

# Guidelines for the determination of the long-term strength of geosynthetics for soil reinforcement

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## National foreword

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# TECHNICAL REPORT

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## **Guidelines for the determination of the long-term strength of geosynthetics for soil reinforcement**

*Lignes directrices pour la détermination de la résistance à long terme  
des géosynthétiques pour le renforcement du sol*



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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 20432 was prepared by Technical Committee ISO/TC 221, *Geosynthetics*.

# Guidelines for the determination of the long-term strength of geosynthetics for soil reinforcement

## 1 Scope

This Technical Report provides guidelines for the determination of the long-term strength of geosynthetics for soil reinforcement.

This Technical Report describes a method of deriving reduction factors for geosynthetic soil-reinforcement materials to account for creep and creep rupture, installation damage and weathering, and chemical and biological degradation. It is intended to provide a link between the test data and the codes for construction with reinforced soil.

The geosynthetics covered in this Technical Report include those whose primary purpose is reinforcement, such as geogrids, woven geotextiles and strips, where the reinforcing component is made from polyester (polyethylene terephthalate), polypropylene, high density polyethylene, polyvinyl alcohol, aramids and polyamides 6 and 6.6. This Technical Report does not cover the strength of joints or welds between geosynthetics, nor whether these might be more or less durable than the basic material. Nor does it apply to geomembranes, for example, in landfills. It does not cover the effects of dynamic loading. It does not consider any change in mechanical properties due to soil temperatures below 0 °C, nor the effect of frozen soil. The Technical Report does not cover uncertainty in the design of the reinforced soil structure, nor the human or economic consequences of failure.

Any prediction is not a complete assurance of durability.

## 2 Normative references

The following referenced documents are indispensable for the application 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, *Geosynthetics — Terms and definitions*

## 3 Terms, definitions, abbreviated terms and symbols

### 3.1 Terms and definitions

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

#### 3.1.1

##### **long-term strength**

load which, if applied continuously to the geosynthetic during the service lifetime, is predicted to lead to rupture at the end of that lifetime

#### 3.1.2

##### **long-term strain**

total strain predicted in the geosynthetic during the service lifetime as a result of the applied load

## 3.1.3

### **reduction factor**

factor ( $\geq 1$ ) by which the tensile strength is divided to take into account particular service conditions in order to derive the long-term strength

NOTE In Europe, the term 'partial factor' is used.

## 3.1.4

### **characteristic strength**

95 % (two-sided) lower confidence limit for the tensile strength of the geosynthetic, approximately equal to the mean strength less two standard deviations

NOTE This should be assured by the manufacturer's own quality assurance scheme or by independent assessment.

## 3.1.5

### **block shifting**

procedure by which a set of data relating applied load to the logarithm of time to rupture, all measured at a single temperature, are shifted along the log time axis by a single factor to coincide with a second set measured at a second temperature

## 3.1.6

### **product line**

series of products manufactured using the same polymer, in which the polymer for all products in the line comes from the same source, the manufacturing process is the same for all products in the line, and the only difference is in the product mass per area or number of fibres contained in each reinforcement element

## 3.2 Abbreviated terms

|                  |                                                                   |
|------------------|-------------------------------------------------------------------|
| CEG              | carboxyl end group                                                |
| DSC              | differential scanning calorimetry                                 |
| HALS             | hindered amine light stabilizers                                  |
| HDPE             | high density polyethylene                                         |
| HPOIT            | high pressure oxidation induction time                            |
| LCL              | lower confidence limit                                            |
| MARV             | minimum average roll value                                        |
| OIT              | oxidation induction time                                          |
| PA               | polyamide                                                         |
| PET              | polyethylene terephthalate                                        |
| PP               | polypropylene                                                     |
| PTFE             | polytetrafluorethylene                                            |
| PVA              | polyvinyl alcohol                                                 |
| RF <sub>CH</sub> | reduction factor to allow for chemical and biological effects     |
| RF <sub>CR</sub> | reduction factor to allow for the effect of sustained static load |
| RF <sub>ID</sub> | reduction factor to allow for the effect of mechanical damage     |
| RF <sub>W</sub>  | reduction factor to allow for weathering                          |
| SIM              | stepped isothermal method                                         |
| TTS              | time-temperature shifting                                         |

### 3.3 Symbols

|                          |                                                                                                                                             |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| $A_i$                    | time-temperature shift factor                                                                                                               |
| $b_a$                    | gradient of Arrhenius graph                                                                                                                 |
| $d_{50}$                 | mean granular size of fill                                                                                                                  |
| $d_{90}$                 | granular size of fill for 90 % pass (10 % retention)                                                                                        |
| $f_s$                    | factor of safety                                                                                                                            |
| $G, H$                   | parameters used in the validation of temperature shift linearity (see 7.4)                                                                  |
| $m$                      | gradient of line fitted to creep rupture points (log time against load); inverse of gradient of conventional plot of load against log time. |
| $M_n$                    | number averaged molecular weight                                                                                                            |
| $n$                      | number of creep rupture or Arrhenius points                                                                                                 |
| $P$                      | applied load                                                                                                                                |
| $R_1$                    | ratio representing the uncertainty due to extrapolation                                                                                     |
| $R_2$                    | ratio representing the uncertainty in strength derived from Arrhenius testing                                                               |
| $S_{sq}$                 | sum of squares of difference of log (time to rupture) and straight line fit                                                                 |
| $S_{xx}, S_{xy}, S_{yy}$ | sums of squares as defined in derivation of regression lines in 9.4.3                                                                       |
| $\sigma_0$               | standard deviation used in calculation of LCL                                                                                               |
| $t$                      | time, expressed in hours                                                                                                                    |
| $t_{90}$                 | time to 90 % retained strength                                                                                                              |
| $t_D$                    | design life                                                                                                                                 |
| $t_{deg}$                | degradation time during oxidation                                                                                                           |
| $t_{ind}$                | induction time during oxidation                                                                                                             |
| $t_{LCL}$                | LCL of time to a defined retained strength at the service temperature                                                                       |
| $t_{max}$                | longest observed time to creep rupture, expressed in hours                                                                                  |
| $t_{n-2}$                | Student's $t$ for $n - 2$ degrees of freedom and a stated probability                                                                       |
| $t_R$                    | time to rupture, expressed in hours                                                                                                         |
| $t_s$                    | time to a defined retained strength at the service temperature                                                                              |
| $T$                      | load per width                                                                                                                              |
| $T_B$                    | batch tensile strength (per width)                                                                                                          |
| $T_{char}$               | characteristic strength (per width) (see 6.1)                                                                                               |
| $T_x$                    | unfactored long-term strength (see 9.4.3)                                                                                                   |

|            |                                                                                                                               |
|------------|-------------------------------------------------------------------------------------------------------------------------------|
| $T_D$      | long-term strength per width (including factor of safety)                                                                     |
| $T_{DR}$   | residual strength                                                                                                             |
| $\theta_j$ | temperature of accelerated creep test                                                                                         |
| $\theta_K$ | temperature                                                                                                                   |
| $T_{LCL}$  | LCL of $T_{char}$ due to chemical degradation                                                                                 |
| $\theta_s$ | service temperature                                                                                                           |
| $x$        | abscissa: on a creep rupture graph the logarithm of time, in hours                                                            |
| $\bar{x}$  | mean value of $x$                                                                                                             |
| $x_i$      | abscissa of an individual creep rupture point                                                                                 |
| $x_p$      | predicted time to rupture                                                                                                     |
| $y$        | ordinate: on a creep rupture graph, applied load expressed as a percentage of tensile strength, or a function of applied load |
| $y_0$      | value of $y$ at 1 h ( $\log t = 0$ )                                                                                          |
| $\bar{y}$  | mean value of $y$                                                                                                             |
| $y_i$      | ordinate of an individual creep rupture point                                                                                 |
| $y_0$      | value of $y$ at time 0, derived from the line fitted to creep rupture points                                                  |

## 4 Design procedure

### 4.1 Introduction

The design of reinforced soil structures generally requires consideration of the following two issues:

- a) the maximum strain in the reinforcement during the design lifetime;
- b) the minimum strength of the reinforcement that could lead to rupture during the design lifetime.

In civil engineering design, these two issues are referred to as the serviceability and ultimate limit state respectively. Both factors depend on time and can be degraded by the environment to which the reinforcement is exposed.

### 4.2 Design lifetime

A design lifetime,  $t_D$ , is defined for the reinforced soil structure. For civil engineering structures this is typically 50 to 100 years. These durations are too long for direct measurements to be made in advance of construction. Reduction factors have therefore to be determined by extrapolation of short-term data aided, where necessary, by tests at elevated temperatures to accelerate the processes of creep or degradation.

### 4.3 Causes of degradation

Strain and strength may be changed due to the effects of the following:

- mechanical damage caused during installation;
- sustained static (or dynamic) load;
- elevated temperature;
- weathering while the material is exposed to light;
- chemical effects of natural or contaminated soil.

### 4.4 Design temperature

The design temperature should have been defined for the application in hand. In the absence of a defined temperature or of site specific in-soil temperature data, the design temperature should be taken as the temperature which is halfway between the average yearly air temperature and the normal daily air temperature for the hottest month at the site. If this information is not available, 20 °C should be used as the default value.

Many geosynthetic tests are performed at a standard temperature of  $(20 \pm 2)$  °C. If the design temperature differs, appropriate adjustments should be made to the measured properties.

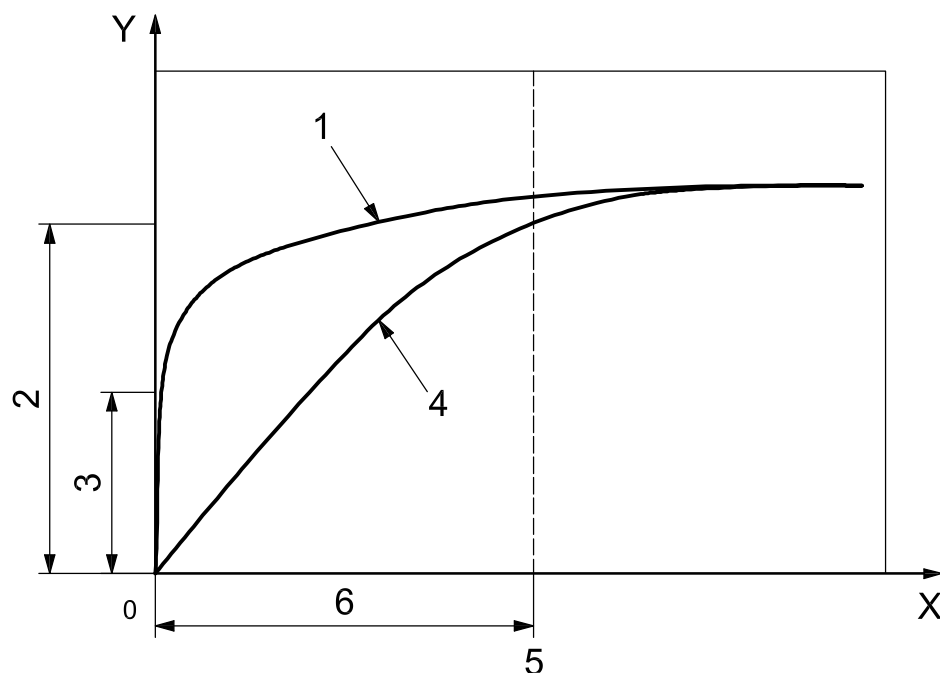
This Technical Report does not cover the effects of temperatures below 0 °C (see Clause 1).

## 5 Determination of long-term (creep) strain

### 5.1 Introduction

The design specification may set a limit on the total strain over the lifetime of the geosynthetic, or on the strain generated between the end of construction and the service lifetime. In the second case, the time at “end of construction” should be defined, as shown in Figure 1. When plotted against  $\log t$ , even a one-year construction period should have negligible influence on the creep strain curve beyond 10 years.

Levels of creep strain encountered in the primary creep regime (creep rate decreasing with time) are thought not to adversely affect strength properties of geosynthetic reinforcement materials.



#### Key

- |                                              |                                            |
|----------------------------------------------|--------------------------------------------|
| 1 Laboratory creep test                      | 5 New time = 0 for post construction creep |
| 2 Load ramp period on wall                   | 6 Wall construction time                   |
| 3 Load ramp period in creep test             | X Time                                     |
| 4 Loading and creep of reinforcement in wall | Y Strain                                   |

**Figure 1 — Conceptual illustration for comparing the creep measured in walls to laboratory creep data**

## 5.2 Extrapolation

Creep strain should be measured according to ISO 13431 and plotted as strain against the  $\log t$ . It may then be extrapolated to the design lifetime. Extrapolation may be by graphical or curve-fitting procedures, in which the formulae applied should be as simple as is necessary to provide a reasonable fit to the data, for example, power laws. The use of polynomial functions is discouraged since they can lead to unrealistic values when extrapolated.

## 5.3 Time-temperature superposition methods

Time-temperature superposition methods may be used to assist with extending the creep curves. Creep curves are measured under the same load at different temperatures, with intervals generally not exceeding 10 °C, and plotted on the same diagram as strain against  $\log t$ . The lowest temperature is taken as the reference temperature. The creep curves at the higher temperatures are then shifted along the time axis until they form one continuous “master” curve, i.e. the predicted long-term creep curve for the reference temperature. The shift factors, i.e. the amounts (in units equivalent to  $\log t$ ) by which each curve is shifted, should be plotted against temperature where they should form a straight line or smooth curve. The cautions given in 7.6 should be noted.

Experience has shown the strains on loading are variable. Since the increase in strain with time is small, this variability can lead to wide variability in time-temperature shifting (TTS). The stepped isothermal method (SIM) described in 7.5 avoids this problem by using a single specimen, increasing the temperature in steps, and then shifting the sections of creep curve measured at the various temperatures to form one continuous master curve.