Tensile test for joints/seams by wide-width strip method*

[6] ISO 10772, *Geotextiles - Test method for the determination of the filtration behaviour of geotextiles under turbulent water flow conditions*

[7] ISO 10776, *Geotextiles and geotextile-related products — Determination of water permeability characteristics normal to the plane, under load*

[8] ISO 11058, *Geotextiles and geotextile-related products — Determination of water permeability characteristics normal to the plane, without load*

[9] ISO 12957-1, *Geosynthetics — Determination of friction characteristics — Part 1: Direct shear test*

[10] ISO 12957-2, *Geosynthetics — Determination of friction characteristics — Part 2: Inclined plane test*

[11] ISO 12956, *Geotextiles and geotextile-related products — Determination of the characteristic opening size*

[12] ISO 13426-1, *Geotextiles and geotextile-related products — Strength of internal structural junctions — Part 1: Geocells*

[13] ISO 13426-2, *Geotextiles and geotextile-related products — Strength of internal structural junctions — Part 2: Geocomposites*

[14] ISO 13427, *Geosynthetics — Abrasion damage simulation (sliding block test)*

[15] ISO 13431, *Geotextiles and geotextile-related products — Determination of tensile creep and creep rupture behaviour*

[16] ISO/TS 13434:2008, *Geosynthetics — Guidelines for the assessment of durability*

[17] ISO 13438, *Geosynthetics — Screening test method for determining the resistance of geotextiles and geotextile-related products to oxidation*

[18] ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

[19] ISO 14688-2, *Geotechnical investigation and testing — Identification and classification of soil — Part 2: Principles for a classification*

[20] ISO 17892 (all parts), *Geotechnical investigation and testing — Laboratory testing of soil*

[21] ISO/TR 18228-5[2)], *Design using geosynthetics — Part 5: Stabilization*

[22] ISO 18325, *Geosynthetics — Test method for the determination of water discharge capacity for prefabricated vertical drains*

[23] ISO 22476 (all parts), *Geotechnical investigation and testing — Field testing*

2) Under preparation.