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Design using geosynthetics —

Part 6: Protection

Conception utilisant des géosynthétiques —

Partie 6: Protection

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Foreword

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This document was prepared by Technical Committee ISO/TC *221*, *Geosynthetics*, Working group WG 6, *Design using geosynthetics*.

A list of all parts in the ISO/TR 18228 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO/TR 18228 series provides guidance for designs using geosynthetics for soils and below ground structures in contact with natural soils, fills and asphalt. The series contains 10 parts which cover designs using geosynthetics, including guidance for characterisation of the materials to be used and other factors affecting the design and performance of the systems which are particular to each part, with ISO/TR 18228-1 providing general guidance relevant to the subsequent parts of the series.

The series is generally written in a limit state format and guidelines are provided in terms of partial material factors and load factors for various applications and design lives, where appropriate.

This document includes information relating to the use of geosynthetics in a protective function.

Design using geosynthetics —

Part 6:
Protection

1 Scope

This document provides general considerations to support design guidance for the evaluation of geosynthetics to fulfil a protective function to any surface or material placed in contact with the protective element.

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

3 Terms, definitions and symbols

3.1 Terms and definitions

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

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

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

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

3.2 Symbols

For the purposes of this document, the symbols in ISO 10318-2 apply.

4 Concepts and fundamental principles

Geosynthetics for protection (protectors) are frequently incorporated with other geosynthetics and soil components in barrier systems. The objective of any barrier protector is to ensure that the stresses and strains encountered during the construction phase and operational life of a site pose no significant risk of damage to the barrier. The aim of the geosynthetic protection layer is to limit damage to the barrier caused by the drainage aggregate placed above the barrier (see Figure 1 and Figure 2). Designers would normally assess the potential for stresses and strains in the protector. This document covers the use of geosynthetics as a protection layer for barriers.

Figure 1 — Drainage aggregate in contact with protection geotextile

Figure 2 — Placement of drainage aggregate

The purpose of the protective layer is to:

— minimize the risk of barrier damage or puncture during construction i.e. placement of the aggregate drainage layer (dynamic loads) (static loads). The test methods described in Clause 4 don't cover this aspect of the design. Test pads using the actual geotextile grade, drainage aggregate and placement equipment are normally performed in order to assess the minimum aggregate placement thickness. Figure 3 shows barrier damage from a rounded river gravel due to trafficking with <150 mm cover; and

— minimize the localized strains in the barrier during the subsequent operation and life of the containment facility. Hence reducing the risk for future mechanical damage forming due to, for example, environmental stress cracking.

Figure 3 — Barrier damage due to construction traffic

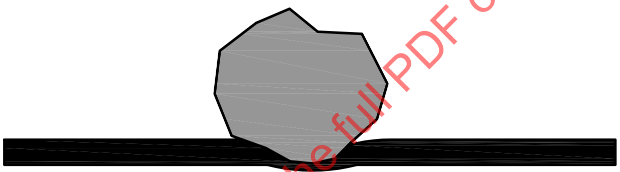


Figure 4 — Deformation without protection layer

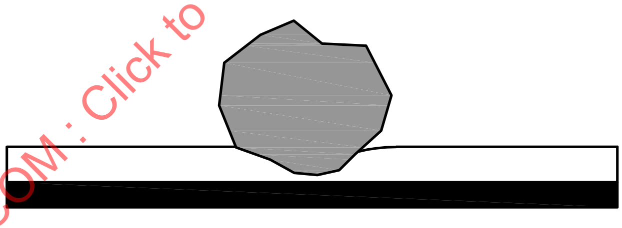


Figure 5 — Deformation with protection layer

A geosynthetic can provide some stress reduction (Figures 4 and 5) however, this layer alone would not normally be relied upon to reduce all stresses from the barrier. While strain minimization is desirable, designers would normally be aware that zero strain is unlikely to be achieved.

5 Design approaches for protection

Table 1 outlines some of the common issues designers normally consider in selecting the most effective geosynthetic for protection.

Table 1 — Issues considered by designers

Environment	Issue
Physical	— The likely stresses and strains imposed during the construction period. — The likely stresses and strains imposed by settlement and movement. — The likely stresses and strains imposed by the materials placed in contact with the geosynthetic, particularly any drainage stone. — The duration of exposure to ultraviolet light. — The likely temperatures expected adjacent to the geosynthetic and whether these are likely to have a damaging effect upon the material properties in any way. — The interface friction angles between the materials around the geosynthetics and the geosynthetics themselves, particularly on slopes.
Chemical	— The likely interaction between the geosynthetic and the material around the geosynthetic. It is usual for there to be little or no interaction. — The polymeric structure of the geosynthetic itself and whether it will be prone to degradation which would affect its ability to protect the barrier. The polymeric structure would normally be such as to cover the predicted life of the geosynthetic and barrier. — The effects of mineral precipitation on the geosynthetics performance.
Biological	— The effects of microbial growth on the polymer of the geosynthetic. — The effects of microbial growth on the characteristics of the geosynthetic.

Currently there are two main approaches regarding the design of protective geosynthetics: strain minimization and resistance to puncture.

Strain minimization considers whether the protective effect of a protection layer is sufficient if the load distribution is dispersed to such an extent that only slight indentations arise in the barrier. By limiting the strain of a barrier to within a strain limit, damage can usually be prevented in the microstructure of the material that would otherwise develop when strains exceed this limit. Excessive strain can sometimes develop into macroscopic stress cracks. Conversely, stress crack formation is impossible when deformations stay below this limiting strain, regardless of the stresses imposed.

A limiting value for the permissible deformation can be derived another way. Koch et al.[1] suggested that tensile stresses be considered. These arise from different deformation events, taking stress relaxation in the barrier into account. The stresses are then compared with the stress level that the HDPE material can tolerate over the long-term without stress crack formation (long-term pipe pressure tests).

Narejo[2] defined levels of protection against puncture for barriers under typical loading conditions as follows:

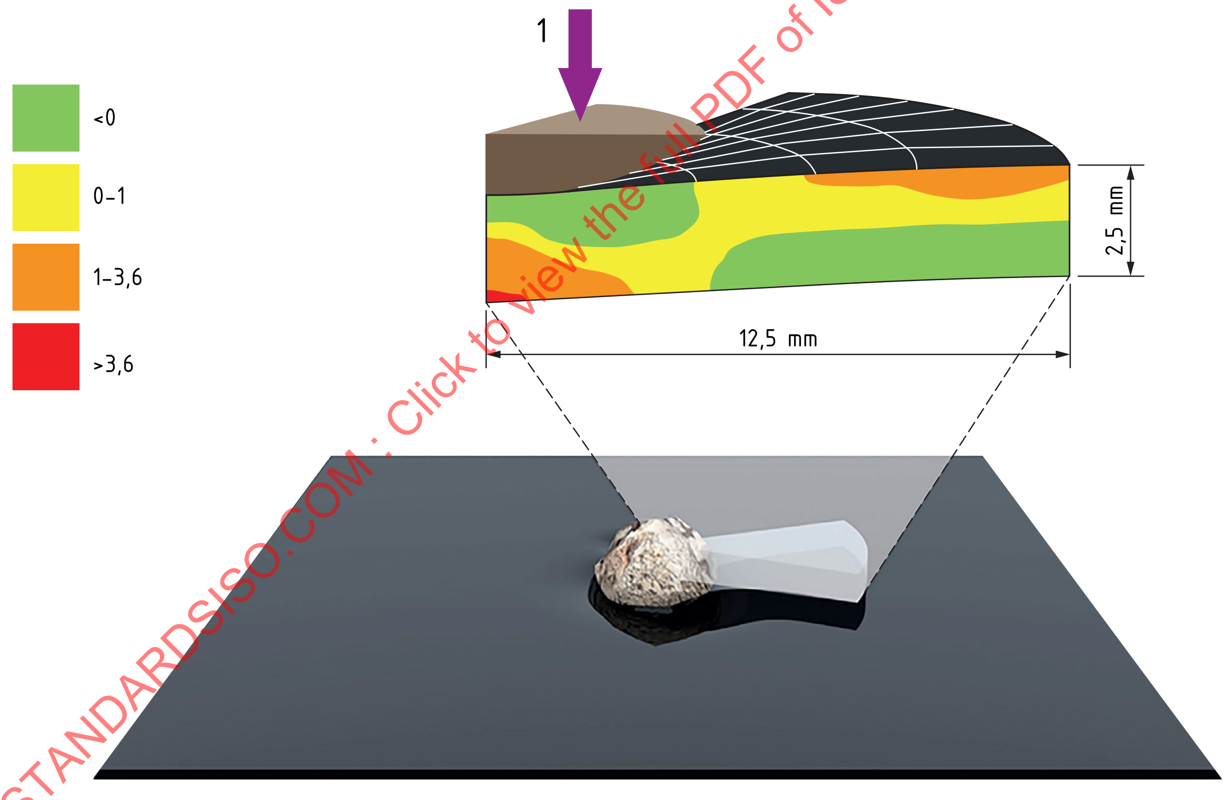
— Level I: typically applied to barrier systems for hazardous waste facilities. This level requires that the barrier system be designed such that less than 0,25 % localized strain (average strain over the length of the indentation measured in 3 mm increments) occurs in the barrier from the imposed loading.

— Level II: (intermediate protection level) for non-hazardous waste facilities. The “intermediate protection level” lies between level I protection and the yield of an GBRP. The yield of GBRPs in the puncture mode is considered as a failure of level II protection. In other words, the liner system is allowed to have barrier strains greater than 0,25 %, but not if it results in yielding of an GBRP.

Wilson-Fahmy et al.,[3] Narejo et al.,[4] Koerner et al.[5] and, more recently, Koerner et al.[6] provide a basis for protection layer design consistent with this philosophy.

The maximum of 0,25 % local strain ($\mathcal{E}_L$) was proposed by the German “Quo Vadis working group” (Dixon, J.H., von Maubeuge, K[7].), explained by Seeger, S. and Müller, W[8]. and in Müller, W.[9] The critical strain limit of HDPE lies within the range of 3 % to 5 %. If these strains are exceeded, damage develops in the microstructure and stress cracks can develop. The value of 3 % to 5 % has to be compared with the edge deformation ($\mathcal{E}_B$) of a local strain ($\mathcal{E}_L$). For example, the outer part of the bent barrier is stretched, and the inner part compressed due to the bending.

Figure 6 shows an example of an FEM calculation with a local strain ($\mathcal{E}_L$) of 0,25 %. The figure shows in some parts edge or bent deformations ($\mathcal{E}_B$) of ≈ 4 % (lower left corner) and 1,0 % to 3,6 % (upper right corner).



Key

1 gravel

Figure 6 — Elongation in the tangential plane $\mathcal{E}_B$ (%) when $\mathcal{E}_L$ = 0,25 % (picture courtesy of Naue)

The upper limit for the local strain ($\mathcal{E}_L$) in Figure 6 was set with 0,25 % as it was shown that this value is similar to a bent deformation ($\mathcal{E}_B$) of 3 %, which is a critical deformation value for HDPE.

Furthermore, due to thermal variances and chemical attack, the barrier can become more stressed on site. Allowing for the strains (2,75 %) induced by installation and long-term settlement of the subgrade, the group set a 0,25 % local strain as the limiting value for local deformation (deformations caused by point loads from drainage aggregate). This is similar to the level I protection proposed by Narejo[2].

6 Laboratory testing for protection

6.1 General

Test procedures used to determine the performance of geosynthetic protection layers are related to the philosophy a designer wishes to follow and the governing regulatory requirements impacting their design. In order to assess the suitability and ability of a proposed protective geosynthetic a range of tests are available. The tests can often take the form of index, performance or field tests.

6.2 Index testing

An index design method can sometimes focus solely on the selection of a nonwoven needle-punched geotextile protection layer with sufficient mass per unit area to provide an adequate global factor of safety against barrier yield. This approach governs in most of the cases the acceptability of the protection layer (e.g. Richardson[10]; Reddy et al[11]; Reddy and Saichek[12]; Richardson and Johnson[13]).

6.2.1 Burst strength and elongation (ISO 12236)

CBR burst strength is a relatively good indicator of puncture performance, however the rate at which the strength is engaged is also important as geosynthetic protection would normally have high burst strength at low elongation.

6.2.2 Tear strength (ISO 9073-4)

The ability of a geosynthetic to resist tearing will increase the protection of the barrier during installation. A higher tear strength will provide better protection.

6.2.3 Mass (ISO 9864) and thickness (ISO 9863-1)

Mass alone is not an indicator of protection capacity, a heavyweight but lightly needled-punched (thick) geotextile can sometimes not perform as well as the same weight geotextile which has been heavily needle-punched (relatively thin) or vice versa. There is a point where too much needling will reduce the bedding effect for the gravel, so an optimum needling rate would normally be determined. A minimum mass, along with thickness, is often specified.

6.2.4 Needle free

As protective geotextiles are placed adjacent to barriers, it is vitally important that the geosynthetic is needle free, as broken needles will readily puncture the barrier. As many designs are oriented to achieve lower barrier strains, the requirement for heavier nonwoven geotextiles has increased. This creates greater potential for broken needles, and any specification would normally include a requirement that the geotextile be needle free.

6.3 Field testing

Where site conditions or the requirements of a protection geotextile are unique, a field test/site trial is often performed. This would normally be undertaken to ensure the unique criteria are met and that the trial is carried out in conjunction and with the agreement of the design engineer and any relevant third parties (such as a government regulator). The pass-fail criteria would normally also be agreed by all parties. The trial would normally be documented along with photographs showing the trial, the geotextile and the barrier before and after the trial.

6.4 Performance-index testing

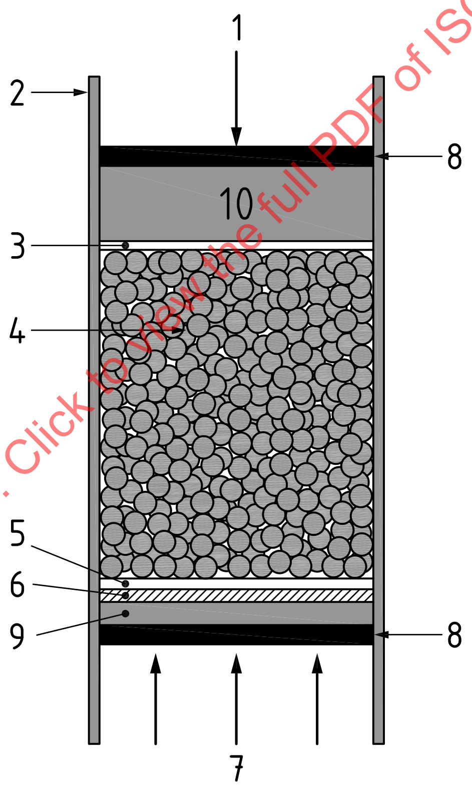
6.4.1 General

Performance-index tests attempt to mimic site conditions as closely as possible using site specific materials and representative operating conditions. The results of such tests are considered the most applicable to and practical for the selection of field protection layers.

6.4.2 Undertaking and reporting of the cylinder test

The EN 13719 methodology was developed to provide consistency in the undertaking and reporting of the cylinder test. The criteria employed to evaluate the performance of the geotextile are in terms of both damage and deformation of the barrier. EN 13719 outlines an index test but contains the performance test in Annex B. The index/standard method always requires tests to be carried out at loads of 300 kN/m^2, 600 kN/m^2 and 1 200 kN/m^2 and always with 20 mm diameter steel balls.

Annex B of EN 13719:2016 describes in detail how to carry out site specific testing. The load encountered on site, as well as the site specific geosynthetics and gravel, are used. See Figure 7 for a general description of both methods.



Key

1 applied load
2 cylinder
3 separation geotextile
4 20 mm steel balls (index test) or mineral drainage layer (Annex B)
5 protection geosynthetic and barrier
6 soft metal place
7 load cells
8 top and bottom plate
9 elastomer pad as base
10 sand

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Figure 7 — Cylinder test according to EN 13719

For a protection efficiency investigation, a smooth barrier is used. To simulate the expected site conditions the test runs for 1 000 h at a temperature of 40 °C with 1,5 times the expected confining stress on site. To enable shorter term testing at 20 °C laboratory conditions, instead of realistic landfill conditions at 40 °C, the test procedure allows a reduction of the temperature (from 40 °C to 20 °C) and a shorter testing time (100 h instead of 1 000 h) if the confining stress is increased by an additional factor of 2,25 or 2,5 (see Table 2). These factors are not only stated in EN 13719:2016, Annex B but also in German BAM Guidelines for the Certification of Protection Layers for Geomembranes in Landfill Sealing Systems, Seeger and Muller (2003) and in UK Environment Agency guidance LFE 2.

Table 2 — Factors for long-term behaviour and testing load

Test temperature	Test duration	Test load
40 °C	1 000 h	1,50 × design load
20 °C	1 000 h	2,25 × design load
20 °C	100 h	2,50 × design load

The EN 13719 test method uses a dense rubber simulated subgrade which supports the barrier and protection geosynthetic and limits strain development in the liner system, while the ASTM test method removes any support from the subgrade transferring all the load to the barrier and protection geosynthetic. Results of the two methods are usually not compared and designers normally consider the effects of the test method used to determine strain values.

The EN 13719 method requires the operator to identify the five worst indentations and then measure the stains developed in two axes on each of the five indentations.

Strain is reported in two ways:

a) local strain: the average strain across the length of the deformation; and

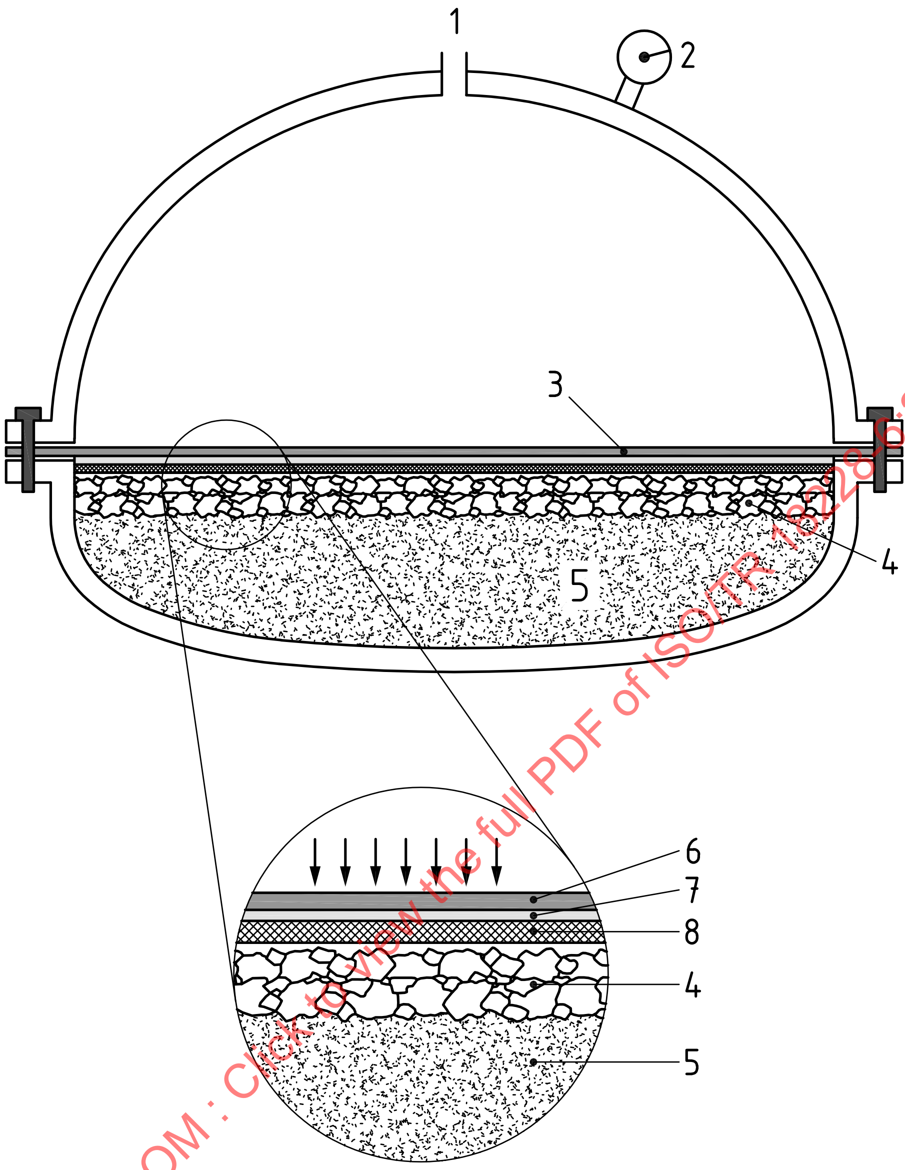
b) incremental strain: the individual strain measured at 3 mm increments along the axis.

ASTM D5514 method

ASTM D5514 uses an inverted liner profile which is constructed in the test chamber (see Figure 8). Two possible scenarios are assessed:

a) Increasing applied pressure until puncture of barrier occurs.

b) Measuring strains developed under a specific load.



Key

1 air pressure
2 pressure gauge
3 geomembrane clamped in position
4 drainage aggregate
5 sand
6 geomembrane
7 metal sheet
8 geotextile

Figure 8 — ASTM D5514 test setup

The placement of drainage gravel in this way produces a very aggressive surface profile which does not mimic actual site conditions well but does produce high strain values.

In a routine application of this test procedure, the test rig uses a 450 mm diameter fixed stone profile constructed from the proposed site-specific aggregate. Pneumatic pressure is used to load the barrier to the designated test pressure and push it onto a thin metal strain indicator sheet, protection layer and drainage stone. Following the test loading period, the test samples are removed and the aluminium strain indicator sheet is laser scanned to measure the strain in 1 mm increments, Figure 9. The cumulative strain in the barrier is also calculated in 0,25 % increments. A three-dimensional laser scan of the strain "record" provides a method of strain analysis across the whole contoured surface of the barrier rather than relying on traditional methods that require visual pre-selection of the highest strain regions for detailed manual analysis.

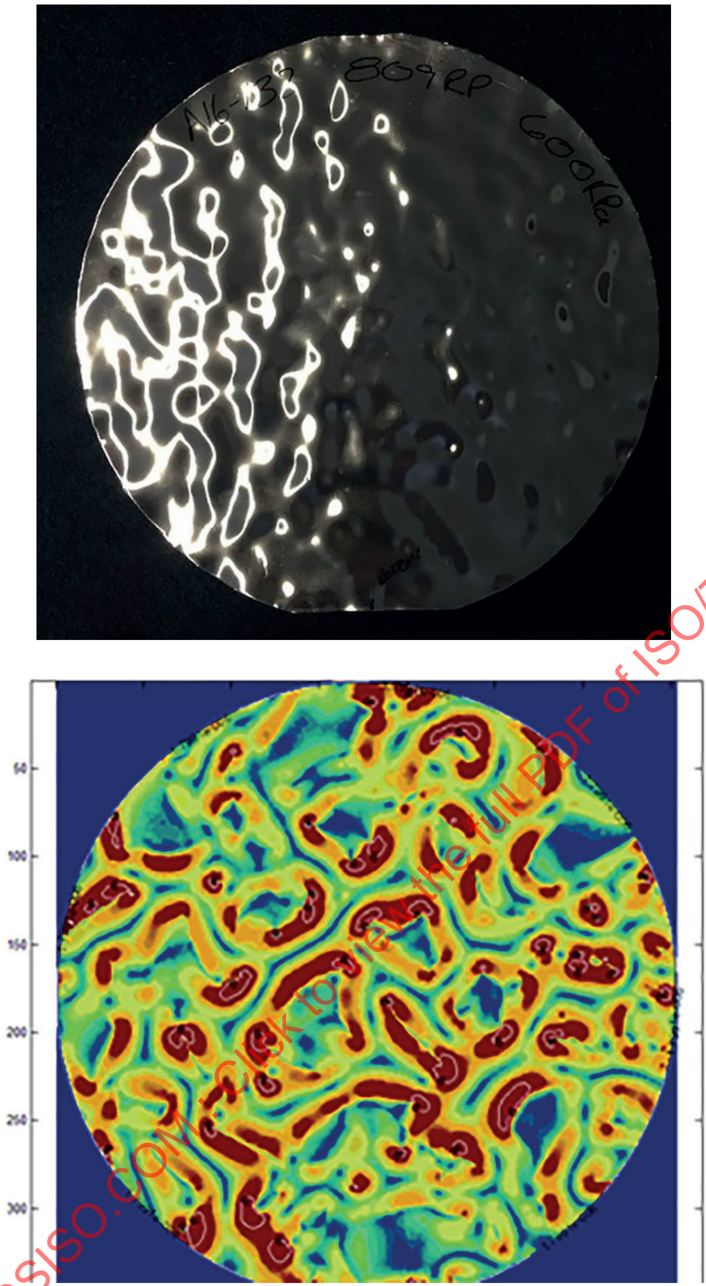
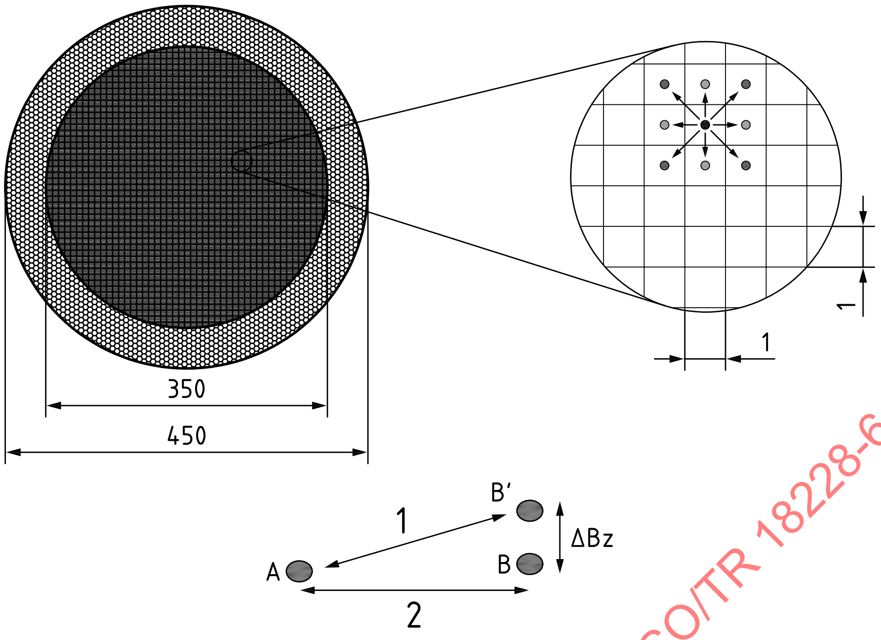


Figure 9 — Aluminium plate and strain analysis

Strain is measured in 1 mm increments over the whole surface of the plate as described in Figure 10 below.



Key

1 deformed

2 original

To calculate the strain as a percentage of the original length ε in %:

$$\varepsilon = \left[\frac{d}{o} - 1\right] \times 100$$

NOTE The results obtained from the two different test methods cannot be compared as the test setup is different and the strain measurement methods are different.

Figure 10 — Laser strain capture and calculation

As discussed, there are a number of methods available to designers, demonstrating that a geosynthetic protector will perform as predicted for the lifetime of a site.

EN 14574 method

EN 14574 is useful for sites where no drainage gravel is used, but for when a protection geosynthetic is used against concrete in tunnels, for example.

7 Handling and installation

In most cases, geotextile protectors are handled and stored with care to preserve the material's properties. Normally, storage is on a flat, draining surface. To keep the geotextile from deteriorating in the sun's ultraviolet rays, the material is typically transported and stored in light-resistant wrappings.

Normally, the geotextile is installed in a way that minimises the risk of damage. Any blades or sharp objects are handled with care to avoid damaging the barrier.

Typically, adjacent panels are overlapped or hot-air welded, depending on the design requirements. Sometimes, welding can stop any materials above the protector from moving under it, which can cause damage to the barrier. Overlapping can be utilized in situations where settlement is considered likely to occur.