Standard Guide for Selecting Test Methods for Experimental Evaluation of Geosynthetic Durability[1]

This standard is issued under the fixed designation D 5819; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers a designer/specifier through a systematic determination of those factors of the appropriate application environment that may affect the post-construction service life of a geosynthetic. Subsequently, test methods are recommended to facilitate an experimental evaluation of the durability of geosynthetics in a specified environment so that the durability can be considered in the design process.

1.2 This guide is not intended to address durability issues associated with the manufacturing, handling, transportation, or installation environments.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1204 Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature[2]

D 1987 Test Method for Biological Clogging of Geotextiles or Soil/Geotextile Filters[3]

D 2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics[4]

D 3083 Specification for Flexible Poly(Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining[5]

D 3895 Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry[4]

D 4355 Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)[3]

D 4594 Test Method for Effects of Temperature on Stability of Geotextiles[3]

D 4716 Test Method for Determining the (In-Plane) Flow Rate Per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head[3]

D 4886 Test Method for Abrasion Resistance of Geotextiles (Sand Paper/Sliding Block Method)[3]

D 5101 Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio[3]

D 5262 Test Method for Evaluating the Unconfined Tension Creep Behavior of Geosynthetics[3]

D 5322 Practice for Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids[3]

D 5397 Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test[3]

D 5496 Practice for In Field Immersion Testing of Geosynthetics[3]

D 5567 Test Method for Hydraulic Conductivity Ratio (HCR) Testing of Soil/Geotextile Systems[3]

D 5885 Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry[3]

D 5970 Test Method for Deterioration of Geotextiles from Outdoor Exposure[3]

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[6]

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials[6]

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources[6]

G 152 Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials[6]

G 153 Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials[6]

G 154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials [6]

3. Summary of Guide

3.1 The effects of a given application environment on the durability of a geosynthetic must be determined through appropriate testing. Selection of appropriate tests requires a systematic determination of the primary function(s) to be performed and the associated degradation processes that should be considered. This guide provides a suitable systematic approach.

---

[1] This guide is under the jurisdiction of ASTM Committee D-35 on Geosyntheticsand is the direct responsibility of Subcommittee D35.02 on Endurance Properties.

Current edition approved Dec. 10, 1999. Published March 2000. Originally published as D 5819 – 95. Last previous edition D 5819 – 95.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] Discontinued; see *1997 Annual Book of ASTM Standards*, Vol 04.09.

[6] *Annual Book of ASTM Standards*, Vol 14.04.

TABLE 1 Functions[A] and Other Performance Characteristics[B]

Containment[B](C)—A geosynthetic provides containment when it encapsulates or surrounds materials such as sand, rocks, and fresh concrete.[C]
Filtration[A](F)—A geosynthetic performs the filtration function when the equilibrium geotextile-to-soil system allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration.
Fluid Barrier[A](FB)—A geosynthetic performs the fluid barrier function when it essentially eliminates the migration of fluids through it.
Fluid Transmission[A] (*a.k.a. drainage*)—A geosynthetic performs the fluid transmission function when the equilibrium geotextile-to-soil system allows for adequate flow with limited soil loss within the plane of the geotextile over a service lifetime compatible with the application under consideration.
Insulation[B](I)—A geosynthetic provides insulation when it reduces the passage of heat, electricity, or sound.
Protection[A](P)—A geosynthetic, placed between two materials, performs the protection function when it alleviates or distributes stresses and strains transmitted to the material to be protected.
Reinforcement[A](R)—A geosynthetic performs the reinforcement function when it provides often synergistic improvement of a total system's strength created by the introduction of a tensile force into a soil (good in compression but poor in tension) or other disjointed and separated material.
Screening[B](Scr)—A geosynthetic, placed across the path of a flowing fluid (ground water, surface water, wind) carrying particles in suspension, provides screening when it retains some or all soil fine particles while allowing the fluid to pass through. After some period of time, particles accumulate against the screen which requires that the screen be able to withstand pressures generated by the accumulated particles and the increasing fluid pressure.
Separation[A](S)—A geosynthetic placed between dissimilar materials so that the integrity and functioning of both materials can remain intact or be improved performs the separation function.
Surface Stabilization[B](SS)—A geosynthetic, placed on a soil surface, provides surface stabilization when it restricts movement and prevents dispersion of surface soil particles subjected to erosion actions (rain, wind), often while allowing or promoting vegetative growth.
Vegetative Reinforcement[B](VR)—A geosynthetic provides vegetative reinforcement when it extends the erosion control limits and performance of vegetation.

[A]Functions are used in the context of this guide as terms that can be quantitatively described by standard tests or design techniques, or both.
[B]Other performance characteristics are qualitative descriptions that are not yet supported by standard tests or generally accepted design techniques.
Note—during the placement of fresh concrete in a geotextile flexible form, the geosynthetic functions temporarily as a filter to allow excess water to escape.

3.2 Primary functions of geosynthetics are listed and defined in Table 1. With knowledge of the specific geosynthetic application area and end use, the corresponding primary function(s) is (are) identified. Table 2 gives degradation concerns as they relate to geosynthetic functions. Table 3 gives the environmental elements that relate to the various degradation processes and the currently available ASTM Committee D-35 test method for the experimental evaluation of specific types of geosynthetic degradation. The following appendixes are included to provide background information:

X1. Terminology
X2. Application/End Use/Primary Function Tables
X3. Example of Test Method Selection Procedure
X4. Design-by-Function Discussion
X5. Commentary on Geosynthetic Durability
X6. Bibliography

4. Significance and Use

4.1 Designers/specifiers of geosynthetics should evaluate geosynthetic durability as an integral part of the geosynthetic specification/selection process. This guide is intended to guide a designer/specifier through a systematic determination of degradation concerns based on the intended geosynthetic function or performance characteristic. This guide then provides a guide to select available test methods for experimentally evaluating geosynthetic durability and to identify areas where no suitable test exists.

4.2 This guide does not address the evaluation of degradation resulting from manufacturing, handling, transporting or installing the geosynthetic.

5. Suggested Procedure

5.1 To utilize a structured procedure for selecting appropriate test methods, the geosynthetic designer/specifier must have knowledge of:

5.1.1 The intended geosynthetic application,

5.1.2 The end use of the geosynthetic via its primary function(s) or performance characteristic(s), or both,

5.1.3 The specific environment to which the geosynthetic will be exposed,

5.1.4 The types of geosynthetics that may or will be used, and

5.1.5 The duration or time of use (that is, service life).

5.2 With this knowledge, the designer/specifier follows the following procedure:

5.2.1 Identify the primary function(s) or performance characteristic(s), or both, to be performed by the geosynthetic in the specific application and end use intended. Functions and performance characteristics are defined in Table 1. (Tables for guidance in identifying primary function(s) and performance characteristics are given in Appendix X2.)

5.2.2 Using Table 2, identify the potential degradation process(es) that will almost always (denoted as "A") or sometimes (denoted as "S") be of concern when a geosynthetic performs the primary function(s) or provides the performance characteristic(s), or both, which were identified in 5.2.1. Annex A1 contains associated notes to Table 2 that help to identify the process(es) that is (are) sometimes a concern in the specific expected application environment.

5.2.3 Using Table 3, select the test method(s) that applies to the potential degradation process(es) identified in 5.2.2 as a concern(s) in the specific application environment expected.

NOTE 1—Guidance is given in Table 3 to identify the most important elements or variables relating to each degradation process.

6. Keywords

6.1 aging; degradation; durability; environment; exposure; geosynthetic; long-term performance

TABLE 2 Geosynthetic Function/Durability Assessment[A]

Function	Potential Degradation Process[B]														Explanations of Primary Long-Term Concerns
	Abbreviation	Biological Degradation	Chemical Degradation	Chemical Dissolution	Clogging/ Piping	Creep	Environmental Stress Cracking	Hydrolysis	Mechanical Damage	Photo-Degradation	Plasticization	Stress Relaxation	Temperature Instability	Thermal-Degradation	
Containment	C	P[C,D]	S[E]	S[E]	S[F]	S[G]	N	S[H]	S[I]	S[J]	N	S[G]	N	S[K]	Remain intact and maintain filtration performance
Filtration	F	P[C,D]	S[E]	S[E]	A[L]	S[M]	N	S[H]	S[I]	S[J]	N	S[M]	N	S[K]	Maintain design filtration and resist deformation and intrusion
Fluid Barrier	FB	S[C]	S[E]	S[E]	N	S[G]	A[N,O]	S[H]	S[I]	S[J]	N	S[G]	S[P]	S[K]	Maintain intended level of essential impermeability
Fluid Transmission	FT	P[C,D]	S[E]	S[E]	A[Q]	A[R]	A[O]	S[H]	S[I]	S[J]	N	A[R]	N	S[K]	Maintain flow under compressive loads
Insulation	I	P[C,D]	S[E]	S[E]	N	N	N	N	N	N	N	N	N	N	Minimize temperature losses and gains across geosyn
Protection	P	P[C,D]	S[E]	S[E]	N	S[S]	N	S[H]	N	S[J]	N	S[S]	N	S[K]	Maintain protective performance
Reinforcement	R	P[C,D]	S[E]	S[E], P[T]	N	A[U]	P[O]	S[H]	P[T]	S[J]	P[V]	S[U]	S[U]	S[K]	Provide necessary strength, stiffness and soil interaction
Screening	Scr	P[C,D]	S[E]	S[E]	S[W]	N	N	S[H]	S[I]	S[J]	N	N	N	S[K]	Maintain filtration performance and resist deformation
Separation	S	P[C,D]	S[E]	S[E]	N	N	N	S[H]	P[X]	S[J]	N	N	N	S[K]	Remain intact
Surface Stabilization	SS	P[C,D]	S[E]	S[E]	N	N	N	S[H]	A[Y]	A[Y]	N	N	N	S[K]	Remain intact to resist erosive forces until vegetation is established
Vegetative Reinforcement	VR	P[C,D]	S[E]	S[E]	N	N	N	S[H]	A[Y]	A[Y]	N	N	N	S[K]	Remain intact throughout vegetation

[A] Refer to Appendix X1 for terminology relating to Table 2.

[B] *M* = Not a generally recognized concern; S = Sometimes a concern; A = Almost always a concern; P = Potential concern being researched.

[C] Microorganisms have been known to attack and digest additives (plasticizers, lubricants, emulsifiers) used to plasticize some base polymers. This attack will change physical and mechanical properties. Study is needed to determine relevance to polymers incorporated into geosynthetic products. Embrittlement of geosynthetic surfaces may influence interaction properties.

[D] Microbial enzymes have been known to initiate and propagate reactions deteriorative to some base polymers. Study is needed to determine relevance to polymers used in geosynthetic products.

[E] Chemical degradation or dissolution, or both, including the leaching of plasticizers or additives from the polymer structure, may be a concern for some geosynthetics exposed to liquids containing unusually high concentrations of metals, salts, or chemicals, especially at elevated temperatures.

[F] If select fill is not available, then a clogging resistance test should be performed with the job-specific soil.

[G] Geosynthetics in containment structures which require long term strength characteristics should be designed using appropriate creep and stress relaxation criteria.

[H] Hydrolysis may be a concern for polyester (PET) and polyamide (PA) geosynthetics exposed to extreme pH conditions, especially at elevated temperatures.

[I] When subject to rocking (abrasion), puncture (floating or airborne debris), or cutting (equipment or vandalism).

[J] When permanently exposed or in extended construction phases (>2–4 weeks) and in "wrap-around" construction, photo degradation may be a concern for the exposed geosynthetic.

[K] Geosynthetics in applications such as dam facings and floating covers which results in exposure to temperatures at or above ambient must be stabilized to resist thermal oxidation.

[L] Clogging resistance of geotextiles can only be assessed by testing with site-specific soil and (sometimes) liquid.

[M] If a filter geotextile is used with a geonet, it is important to assess short-term extrusion and long-term intrusion into the net.

[N] Residual stresses and surface damage may produce synergistic effects with other degradation processes.

[O] Polyethylene geosynthetics may experience slow crack growth under long-term loading conditions in certain environmental conditions.

[P] Excessive expansion and contraction resulting from temperature changes may be a concern for geosynthetics without fabric reinforcement.

[Q] Composite drains must resist clogging due to soil retention problems and intrusion of filter medium.

[R] Geosynthetics relying on a 3-D structure to facilitate flow must demonstrate resistance to compression creep.

[S] Sufficient thickness must be maintained by a protective layer over an extended period of time.

[T] Chemical dissolution of, or mechanical damage to geosynthetic surfaces or coatings may effect their interaction properties, i.e. lead to surface or joint slippage.

[U] Geosynthetics creep and stress relax at different rates depending primarily on manufacturing process, polymer type, load levels, temperature, and application.

[V] Plasticization may be a concern for polyester (PET) geosynthetics exposed to humid conditions or polypropylene and polyethylene geosynthetics exposed to hydrocarbons while under stress.

[W] If the screen is expected to operate indefinitely, then clogging should be assessed often. Commonly, screens are considered temporary.

[X] Holes resulting from mechanical damage may alter the effectiveness of separators.

[Y] Always exposed therefore resistance to photo oxidation and mechanical damage must be determined.

TABLE 3 Environmental Factors of Degradation

Potential Degradation Process	Environmental Elements Relating to Degradation											Test Methods Relating to Geosynthetics	
	Air Chemistry	Fluid Content	Geometry of Exposure	Liquid Chemistry	Macro-Organisms	Micro-Organisms	Radiation	Soil Chemistry	Stress	Temperature of Exposure	Time of Exposure		
Biological degradation	X	X			X	X		X		X	X	D 3083	Microbiological Attack (In Soil)
Chemical degradation				X				X		X	X	D 5322	Chemical Immersion
												D 5496	In situ Immersion
Chemical dissolution				X				X		X	X	None	Effect of Solvents
Clogging/piping		X		X		X		X		X	X	D 5567	
												D 5101	Gradient Ratio
												D 1987	Biological Clogging
												None	Precipitate Clogging
Creep			X						X	X	X	None	
												D 5262	Tension
												D 4716	Transmissivity
												D 2990	Time-Temperature Superposition
Environmental stress cracking	X			X				X	X	X	X	D 5397	Stress Cracking and Appendix
Hydrolysis		X		X				X		X	X	None	Effect of Water
Mechanical damage			X						X		X	D 4886	Abrasion
												None	Fatigue
												D 4833	Puncture
Photo-degradation	X						X			X	X	None	
												D 4355	Xenon Arc
												D 5970	Outdoor Exposure
												None	Fluorescent
Plasticization		X		X						X	X	None	Effect of Liquids
Stress relaxation			X						X	X	X	None	
Temperature instability										X	X	D 4594	Temperature Instability
												D 1204	Temperature Instability
Thermal degradation	X						X			X	X	None	Effect of Heat
												D 3895	OIT
												D 5885	HPOIT

NOTE 1—This table provides the standard test methods current at the time of the writing of this guide. ASTM Standards are in constant development, review, revision, and replacement. It is the responsibility of the geosynthetic specifier to identify the most current applicable standard test method. Refer to Appendix X1 for terminology relating to Table 3.

APPENDIXES

(Nonmandatory Information)

X1. TERMINOLOGY

X1.1 The *application environment* in which a geosynthetic is placed can be characterized by the following environmental elements:

Air Chemistry
Fluid Content
Geometry of Exposure
Liquid Chemistry
Organisms (micro- and macro-)
Radiation
Soil Chemistry
Stress
Temperature of Exposure
Time of Exposure

X1.1.1 *Air chemistry* shall include the identification of the following characteristics of the gases expected to be present or created, or both:

Oxygen content
Gaseous pollution (for example, NO_x, SO_2)
Ozone
Organics (for example, methane)

X1.1.2 *Fluid content* is a measure of the amount of liquid or vapor, or both, which is in the environment immediately surrounding the geosynthetic.

X1.1.3 *Geometry of exposure* may be described by:

Angle of exposure
Degree of exposure (surface versus complete)

X1.1.4 *Liquid chemistry* shall include the identification of the following characteristics of the ground water or leachate:

pH
Electrolytic conditions
Dissolved/suspended minerals
Chemicals

B.O.D., C.O.D.
D.O.

X1.1.5 *Macro-organisms*—Those which are or could be present in the environment shall be identified. Macro-organisms such as insects, rodents and other higher life forms shall be considered.

X1.1.6 *Micro-organisms*—Those which are or could be present in the environment shall be identified. Possible micro-organisms included:

Bacteria
Fungi
Algae
Yeast

X1.1.7 *Radiation* shall be considered as including:

Ultraviolet Radiation
Ionizing Radiation
Infra-Red and Visible Radiation

X1.1.8 *Soil chemistry* shall include the identification of the following characteristics of the soil or waste:

Transition Metals
Soluble Minerals
Polarizability
Clay Mineralogy

X1.1.9 *Stress* shall be focused upon mechanical forces applied externally to the geosynthetic/soil system, resulting in tensile compressive or shear stresses, or both, on the geosynthetic. Stresses on the geosynthetic shall be described by:

Normal stresses
Planar stresses
Surface stresses
Intensity of stresses
How stresses vary with time (static, dynamic, periodic)
How stresses are distributed over the geosynthetic

X1.1.10 *Time of exposure* shall be defined by the duration of exposure to any specific set of environmental elements.

X1.1.11 *Temperature of exposure* shall be defined as the temperature of the geosynthetic, which is not necessarily that of the surrounding medium.

X1.2 The *effects* of the application environment are characterized by the following degradation processes:

Biological Macro- and Micro-Degradation	Mechanical Damage
Chemical Degradation	Oxidative Degradation
Chemical Dissolution	Photo Degradation
Clogging	Plasticization
Creep	Stress Relaxation
Environmental Stress Cracking	Temperature Instability
Hydrolysis	Thermal Degradation

X1.2.1 *Chemical degradation* is the reaction between a chemical(s) and a specific chemical structure within a polymer resulting in chain scission, and a reduction in molecular weight and physical properties.

X1.2.2 *Chemical dissolution* is the physical interaction between a solvent and polymer whereby the polymer absorbs the solvent, swells, and eventually dissolves.

X1.2.3 *Clogging* is the collection of soil particles, microbiological growth, precipitates, or combination thereof on or within the geosynthetic altering its initial hydraulic properties.

X1.2.4 *Creep* is the time-dependent part of a strain resulting from an applied stress.

X1.2.5 *Environmental stress cracking* is the deterioration of a polymer's mechanical properties that occurs when cracks created by high stress concentrations are exposed to certain environmental conditions.

X1.2.6 *Hydrolysis* is the degradative chemical reaction between a specific chemical group within a polymer and absorbed water causing chain scission and reduction in molecular weight.

X1.2.7 *Macrobiological degradation* is the attack and physical destruction of a geosynthetic by macroorganisms leading to a reduction in physical properties.

X1.2.8 *Microbiological degradation* is the chemical attack of a polymer by enzymes or other chemicals excreted by microorganisms resulting in a reduction of molecular weight and changes in physical properties.

X1.2.9 *Mechanical damage* is the localized degradation of the in-service geosynthetic as a result of externally applied load—abrasion, fatigue and puncture are examples.

X1.2.9.1 Discussion—*Construction damage* is excluded, but is an important consideration in geosynthetic selection.

X1.2.10 *Oxidation* is the chemical reaction between oxygen and a specific chemical group within a polymer converting the group into a radical complex which ultimately leads to molecular chain scission or crosslinking, thus changing the chemical structure, physical properties, and sometimes appearance of the polymer. Oxidation can occur during photo or thermal degradation, or both.

X1.2.11 *Photo degradation* is the change in chemical structure resulting in deleterious changes to physical properties and sometimes appearance of the polymer as a result of the irradiation of the polymer by exposure and light.

X1.2.12 *Plasticization* is the physical process of increasing the molecular mobility of a polymer by absorption or incorporation of material(s) of lower molecular weight. The effects are usually reversible when the material(s) are removed.

X1.2.13 *Stress relaxation* is the decrease in stress, at constant strain, with time.

X1.2.14 *Thermal degradation* is the change in chemical structure resulting in changes in physical properties, and sometimes appearance of a polymer caused by exposure to heat alone.

X1.2.15 *Temperature instability* is the change in appearance, weight, dimension, or other property of the geosynthetic as a result of low, high, or cyclic temperature exposure.

X1.3 *Aging* is the alteration of physical, chemical, and mechanical properties caused by the combined effects of environmental conditions over time. The following tests have been utilized or considered to simulate some of these conditions.

Accelerated Soil Burial Testing (ASTM D 3083)
Environmental Stress Rupture (Withdrawn)
Environmental Stress Cracking (ASTM D 5397)
Radiation, Moisture, and Heat Exposure (ASTM G 23 Carbon Arc; D 4355 Xenon Arc; G 53 U.V. Fluorescent; G 151, G 152, G 153, and G 154 Standard Practice)

X1.3.1 Aging can manifest itself in numerous ways, including:

Blistering

Chalking
Changes in Chemical Resistance
Changes in Puncture, Burst, or Tear Resistance, or other index properties
Crack Propagation
Delamination
Dimension Changes
Discoloration
Embrittlement
Loss of Gloss
Permeability Changes
Stiffness Changes
Surface Cracking
Surface Crazing
Tensile or Compressive Elongation Changes
Tensile or Compressive Modulus Changes
Tensile or Compressive Strength Changes

X1.4 *Geosynthetics*—The latest versions of these terms will be inserted upon adoption of this guide by ASTM.

X1.4.1 *Geocomposites*.
X1.4.2 *Geogrids*.
X1.4.3 *Geomembrane*.
X1.4.4 *Geonets*.
X1.4.5 *Geopipe*.
X1.4.6 *Geotextiles*.

X1.5 *Geosynthetic polymers*—The following polymeric materials are the most widely used in the manufacture of currently available geosynthetics.

Acrylics—latex geogrid coatings
Bitumen—geogrid coatings
Chlorinated Polyethylene (CPE)
Chlorosulfonated Polyethyelene (CSPE)
Polyamide (PA)—principally polycaprolactam (nylon 6).
Polyester (PET)—principally polyethylene terephthalate
Polyethylene (PE)—including a range of densities.
Polypropylene (PP)
Polystyrene (PS)
Poly (vinyl chloride)(PVC)—both plasticized (geomembranes and geogrid coatings) and rigid (geopipe).
Polyurethane (PUR)
Ethylene Interpolymer Alloy (EIA)

X2. APPLICATION/END USE/PRIMARY FUNCTION

X2.1 See Tables X2.1-X2.5.

TABLE X2.1 Geotechnical/Transportation Engineering

Application	Use	Primary Function(s) and Performance Characteristic(s)
Embankments	Horizontal drain between saturated soil and embankment, filter during consolidation.	F, FT
	Separation of soft soil and embankment materials.	S
	Reinforcement to improve embankment stability.	R
	Tensioned membrane to bridge soft soils.	R
Slope stabilization and protection	Filter between earth embankment and slope protection.	F
	Placed over slopes to prevent erosion.	VR
	Reinforcement of slopes.	R
Soil retaining structures	Reinforced soil walls.	R
	Retained and protected slopes.	R
	Wall waterproofing systems.	FB, P
Roads on expansive soils, soft soils, or peat	Reinforcement of soft subgrades, bridging of soft materials.	R
	Separation of pavement material from soft soils.	S
	Horizontal filters, drainage of saturated subgrade.	F, FT
	Control of expansive soils.	FB, P
	Prevention of frost heave.	FB, FT, P, I
	Prevention of enlargement of karst sinkholes.	FB, P
	Temporary spanning over sinkholes.	R
	Protecting frost sensitive soils by encapsulation.	FB
Pavement	Placed between pavement layers to act as moisture barrier.	FB
	Placed between or within pavement layers to deter reflective cracking.	R
	Placed between subgrade and aggregate base to improve performance of the base material.	R
Railroad tracks	To separate ballast from embankment.	S
	Moistureproofing railroad subgrades.	FB, P
	To reinforce track systems and distribute loads.	R
	To prevent upward groundwater movement in a railroad cut.	FB, P
	To prevent contamination in railroad refueling areas.	FB, P
Tunnel lining	To prevent puncturing of geomembrane lining.	P
	To provide drainage of seepage waters.	FT
	To prevent migration of seepage through the tunnel lining.	FB, P
Drainage	Filter to wrap gravel drains and pipes.	F
	Drainage medium to collect and transport groundwater.	FT
	Pipeline trench base reinforcement.	R

TABLE X2.2 Geotechnical/Water Resources Engineering

Application	Use	Primary Function(s) and Performance Characteristic(s)
Earth dams	Downstream face protection.	F, P
	Wrapping of aggregate drains.	F, S
	Separation between bank protection stone and earth fills.	F, S
	Chimney, toe and blanket drains.	FT
	Upstream face infiltration cut-off.	FB, P
	Stabilize downstream slope face.	R
Rivers, reservoirs	Filter between earth bank and crushed rock protection.	F, S
	Erosion control.	F
	Wrapping capillary breaks.	F
Rivers, canals	Soil filled geotextile pillows.	C, Scr
	Bags or mattresses used for bank protection, filled with soil or concrete.	C, Scr
	To prevent leakage/soil infiltration.	FB, P
Reservoir	To bridge weak or unsupported areas under geomembranes.	R
	To prevent puncturing of geomembranes.	P
	To vent gases and liquids collected under geomembranes.	FT
	To prevent leakage/soil infiltration	FB, P
Canals, ditches, rivers	To prevent erosion of underwater surfaces.	C

TABLE X2.3 Geotechnical/Environmental (Geoenvironmental) Engineering

Application	Use	Primary Function(s) and Performance Characteristic(s)
Landfills, waste piles, heap leach pads	To prevent leachate from infiltrating into soil and contaminating ground water or surface water.	FB, P
	To reinforce landfill slopes.	R
	To drain leachate or infiltration.	FT
	To provide erosion control.	VR
	To prevent puncturing of geomembrane lining.	P
	Filter for leachate drains.	F, S
	To provide reinforcement of landfill liner to span over cavities or voids.	R
	To provide veneer stability.	R
Surface impoundments	Filter under slope protection installations.	F
	Filter on bank protection systems.	F
	Geotextile used to prevent puncturing of geomembranes.	P
	To vent gases and liquids collected under geomembranes.	FT
	Construction of closure caps.	FB, R, S
Tailing dams	Wrapping of underdrains.	F
	Reinforcement of tailing materials.	R
Sand dunes	To prevent sand dunes from eroding or migrating, or both.	C
	Sand barriers for sand and silt dunes.	Scr
Canals, sluices, channels, rivers	To minimize the migration of sediments.	Scr
Silt fences	To prevent the transportation of solid particles suspended in surface water.	Scr

TABLE X2.4 Coastal Engineering

Application	Use	Primary Function(s) and Performance Characteristic(s)
Jetties, groins, breakwaters	Filter between crushed rock and shoreline.	F
	Erosion control of shoreline.	C
	Geosynthetic mattresses or cellular structures filled with soil, aggregate or concrete to prevent erosion and scouring.	C, Scr
	Geotextile bags and tubes filled with soil to prevent erosion and scour around underwater foundation; and to form underwater foundations.	C, Scr
Forming	Underwater forming of concrete mats.	C, Scr
	Repair of pile foundations for coastal structures.	C, Scr
Sand dunes	To prevent sand dunes for eroding or migrating, or both.	C
	Sand barriers for sand and silt dunes.	Scr

X3. TEST METHOD SELECTION PROCEDURE—EXAMPLE

X3.1 *Problem*—Select the appropriate standard test methods to assess the durability characteristics of a geotextile to be used as a filter over a geonet in the leachate collection layer of a 30-acre double lined landfill.

X3.1.1 The landfill will be filled in two years. During filling the geotextile will be fully exposed above the level of filling.

X3.1.2 The design life of the facility is 30 years.

TABLE X2.5 Sediment and Erosion Control Engineering

Application	Use	Primary Function(s) and Performance Characteristic(s)
Slope stabilization and protection	Placed between earthen slope and overlying slope armor.	F
	Placed over earthen slopes to prevent erosion while vegetation is being established.	VR
Channel protection	Placed between earthen channel and channel armor.	F
	Placed over earthen channel surfaces to prevent erosion while vegetation is being established.	SS
	Placed at the soil surface to strengthen vegetation.	VR
Shoreline stabilization	Placed between earthen shoreline and overlying armor.	F
	Placed over earthen slopes to prevent erosion while vegetation is being established.	SS
	Geotextile bags and tubes filled with soil to prevent erosion.	C, Scr
Sediment Control	Vertical barrier to passage of sediment laden runoff from a disturbed area, slope or channel.	Scr

X3.2 *Selection Procedure:*

X3.2.1 *Application:* Landfill (See Table X2.3)
End Use: Filter for Leachate drain
Primary Function(s): Filtration, Separation
X3.2.2 *Function*:
Filtration (See Table X2.3)
Potential Degradation Processes:
Mechanical Damage (Sometimes[7])
Thermal-Oxidation (Sometimes[8])
Photo-Oxidation (Sometimes[9])
Hydrolysis (Sometimes[10])
Chemical Degradation (Sometimes[11])
Biological Degradation (Potential being Researched[12,13])
Creep (Sometimes[14])
Clogging (Always)
Function: Separation
Potential Degradation Processes:
Thermal-Oxidation (Sometimes[8])
Photo-Oxidation (Sometimes[9])
Hydrolysis (Sometimes[10])
Chemical Degradation (Sometimes[11])
Biological Degradation (Potential being Researched[12,13])
X3.2.3 See Table 3:

Potential Degradation Process	Standard Test Method
Thermal Oxidation	No Standard Test
Photo Oxidation	D 4355
Chemical Degradation	D 5322
Creep (intrusion)	D 4716
Clogging	D 5101, D1987, and D5567

[7] No rocking, puncture, or cutting is expected because of a thick operational cover layer. Therefore mechanical damage is not a concern.
[8] Extended exposure is expected. Therefore, a test is required.
[9] Extended ultraviolet exposure is expected. Therefore a test is required.
[10] Extreme pH conditions are not expected. Therefore hydrolysis is not a concern.
[11] Unknown, complex leachate is expected. Therefore a test is required.
[12] Research topics. Not a documented concern at this time.
[13] Research topics. Not a documented concern at this time.
[14] Since the geotextile will be used over a geonet, extrusion and intrusion should be investigated.

X4. DESIGN BY FUNCTION

X4.1 "Design by function" consists of assessing the primary function that the geosynthetic will be asked to serve and then calculating the required numerical value of that particular property. By dividing this value into the candidate geosynthetic's allowable property value, a factor of safety (FS) will result.

$$FS = \text{Allowable Property/Required Property} \quad (X4.1)$$

where:

Allowable Property = a value based on a laboratory test that models the actual situation, and
Required Property = a value based on a design method that models the actual situation.

X4.2 If the factor of safety is sufficiently greater than 1, this is an acceptable geosynthetic. The above process can be done for a number of available geosynthetics, and then the choice becomes one of availability, least cost and construction. The individual steps in this process are as follows:

1. Assess the particular application considering not only the geosynthetic but the material system on both sides of it.
2. Select a factor of safety based on the risk and impact of failure.
3. Decide on the geosynthetic's primary function.
4. Calculate the required geosynthetic property value in question on the basis of its primary function.
5. Test for or otherwise obtain the candidate geosynthetic's allowable value of this particular property (recall the differences between minimum, average roll, and average lot values).
6. Calculate the actual factor of safety on the basis of the allowable property (Step 5) divided by required property (Step 4) for the actual factor of safety (that is, Eq X4.1).
7. Compare this factor of safety to required minimum value decided on in Step 2.
8. If not acceptable, check into geosynthetics with more appropriate properties.
9. If acceptable, check if any other function of the geosynthetic is more critical.
10. When sufficient geosynthetics (that are available) are found that satisfy the minimum requirement, select the geosynthetic on the basis of cost/benefit, including the value of

experience and product documentation.

X4.2.1 This method (that is, design-by-function) obviously bears heavily on identifying the primary function that the geosynthetic is to serve.

X4.3 In an emerging technology such as geosynthetics we often must use what is available either by way of an "imperfect" test method which is not site specific or by use of available product information in manufacturers' literature which is often index-value oriented. If this is the case, it is recommended to modify the test value at hand to an allowable value before entering into Eq X4.1 for the design factor of safety:

$$\text{Property}_{\text{allowable}} = \text{Property}_{\text{test}}/(FS_1 \times FS_2 \times FS_3 \times ...) \quad \text{(X4.2)}$$

where:

$\text{Property}_{\text{allowable}}$ = the value to be used in Eq X4.1 for the design factor of safety;

$\text{Property}_{\text{test}}$ = the test, or listed, property value that only partially models the in-situ behavior, that is, a test value which in some way(s) is deficient of site specific considerations; and

FS_1, FS_2, FS_3, etc. = the various partial factors of safety needed to account for differences between the laboratory test and the in-situ or site-specific conditions.

X4.3.1 These values of partial factors of safety will customarily be greater than one and reflect appropriate degradation processes.

X5. COMMENTARY ON GEOSYNTHETIC DURABILITY

X5.1 *Abstract* :

X5.1.1 Geosynthetics have evolved from speciality materials, considered state-of-the-art in unique geotechnical designs, to commonly used construction materials, considered state-of-the-practice in many civil engineering applications. This relatively quick acceptance of geosynthetics can best be explained by their proven track record. Geosynthetics have generally performed as expected, though relatively few installations have yet reached their designed service lives.

X5.1.2 Maintaining satisfactory performance of geosynthetics is commonly termed, "durability." Durability can be thought of as relating to changes over time of both the polymer microstructure and the geosynthetic macrostructure. The former involves molecular polymer changes and the latter assesses geosynthetic bulk property changes. This guide focuses upon each of these components of durability as they relate to the use of geosynthetics in various civil engineering applications.

X5.2 *Introduction:*

X5.2.1 Since the late 1960s, planar materials constructed of synthetic polymers have been utilized in the construction of impoundments, roads, drainage systems, earth structures and other civil engineering projects. These materials have become known as "geosynthetics" because they are synthetic materials used in conjunction with the ground (hence "geo-"). Geosynthetics are designed to perform a function, or combination of functions, within the soil/geosynthetic system. Such functions as filtration, separation, planar flow, reinforcement or fluid barrier, as well as others, are expected to be performed over the life of the installation, which is often 50 to 100 years, or more.

X5.2.2 Geosynthetics are accepted construction materials and, like all other materials, they have unique characteristics.

X5.2.3 As pointed out by Colin **(1)**[15], all polymeric materials can be made to degrade. For example, polyolefins such as polypropylene and polyethylene undergo oxidative degradation, whereas poly(ethylene terephthalate) (PET) can be hydrolyzed, and polyamides degrade by both hydrolysis and oxidation. However, it must be emphasized that these reactions are usually slow and can be retarded even more by the use of suitable additives.

X5.2.4 Additionally, the degradative processes may be catalyzed by, for example, transition metals in the case of oxidations and by extreme pH in the case of polyester hydrolysis.

X5.3 *Polymer Degradation*

X5.3.1 For geosynthetics, oxidation and hydrolysis are the most common forms of chemical degradation as are processes that involve solvents. Generally, chemical degradation is accelerated by elevated temperatures because the activation energy for these processes is commonly high. The moderate temperatures associated with most installation environments is, therefore, not expected to promote excessive degradation within the usual service lifetimes of most civil engineering systems. Additionally, the majority of synthetic polymers is rather inert towards biological enzymatic attack **(2)**. Yet, prudent attention should always be given to unique environments to assess their potential for causing polymer degradation.

X5.3.2 Since many geosynthetics users are not familiar with polymer chemistry, it will be more useful to assess geosynthetic performance on a functional basis and reserve the polymer chemistry for interpreting unsatisfactory test results or performing forensic studies, if necessary.

X5.4 *Geosynthetic Performance:*

X5.4.1 Geosynthetic performance is most obvious to the geosynthetic user. Table X5.1 lists several geosynthetic failure mechanisms that result in unsatisfactory performance.

X5.4.2 In general, long-term piping and clogging resistance, as well as tensile and compression creep resistance, are the most common properties related to durability in geotextiles,

[15] The boldface number in parentheses refer to the list of references at the end of this guide.

TABLE X5.1 Geosynthetic Failure Mechanisms[A]

Function	Failure Mode	Possible Cause
Separation/filtration	Piping of soils through the geotextile	Openings in geotextile are incompatible with retained soil. Openings may be enlarged as result of in-situ stress or mechanical damage.
Filtration	Clogging of the geotextile	Permeability/permittivity of the geotextile is reduced as a result of particle buildup on the surface of or within the geotextile. Openings may have been compressed as a result of long-term loading.
Reinforcement	Reduced tensile resisting force.	Excessive tensile stress/relaxation of the geosynthetic.
Reinforcement	Unacceptable deformation of the soil/geosynthetic structure	Excessive tensile creep of the geosynthetic.
Fluid transmission	Reduced in-plane flow capacity	Excessive compression creep of the geosynthetic.
Protection	Reduced resistance to puncture	Excessive compression creep of the geosynthetic.
Fluid barrier	Leakage through the membrane	Openings are found in the geomembrane as a result of puncture or seam failure.

[A] These failure mechanisms do not include polymer microstructure degradation mechanisms nor installation damage and the resulting synergistic effects that may arise.

geogrids, geonets, and geocomposites. With geomembranes, development of openings which lead to leakage is a common concern.

X5.4.3 The first step in assessing geosynthetic performance is to clearly define the environment that the geosynthetic will be exposed to. With an understanding of the exposure environment, the user can select appropriate test methods to best simulate the aging of the geosynthetic.

X5.5 *Aging:*

X5.5.1 The exposure environment will generally be characterized by complex air, soil and water chemistry as well as unique radiation, hydraulic and stress-state conditions. The effect of this combination of exposures, over time, is termed aging. Aging therefore includes both polymer degradation and reduced geosynthetic performance and is dependent on the specific application environment. Durability refers to a geosynthetic's resistance to aging.

X5.5.2 A 1986 study by the U.S. Army Engineer Waterways Experiment Station found no cases of geotextile failure because of attack from chemicals present in a natural soil environment reported in the literature **(3)**. However, in cases of geosynthetic burial in soils having a very low or very high pH, consideration should be given to the composition of the geosynthetic selected. This should be a rare occurrence because most soils have a pH in the range of three to ten **(4)**. Geosynthetic composition should also be considered in cases of complex chemical exposure (for example, leachate), burial in metal-rich soils, and extended exposure to sunlight. In order to evaluate these unique exposure conditions, tests that simulate actual exposure conditions on the geosynthetic selected are recommended. Accelerated tests should have a generally accepted relationship to real conditions.

X5.5.3 Geosynthetics, however, almost always encounter soil conditions that would be expected to cause reductions in geosynthetic performance. But, whether it's a gap-graded soil which could lead to clogging of a geotextile, or large embankment loads which must be resisted with little creep, geosynthetic properties can be selected to protect against excessive reductions in performance and prudent factors of safety can be utilized in designs incorporating geosynthetics. The notable exception to the above discussion is the environmental engineering field where there is relatively little long-term experience with geosynthetics. Specifically, landfill liner systems that are expected to have extended service lives have been extensively installed only since the mid 1980s, though the first geomembrane, a butyl thermoset polymer, was installed in a pineapple waste pond in Hawaii in 1954 and PVC was used in sanitary landfills in 1973. This limited track record requires that the geosynthetic user closely scrutinize environmental applications of geosynthetics to characterize the exposure conditions. Clearly, knowledge of the specific application of a geosynthetic is a key for assessing the appropriate exposure environment.

X5.6 *Applications:*

X5.6.1 In order to properly assess the effects of any given application environment on the performance life of the geosynthetic, a clear understanding of how the geosynthetic is to be used is required. For any given use, there will be one or more primary functions that the geosynthetic will be expected to perform during its design life. Accurate identification of the application and the geosynthetic function is essential. It is the ability of the geosynthetic to satisfactorily perform the required primary functions during the design life that constitutes acceptable geosynthetic durability." Design by Function" is the preferred design approach for geosynthetics and focuses on the primary function, as well. Appendix B discusses the "Design by Function" approach.

REFERENCES

(**1**) Colin, G., Mitton, M. T., Carlsson, D. J., and Wiles, D. M., "The Effect of Soil Burial Exposure on Some Geotextile Fabrics," *Geotextiles and Geomembranes*, Vol 4, 1986, pp. 1–8.
(**2**) Schnabel, W., *Polymer Degradation: Principles and Practical Applications*, Hanser International, 1981.
(**3**) Horz, Raymond, "Geotextiles for Drainage, Gas Venting, and Erosion Control at Hazardous Waste Sites," *U.S. Army Engineer Waterways Experiment Station Report*, EPA/600/2-86/085, September 1986.
(**4**) *Encyclopedia of Chemistry*, Van Nostrand Reinhold, 1984.
(**5**) Giroud, J. P., Arman, A., Bell, J. R., Koerner, R. M., and Milligan, V., International Society for Soil Mechanics and Foundation Engineering Technical Committee on Geotextiles: "Geotextiles in Geotechnical Engineering Practice and Research," *Geotextiles and Geomembranes*, Vol 2, No. 3, 1985.
(**6**) Koerner, R. M. and Hwu, Bao-Lin, "Geomembranes in Transportation Systems," Transportation Research Board, 1989.