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Geosynthetics — Guidelines for the assessment of durability

Géosynthétiques — Lignes directrices concernant la durabilité

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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).

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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.

ISO/TS 13434 was prepared by Technical Committee ISO/TC 221, *Geosynthetics*.

This first edition cancels and replaces ISO/TS 13434:2008, which has been technically revised. The main changes compared to the previous edition are as follows:

- standards and wording actualized;
- added product types in 5.1;
- updated subclauses 5.4, 8.4, 8.5 and Table 3.

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.

Geosynthetics — Guidelines for the assessment of durability

1 Scope

This document provides guidelines for the assessment of the durability of geosynthetics, the object of which is to provide the design engineer with the necessary information, generally defined as changes in material properties or as partial safety factors, to ensure that the expected design life of a geosynthetic can be achieved with confidence.

This document is not applicable to products designed to survive for only a limited time, such as erosion-control fabric based on natural fibres.

This document is applicable to the durability of the geosynthetics and not to the durability of the geotechnical structure as a whole.

NOTE The calculation of reduction factors for soil reinforcement applications is described in ISO/TR 20432.

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*

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

ISO 13438:2018, *Geosynthetics — Screening test method for determining the resistance of geotextiles and geotextile-related products to oxidation*

3 Terms, definitions, symbols and abbreviated terms

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

A	rate of degradation
A_0	constant in Arrhenius equation
d_{50}	50 % soil gradation
E	activation energy

M_n	number-averaged molecular weight
M_w	weight-averaged molecular weight
R	universal gas constant (8,314 J/mol·K)
t_g	glass transition temperature
T	absolute temperature

3.3 Abbreviated items

CMD	cross-machine direction
CPE	chlorinated polyethylene
CSPE	chlorosulfonated polyethylene
DSC	differential scanning calorimetry
EIA	ethylene interpolymer alloy
ENB	ethylidene norbornene
EPDM	ethylene propylene diene monomer
EPS	expanded polystyrene
ESC	environmental stress cracking
fPP	flexible polypropylene
GBR-B	bituminous geosynthetic barrier
GBR-C	geosynthetic clay barrier
GBR-P	polymeric geosynthetic barrier
HALS	hindered amine light stabilizers
PE-HD	high-density polyethylene
HP-OIT	high-pressure oxidation induction time
KEE	ketone ethylene ester
PE-LLD	linear low-density polyethylene
MB	modified bitumen
MD	machine direction
OIT	oxidation induction time
PA	polyamide
PCM	post-consumer material
PE	polyethylene
PEN	polyethylene naphthalate

PET	polyethylene terephthalate
PIM	post-industrial material
PP	polypropylene
PS	polystyrene
PVAL	polyvinyl alcohol
PVC-P	flexible polyvinyl chloride
RPP	reinforced polypropylene
RWM	reworked material
SBS	styrene-butadiene-styrene
S-OIT	oxidation induction time measured by standard method
XPS	extruded polystyrene
UV	ultraviolet

4 Generalized procedure

4.1 General

When a geosynthetic is used in a civil engineering structure, it is intended to perform a particular function for a minimum expected time, called the design life. A geosynthetic is a generic term describing a product, where at least one of the components is made from a synthetic or natural polymer, in the form of a sheet, a strip or a three-dimensional structure, used in contact with soil and/or other materials in geotechnical and civil engineering applications. Geosynthetic products comprise geotextiles, geosynthetic barriers (polymeric, bituminous and geosynthetic clay liners), geogrids, geonets, geocells, geostrips, geomats, geoblankets, geocomposites and geospacers. The eight functions defined in ISO 10318-1 are barrier function, drainage, filtration, protection, reinforcement, separation, stabilisation, stress relief for asphalt overlay and surface erosion control. Each function uses one or more properties of the geosynthetic, such as tensile strength or water permeability for a geotextile and impermeability to liquids for a geosynthetic barrier. These are referred to as functional properties.

Assessment of the durability of structures using geosynthetics 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. The main task 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 to the lack of well-documented experience.

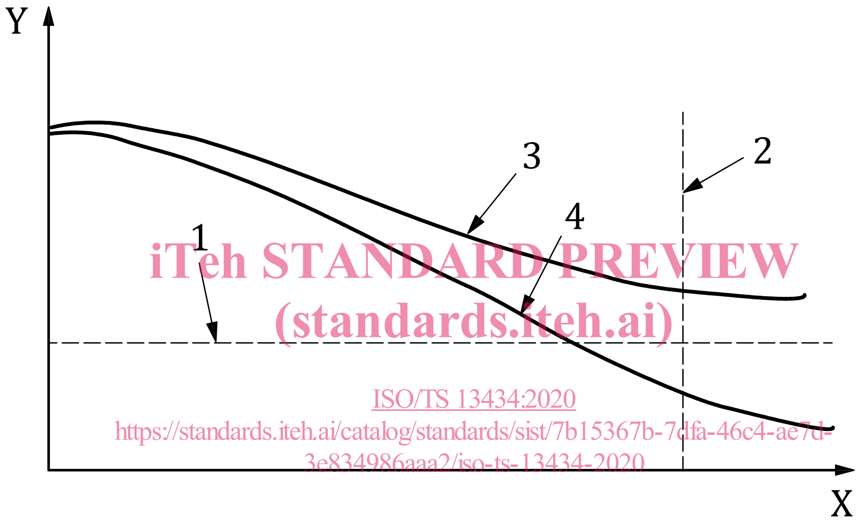
The majority of geosynthetics, when correctly processed and stabilized, are comparatively resistant to chemical and microbiological attack encountered in normal soil environments and for normal design lives. For such applications, only a minimum number of screening or index tests may be necessary. For applications in more severe environments, such as soil treated with lime or cement, landfills or industrial-waste containments, or for applications with particularly long design lives, special tests including “performance” tests with site-specific parameters may be required.

4.2 Available and required properties

4.2.1 Condition of acceptability

A geosynthetic will have one or more functional properties critical to its intended function, for example tensile strength or permeability. It is then necessary to differentiate between the available and required values of this functional property. The available property is that provided by the geosynthetic. The required property is the minimum level necessary for the geosynthetic to perform its intended function.

The available property is expected to change with time due to degradation of the material, as shown in Figure 1. The necessary condition is that, at the design lifetime (Item 2 in Figure 1), the available property exceeds the required property, which is shown for simplicity as remaining constant in time (Item 1). This condition is satisfied under the first set of conditions (Item 3) and is not satisfied under the second set of conditions (Item 4). These are therefore deemed to be acceptable and not acceptable, respectively.



Key

X time

Y property of a geosynthetic, expressed as a percentage of its original value

1 minimum acceptable level of required property

2 design lifetime

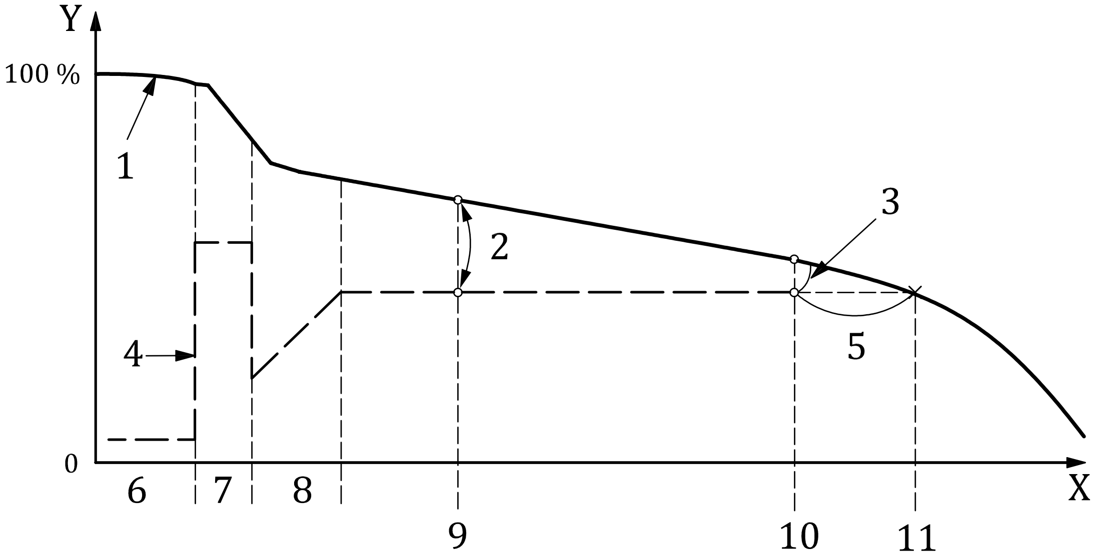
3 available property under first set of conditions (acceptable)

4 available property under second set of conditions (not acceptable)

Figure 1 — Available and required properties as a function of time under two different sets of conditions, the first acceptable and the second not acceptable

4.2.2 Development of the required and available properties with time

In practice, both the available property and the required property can vary with the successive events that occur between manufacture of the product and the design life. Figure 2 shows a schematic example.



Key

X time

Y property of a geosynthetic, expressed as a percentage of its original value

1 available property

2 margin between required and available property at intermediate time

3 margin of safety at design life

4 required property

5 margin of safety between design life and time to failure

6 duration prior to installation (storage and transportation)

7 duration of installation and covering

8 duration of further construction

9 intermediate time during normal use

10 design life

11 time to failure

Figure 2 — Available and required properties of a geosynthetic during storage and transportation, construction, backfilling and use

A new geosynthetic exhibits an initial or short-term available property as defined by a set measurement standard. Depending on the level of quality control and quality assurance, a reduction factor may be applied to cover variations in the initial property.

The available property is shown as line 1 in Figure 2. During storage and transportation (period 6 in Figure 2), this property may change due to weathering, while during installation (period 7) and further construction (period 8), it may suffer from mechanical damage. The extent of the mechanical damage incurred during installation depends on the geosynthetic, the nature of the materials in contact with the geosynthetic, the equipment used and the care provided by the handling team (see 6.4.4). For polymeric geosynthetic barriers, the manufacturing process and the welding parameters during installation may not lead to immediate degradation, but can induce residual stresses in the material which lead to a stress-crack phenomenon and more rapid subsequent degradation.

After backfilling (period 8), the operating life of the material starts. During the operating life, the geosynthetic is subjected to chemical, biological or physical actions due to the soil, its constituents, and its air, water and organic content, resulting in a gradual reduction in the available property until the design life (Item 10 in Figure 2) is reached. The available property will diminish further if the geosynthetic remains in place beyond its design life.

The required property is shown as line 4 in Figure 2. During storage and transportation (period 6 in Figure 2), a minimum required property, generally strength, is needed to resist handling loads. Installation and compaction (period 7) may require a strength higher than that required for the remainder of the design life. During further construction (period 8), the load will increase from a lower level, increasing the required strength. When finally in use, the required property will remain constant.

It should be noted that the available property can diminish due to the level of constraints or the applied load: the greater the applied stress, the shorter the time to failure. This is a particularly important phenomenon that is described in 6.4, particularly in 6.4.1. Thus, there can be an interaction between the required property and the available property. There is no absolute available property curve as shown schematically in the graph by the presence of the two curves.

It should also be noted that there may be more than one functional property. For example, a filter or separator will have a minimum required strength to survive installation and construction, while in operation the required property will be the permeability or opening size. The above analysis should be performed for both properties.

The testing techniques and the assessment methods for estimating the property curves is presented and discussed in later subclauses. Index test methods are intended to ensure a minimum level of durability and do not constitute a comprehensive assessment procedure. Where this is needed, it will be necessary to carry out further performance tests more closely related to service conditions. These tests may also include investigations on samples extracted from sites where the same product has been used for several years in a similar environment. Procedures have been developed, such as those described in ISO 13437. As in other fields of engineering, confidence in the durability of geosynthetics is developing as the technology matures and the results of long-term service experience accumulate. Examples of experience to date are described in Clause 6.

4.3 Design life

The design life is specified on the time axis (Item 2 in Figure 1, Item 10 in Figure 2). It is set by the client (or a design code) and is decided at the design stage. Codes generally propose several fixed durations, according to whether the structure is meant for short-term use (typically a few years and not exceeding five years), temporary use (generally less than 25 years) or permanent use (over 25 years, and generally 50 to >100 years). The nature of the structure, the environmental risk involved and the consequences of failure may influence this duration (example: 70 years for a wall, 100 years for an abutment and beyond 100 years for landfills). Many geosynthetics have a temporary function although the structure is permanent; for example, an embankment over a weak soil may require a geotextile or geogrid reinforcement until the embankment has settled.

4.4 Margin of safety

At the end of the anticipated design life, the designer has to ensure a certain margin of safety (generally also indicated by codes), such that failure (Item 11 in Figure 2) is predicted to be well beyond the design life (Item 10). Item 3, the difference between the predicted available property and the predicted required property, represents the margin of safety for that component. This can be expressed as a ratio. The ratio can also be expressed in terms of the time to reach the end of life if the geosynthetic were to be left in service after the end of its design life (Item 5). These two representations of safety, the ratio of required and available property at the design life, and the ratio of the predicted end of life to design life, should be considered together because, in combination, they give a better idea of the real level of safety that exists.

The calculation of reduction factors for soil reinforcement applications is described in ISO/TR 20432.

4.5 End of life (function)

The end of life is the point on the time axis where the available property curve meets the required property curve (Item 11 in Figure 2). At this point, the product is predicted not to fulfil its function. Residual service may remain either if the expected loads are overestimated, or if they imply a combination of degradation mechanisms that may not all have reached their maximum values. Whatever the case, beyond that point on the graph, the possibility of end of function or failure is high.

4.6 Durability study

The design and durability assessment of a structure using a geosynthetic can be summarized as follows:

- defining the function(s) of the geosynthetic;
- making the inventory of the constraints imposed by the application (environmental, physical, chemical);
- defining the design life of the geosynthetic;
- quantifying the required properties of the geosynthetic (e.g. strength, permeability, impermeability, seam integrity);
- defining the geosynthetic properties;
- making sure that the estimated available properties at the end of the design life are greater than the required properties.

5 Constituents of geosynthetics

5.1 Types of geosynthetic

5.1.1 Polymeric durability considerations

The durability of a polymeric geosynthetic depends upon the unit weight, the formulation from which it is made, on any additives and fillers compounded with it, on the polymer microstructure, the fibre geometry and fabric layout for geotextiles, the unit weight, and thickness of geosynthetic barriers, and the quality of joints and junctions. The geosynthetic should be chemically and biologically resistant if it is to be suitable for long-term applications.

The polymers used to manufacture geosynthetics are generally thermoplastic materials which may be amorphous or semi-crystalline. An amorphous polymer has a randomly coiled structure which, at the glass transition temperature, t_g, undergoes significant change from a stiff, glassy, brittle response to loads below the glass transition temperature to a more ductile, rubbery response above t_g. Most polymers used in geotextiles are semi-crystalline, that is they contain small, more or less oriented crystallites, alternating with amorphous material. Since the change in behaviour only affects the amorphous regions, the glass transition is less marked for a semi-crystalline polymer. At a higher temperature, however, the crystallites melt, which produces an abrupt change in properties. Values of t_g and melting temperature are given in Table 1 for the polymers most commonly used in geosynthetics. In civil engineering applications, polyesters are used below their t_g while polypropylene and polyethylene are used above t_g. Any acceleration of laboratory tests crossing a transition, such as t_g, should be avoided or, if this is not possible, an appropriate factor of safety should be applied.

Mechanical drawing of polymers, e.g. for forming tapes, fibres or filaments, leads to increased orientation that results in higher tensile properties, improved durability and reduction of the changes in properties at the glass transition temperature. As the molecules become more oriented, the fibres become stronger. The crystallites are retained and the ratio of crystalline regions and amorphous regions should be properly balanced to produce the physical properties necessary for fibres used in geotextiles, or for the ribs of extruded geogrids (see 5.1.5). The increased orientation and associated higher density leads to higher environmental resistance. The durability assessment should consider whether any change in this morphology is likely during the service life of the product, and whether such a change will lead to a significant change in properties. Thermal analysis techniques have proved useful in measuring such changes.

Any polymer, whether amorphous or semi-crystalline, consists of long-chain molecules (macromolecules), each containing many chemical units. Each unit may be composed of one or more monomers, the number of which determines the length of the polymeric chain and resulting molecular weight. The nature and the number of the monomer distribution determine the length and structure of the polymeric chain. These factors can affect physical properties such as the tensile strength and modulus, impact strength, flexibility and heat resistance, as well as the durability properties. The mechanical and physical properties of the plastics are also influenced by the bonds within and between chains, chain branching, and the degree of crystallinity.

Crystallinity has a strong effect on polymer properties, especially the mechanical properties, because the tightly packed molecules within the crystallites result in dense regions with high intermolecular cohesion and higher resistance to penetration by chemicals. An increase in the degree of crystallinity leads directly to an increase in rigidity and yield or tensile strength, hardness and softening point, and to a decrease in liquid permeability and gas diffusion.

Durability of all geosynthetics is influenced by fibre or rib diameter or surface-to-volume ratio. Resistance to oxidation and UV exposure is generally dependent on fibre or rib diameter or thickness since the rate of oxidative/photo-oxidative reactions is often limited by the rate of diffusion of oxygen, especially at elevated testing temperatures. Evaporation and extraction of additives is also inversely related to surface-to-volume ratio. These factors should be taken into account in the design of suitable testing procedures and in considering the results of established tests. The choice of test method should ensure that oxygen availability has been simulated correctly. Changes of polymer morphology caused by testing at too high temperatures should be avoided.

Durability is further influenced by the nature and quality of the additives and fillers used.

5.1.2 Geotextiles

A geotextile is a planar, permeable, polymeric (synthetic or natural) textile material, which may be woven, knitted or non-woven. The principal materials used are polypropylene (PP), polyester (PET) and polyethylene (PE).

5.1.3 Geosynthetic barriers or polymeric and bituminous geosynthetic barriers

A geosynthetic barrier is a planar, relatively impermeable, polymeric (synthetic or natural) (GBR-P) or bituminous (GBR-B) sheet. The polymers used to manufacture the geosynthetic barriers are generally thermoplastic materials, elastomeric materials and modified bituminous materials. The materials used are high-density polyethylene (PE-HD), linear low-density polyethylene (PE-LLD), flexible polyvinyl chloride (PVC-P), flexible polypropylene (fPP), ethylene propylene diene monomer (EPDM), ethylene interpolymer alloy (EIA), chlorinated polyethylene (CPE), chlorosulfonated polyethylene (CSPE) and other elastomeric materials.

5.1.4 GBR-C

A geosynthetic clay barrier or liner (GBR-C) is a factory-manufactured geosynthetic hydraulic barrier consisting of clay, bentonite or other very low-permeability material supported by geotextiles, geosynthetic barriers, or a combination thereof, and held together by needle punching, stitching, chemical adhesives or other methods. Its durability is governed by the durability of the geosynthetics, the needle-punching fibres, the stitch-bonding filaments/yarns, the glues, and also the ion exchange between the material and the liquid retained or contained, and also desiccation.

5.1.5 Geoblankets (GBL)

A permeable structure of loose natural and/or synthetic fibres and other elements (natural or synthetic) bonded together to form a continuous sheet.

5.1.6 Geogrids

A geogrid is a geosynthetic formed by a regular open network of integrally connected elements with apertures to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to function primarily as reinforcement and stabilisation. The elements in the machine and cross-directions may be integral or may be linked by bonding or interlacing. The manufacturing techniques vary widely. Currently weaving, knitting, extrusion and welding are used. Some products m ake use of fibres of polyethylene (PE), polypropylene (PP), polyester (PET), polyvinyl alcohol (PVA) and aramid. Coating materials include acrylic polymers, flexible polyvinyl chloride (PVC-P), and polyethylene (PE). In addition, PE and PP geogrids are made by the stretching of punched sheet.

5.1.7 Geonets

A geonet is an open planar, polymeric structure consisting of a regular dense network, whose constituent elements are linked by knots or extrusions and whose openings are larger than the constituents. The polymers used to manufacture the geonet are generally thermoplastic materials, such as high-density polyethylene (PE-HD).

5.1.8 Geocells

A geocell is a three-dimensional, permeable, natural, or synthetic polymeric honeycomb or web structure, made of linked strips of geotextiles, geogrids, perforated sheets or geosynthetic barriers.

5.1.9 Geomats

A geomat is a three-dimensional, permeable, natural, or synthetic polymeric structure, made of bonded filaments, used to reinforce roots of grass and small plants and extend the erosion-control limits of vegetation for permanent erosion-control applications. The polymers used to manufacture the geomats are generally thermoplastic materials, such as PA, PE, PET and PP.

5.1.10 Geocomposites

A geocomposite is a manufactured or assembled material using at least one geosynthetic products among its components.

5.1.11 Geofoam

A geofoam is a block or a planar section of rigid cellular-foam polymeric material used in geotechnical engineering applications. Geofoam is commonly used as a lightweight fill to take up differential thermal expansion and for use in frozen ground.

5.1.12 Geospacers

Cuspated foils produced from extruded laminates, which are profiled during production into wave-shaped or truncated cuspate cone profiles, on one or both faces. They are typically made of polypropylene (PP) or high density polyethylene (HDPE).

5.2 Individual polymer types

5.2.1 General

The polymers used in geosynthetics are described below and three of their most important physical properties are listed in Table 1. The general remarks in 5.1.1 apply.