IGS MINI-LECTURE

Testing of GEOSYNTHETICS

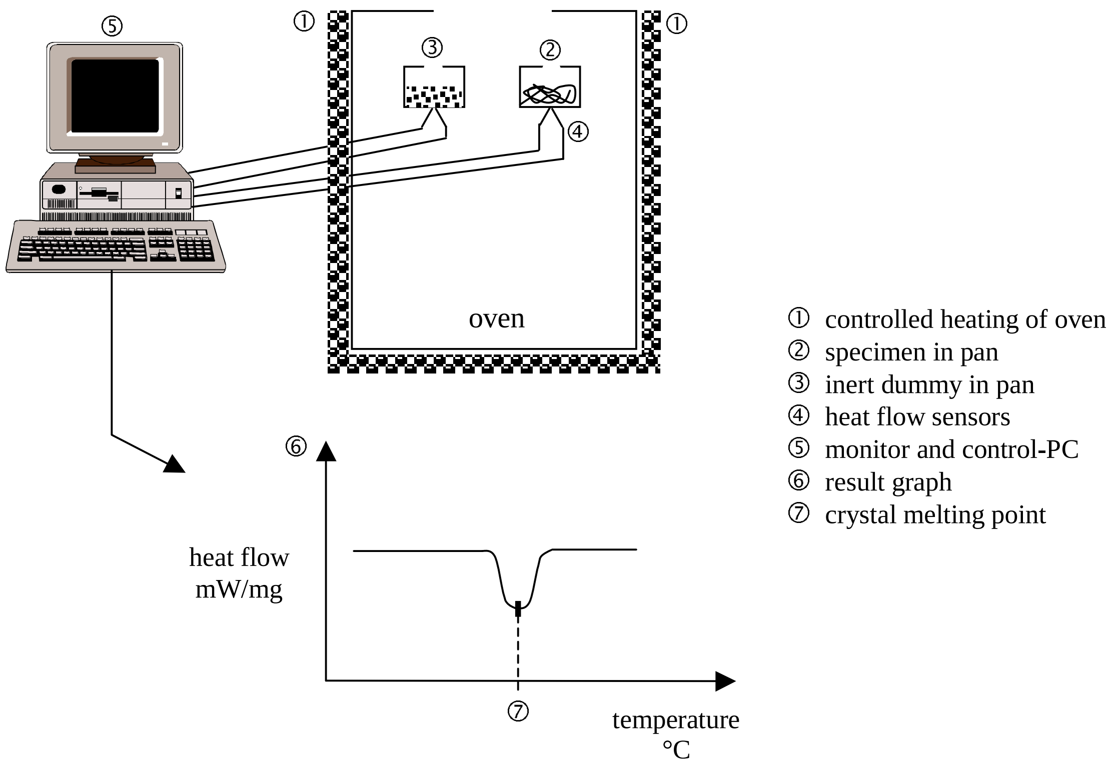
Prof. Dr.-Ing. Müller-Rochholz, Fachhochschule Münster and
tBU - Institut für textile Bau- und Umwelttechnik GmbH, Greven

Content

1 General product identification

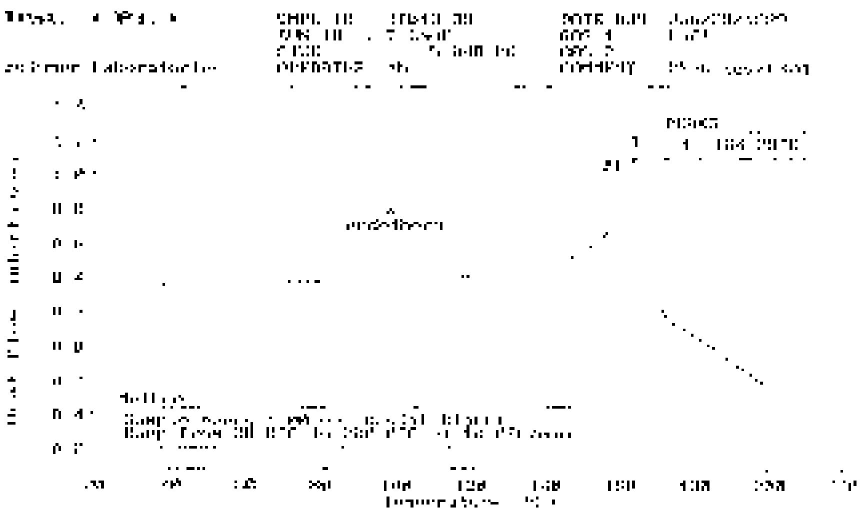
1.1 Polymer identification

By means of a Differential Scanning Calorimetry (DSC) apparatus the crystal melting point of partially crystalline materials can be determined.



Schematic sketch of apparatus and result

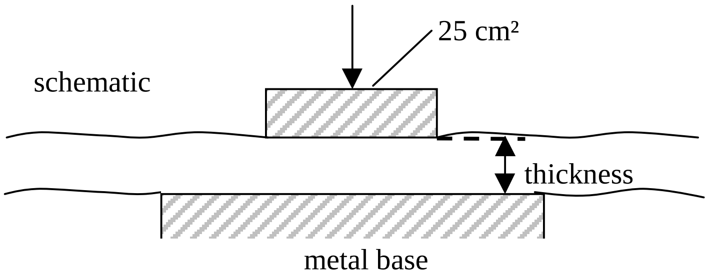
A mass of ca 10 mg is needed, the result plot gives polymer main components (110 °C LDPE, 130 °C...140 °C HDPE, 150 °C...165 °C PP, 240 °C...260 °C PET). Mixtures of polymers and additives of partially crystalline polymers are to be detected from ca 1 % content.



DSC-curve of a polypropylen sample

1.2 Geometrical Information

1.2.1 Thickness (ISO 9863; EN 964.95)
Thickness is of relevance for inplane water flow, filtration. It characterizes at identical mass per unit area the intensity of (mechanical) bonding. It is measured between plane metal plates at loads of 2, 20, 200 kPa; for product identification only the lowest stress is taken.

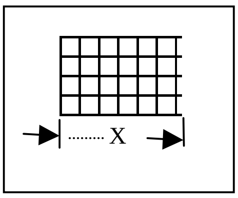


Measuring thickness at 2 kPa

The test is performed according to EN 964 part 1 for single layer products and differently according to part 2 for multilayer products.

1.2.2 Grid opening/pitch
Take a length of close to 1 m with the same part of pitch (f.e. left corner of strand), count the pitches, measure exactly the length and calculate numbers of pitches per m N (m^{-1}).

$$N = \frac{\text{counted pitches}}{\text{measured length X}} \qquad \text{f.e. } N = \frac{43}{0.965\,\text{m}} = 44.56\,\text{m}^{-1}$$



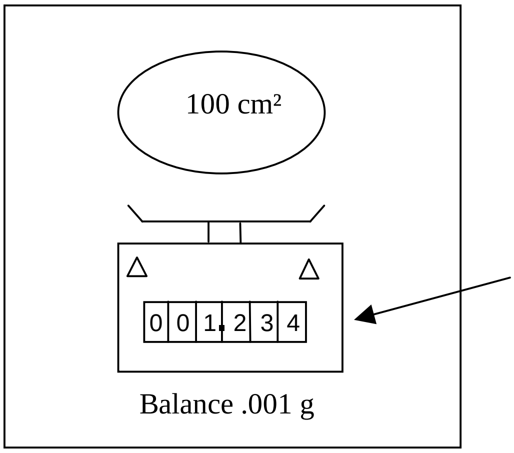
(This value is used for tensile tests results calculation).
Measure width of strands and calculate opening size of the geogrid

$$\lambda = \text{length of one pitch} = \frac{1}{N} \qquad \text{f.e. } \lambda = \frac{1000\,\text{mm}}{44.56} = 22.4\,\text{mm}$$

Grid opening = λ - width of strand (e.g. 7.4 mm) f.e. grid opening = 22.4 – 7.4 = 15 mm

1.3 Mass per unit area (mua) (ISO 9864; EN 965 : 1995)

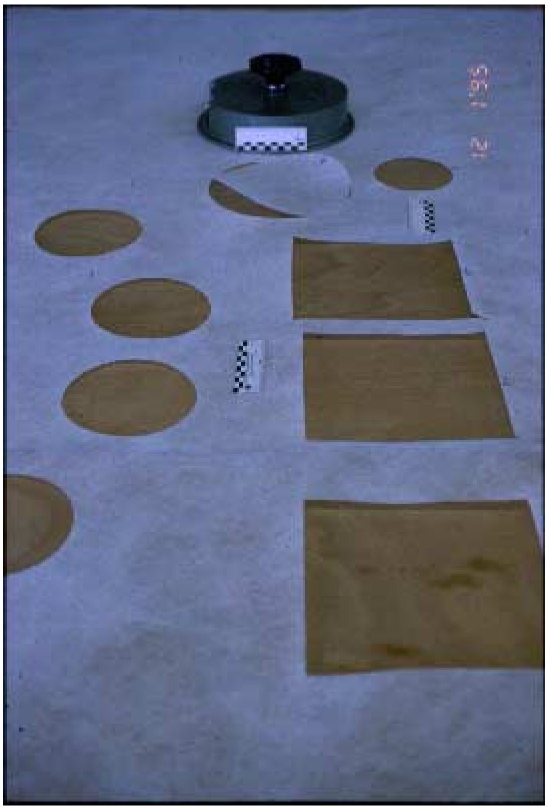
The mass per unit area is one of the most often used characteristic value, giving the price creating mass of the raw material.



mua = 123.4 g/m²

Schematic sketch of measuring device

Specimen are cut preferably with circular cutter (number depending on size; minimum 3, for 100 cm² take 10 specimen) and then weighed exactly. mua is then calculated.



Sampling

Measuring mua

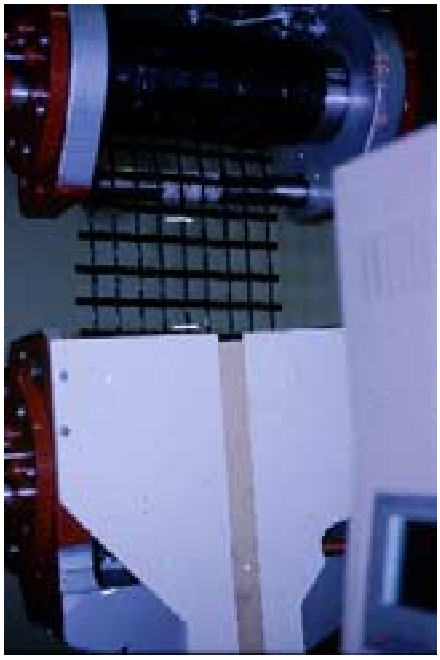
$$\text{mua} = \frac{\text{mass of specimen in g}}{\text{area of specimen in m}^2}$$

2 Mechanical properties

2.1 Short-term tensile strength and dependent deformation (standards see table below)

Tensile strength or maximum force F_m is measured according to different standards on different specimen. Strain rates are of remarkable influence for some polymers and also different real clamping problems arise for high strength grids of polyester-yarns or Aramide yarns.

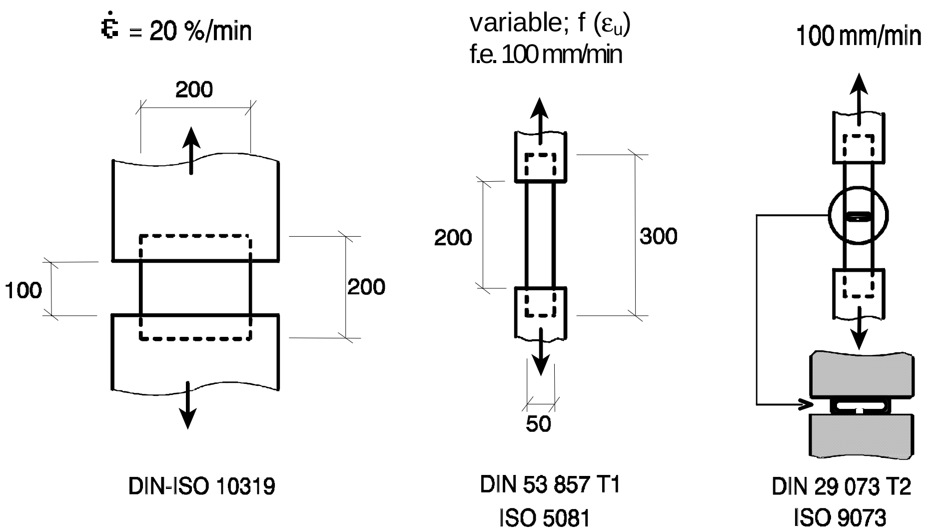
Testing machine with video-extensometer



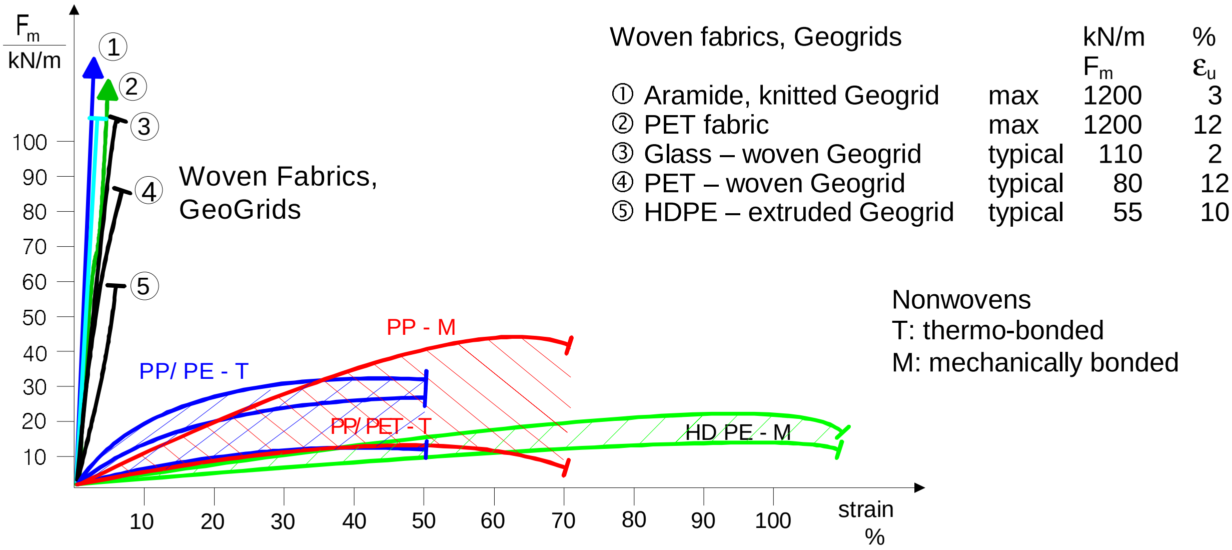
Capstain clamp for geogrid with laser-extensometer

Standard	specimen [1]	strainrate/X-head
EN ISO 10319 : 1996	200 x 200	20 %/min
ISO 5081	50 x 300	variable f (ε_u)
ASTM D 4 595	200 x 200	10 %/min

[1] in mm



The tensile test is the basis of characteristic values of strength for reinforcement and mandatory EU-required value for most applications. Deformation measurement should be a strain measurement on the specimen by means of non contact laser or video optical systems. For accurate measurement of low strains under 1 % clip on gages may be used. Cross head travel gives no accurate values of materials strain, but may be used for production monitoring. Typical behaviour of geosynthetics is shown in the figure with maximum Force F_m and strain at maximum Force (ultimate) ε_u.



Force-strain behaviour of geosynthetics

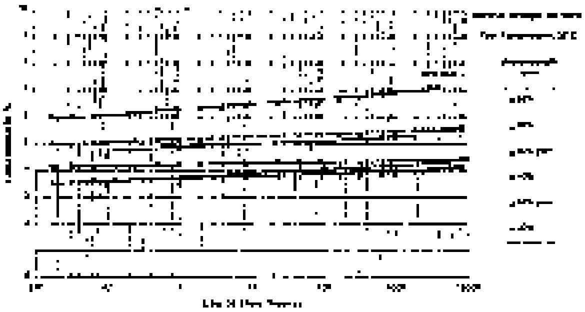
2.2 Tensile creep and creep rupture (EN ISO 13431 : 1996)

Tensile creep tests give information on time-dependent deformation at constant load.
Creep rupture tests give time until failure at constant load. A deformation measurement is not necessary for creep rupture curves. Loads for creep testing are most often dead weights, often enlarged by lever arms. A typical arrangement is shown.

Creep test rigs

Multiple creep rupture rigs in temperature chamber

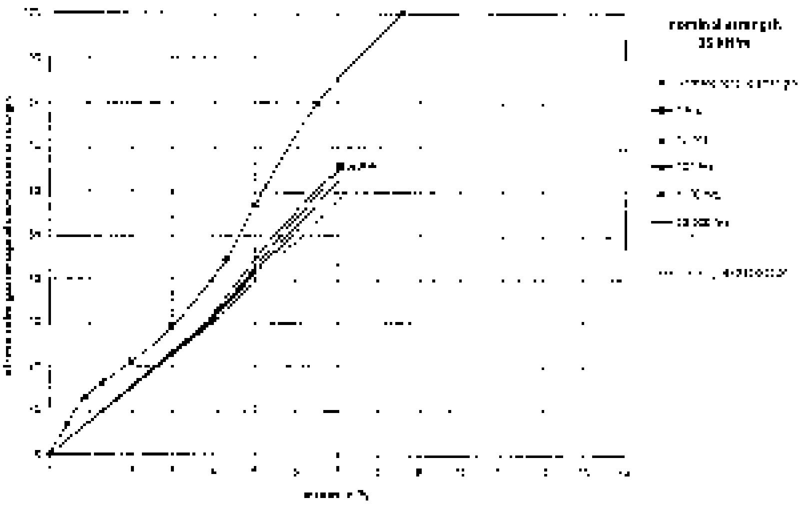
Deformation measurement may be performed by permanent monitoring (LVDT's) or interruptedly by optical or mechanical systems. EN-ISO creep tests require 1000 h testing, for creep rupture extrapolation to long-term (30, 60, 120 years) a test duration greater 10000 h is necessary. Results are plotted for creep as linear deformation vs log time, for creep rupture lin or log stress grade vs log time. Typical curves are shown.



Creep curves

Creep rupture

From creep curves at different stress grades isochronous stress strain curves may be derived for calculation of structure's deformation at a given time.

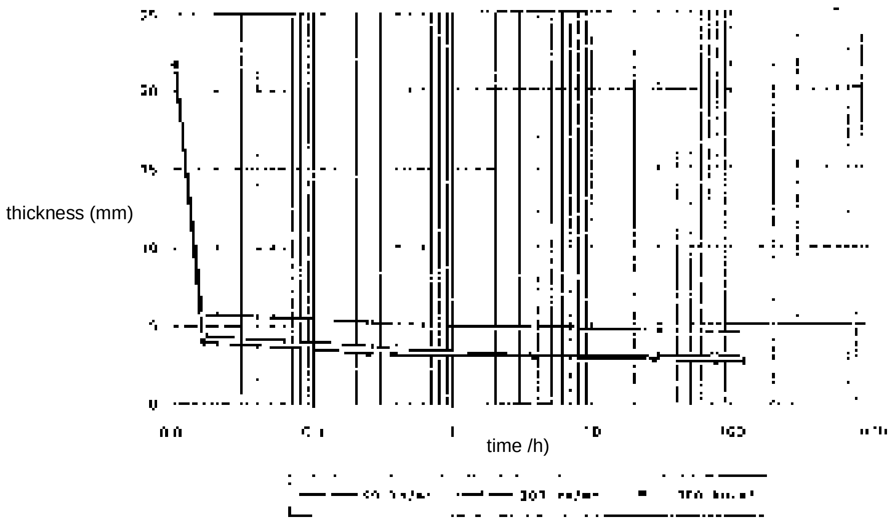


Isochronous curves

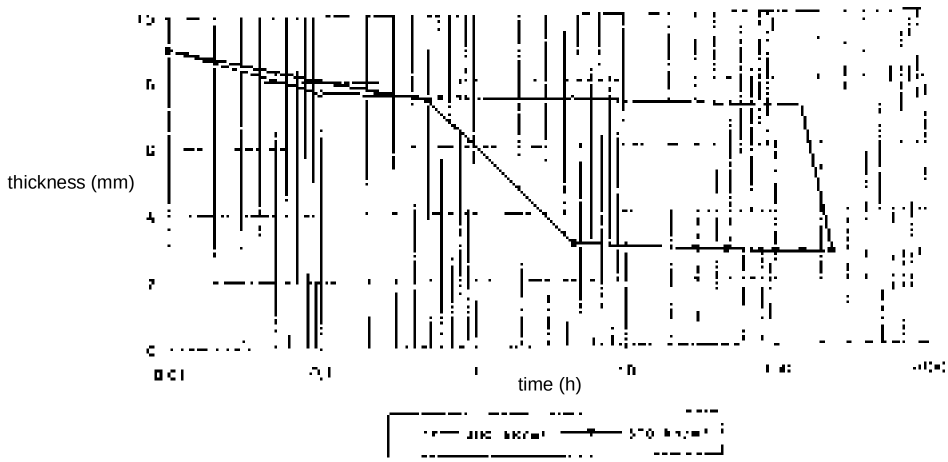
The creep behaviour of geosynthetics depends mainly on the polymer used and how the base materials (yarns, tapes) are treated thermomechanically.

2.3 Compressive behaviour (EN ISO 13432)

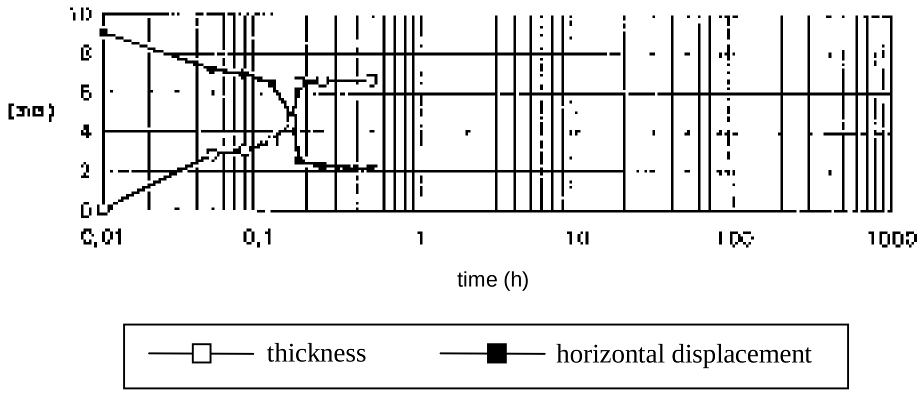
Compressive behaviour describes the deformation of geosynthetics (mainly for drainage applications) depending on stress (normal and shear) and time. Typical curves are shown below, where some types of drainage core materials (cuspated or columnar) show geometric (i. e. sudden collaps) failure. Decreasing thickness of the materials leads to decreasing waterflow in the plane (see 3.1).



Compressive creep random wire drainage product



Compressive creep cuspated film drainage product



Creep under normal and shear stress cuspated film drainage product

2.4 Resistance against puncture

Mineral cover material is dropped during installation of geosynthetics on the fabric, than spread and compacted by vibration and heavy static loads. During these construction elements mineral material shall not puncture the geosynthetic applied as separator or filter. Different tests reflect the different elements.

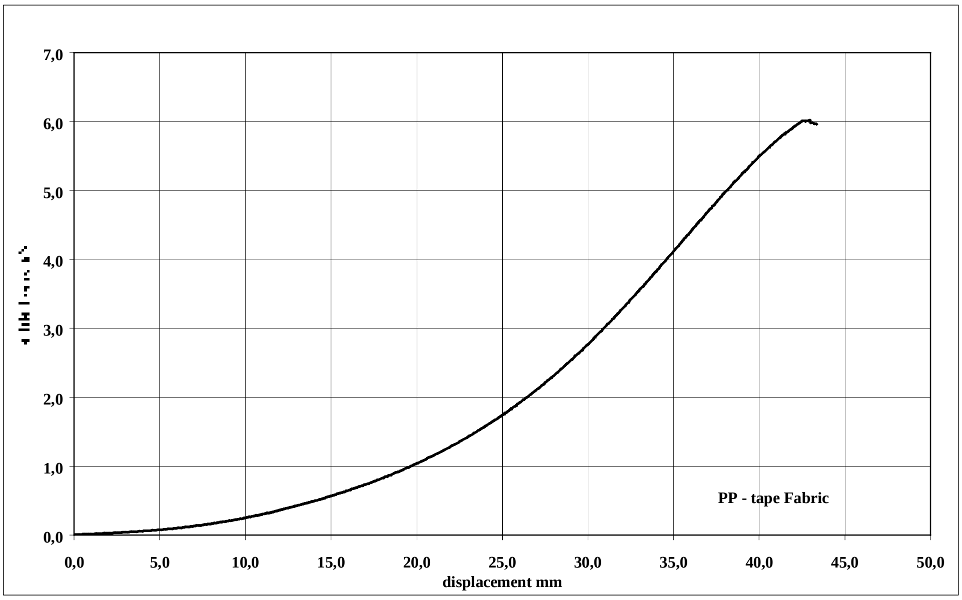
2.4.1 Static puncture test

2.4.1.1 CBR (EN ISO 12236 : 1996)
As elements of a soil mechanical test apparatus (California bearing ratio = CBR) are used, this test is named CBR-test.

CBR-device in testing machine

Inserting specimen in hydraulic CBR-clamps

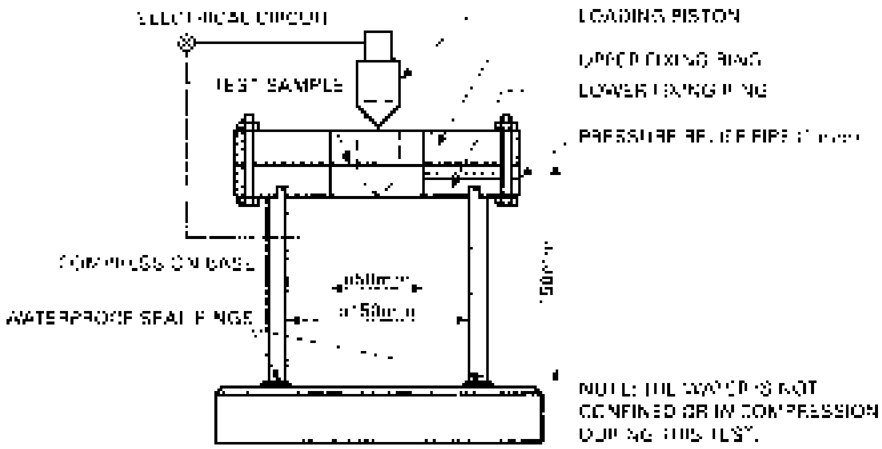
A plunger of 50 mm diameter is moved with a speed of 50 ± 10 mm onto and through the fixed specimen recording force and displacement. The test is widely used for nonwovens, it is not applicable to grids, it may be used for geomembranes.



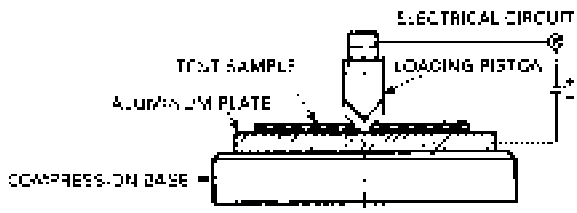
Typical CBR-curve force vs displacement

2.4.1.2 Pyramid puncture (ASTM 5494-93)

A pyramid shaped loading piston is pressed with a speed of 50 ± 10 mm on a specimen on soft or hard subbase. Puncturing closes an electric circuit and gives force and displacement for puncture resistance.



Apparatus according to ASTM 5494



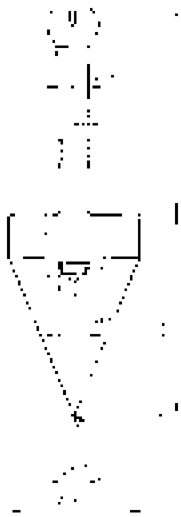
Detail of apparatus

2.4.2 Rapid puncture (ISO 13433, EN 918 : 1995)

2.4.2.1 Cone drop test
A steel cone of 500 g with defined angle and sharpness is dropped from 500 mm above the specimen and caught if there is elastic back motion.

1 head, release mechanism to suit laboratory requirements
2 guide rod
3 cone
4 metal screen
5 screen
6 clamping plates
7 test specimen
8 levelling screws
Note: This diagram is not to scale.

Typical cone drop framework and safety screen



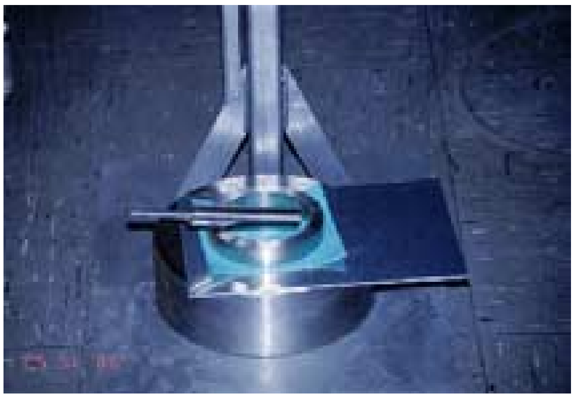
1 top to suit release mechanism and length
2 tip radius (1 ± 0,1 mm)

Cone and guide rod

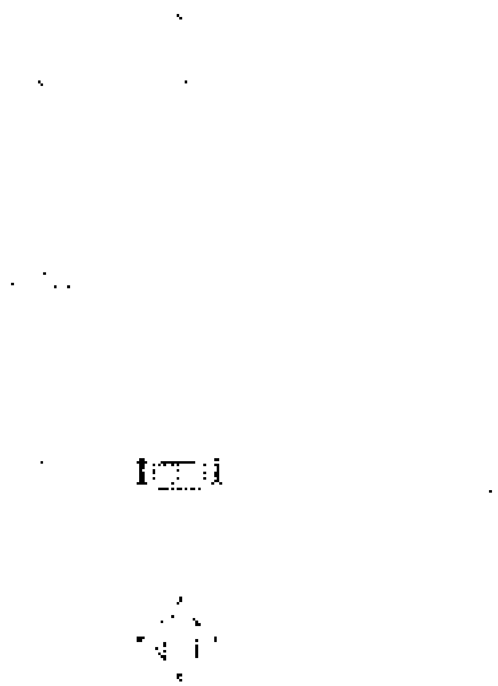
The diameter of a hole created is measured by means of aluminium cone of defined weight (500 g) and smaller angle with metering scale in mm.

Measurement cone for cone drop test

2.4.2.2 Impact test (index: CEN TC 189 WI 14; ISO 13428 draft)
Protection materials are tested by dropping a round shaped drop weight on a specimen placed on a lead platen on a defined mass subbase. The impression in the lead and the status of the specimen are recorded.
Lighter round shaped drop weights are used for liner materials. The deformation of a metal sheet under the tested material gives quantitative results.

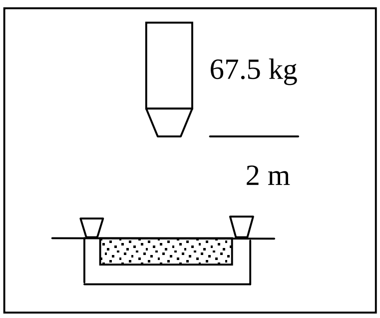


Drop weight, lead platen, specimen under ring



Scheme of testing apparatus (draft European Standard)

2.4.2.3 Impact test (performance: BAW)
A heavy drop weight (67.5 kg) is dropped from 2 m height on the geosynthetic placed on sand and fixed in a ring. The result is a "penetration yes or no" decision.

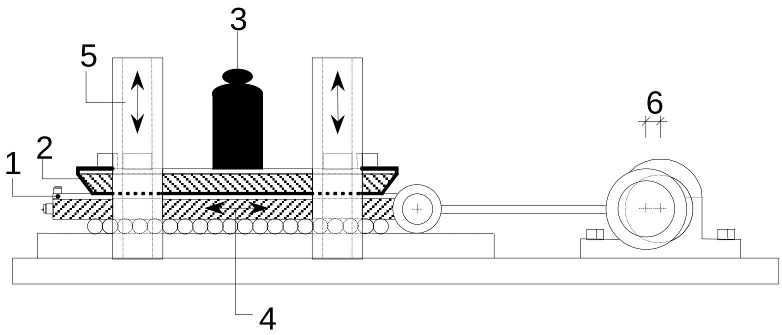


Scheme

Result of drop tests – no penetration

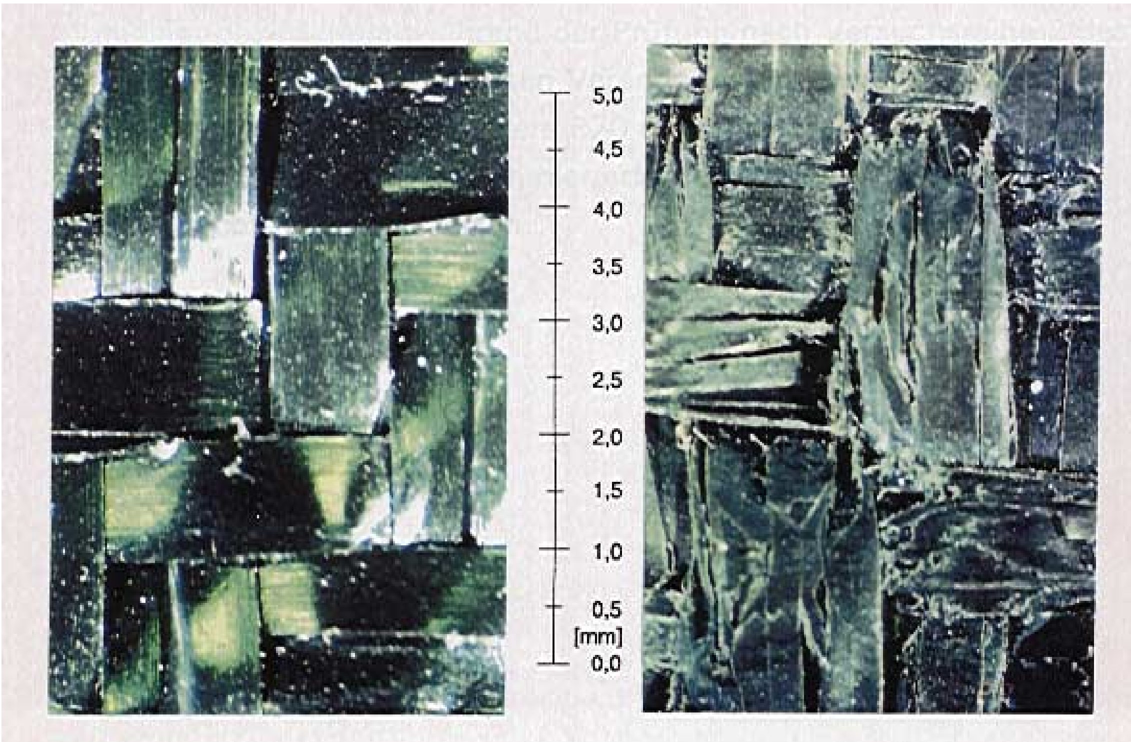
2.5 Resistance against abrasion (EN ISO 13427 : 1995)

Emery cloth of a defined gradation is moved linearly along the specimen. After 750 cycles the specimen may be tested on tensile or hydraulic properties.

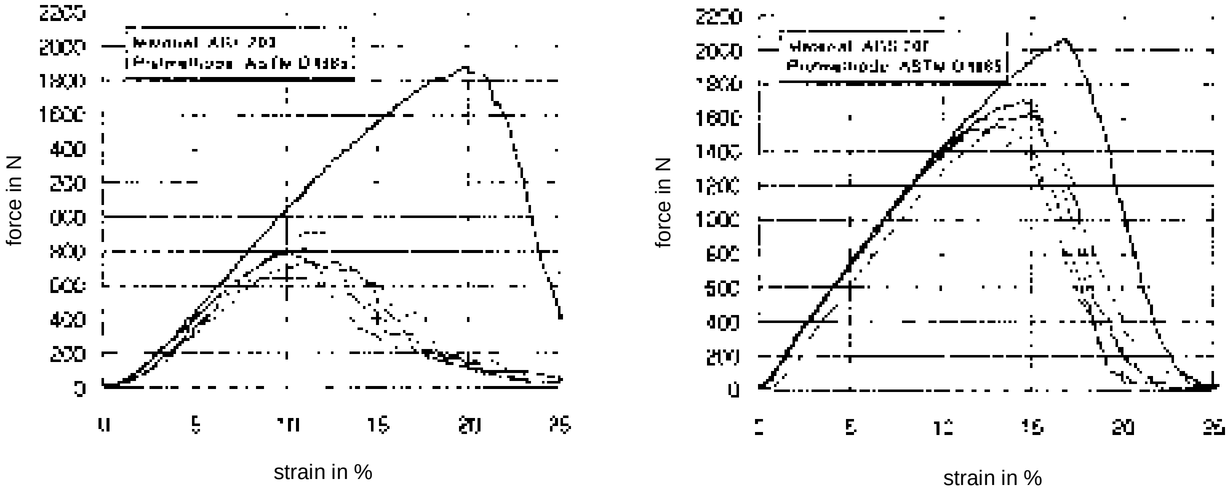


1 Slidingblock with emery cloth P 100
2 Geotextile specimen (50 x 300 mm)
3 Total weight 6 kg
4 25 mm linear motion
5 Vertical guidance
6 Excentricity 12.5 mm

Example of testing apparatus with sliding block



Specimen before test Specimen after abrasion test



PP-tape fabric: warp weft

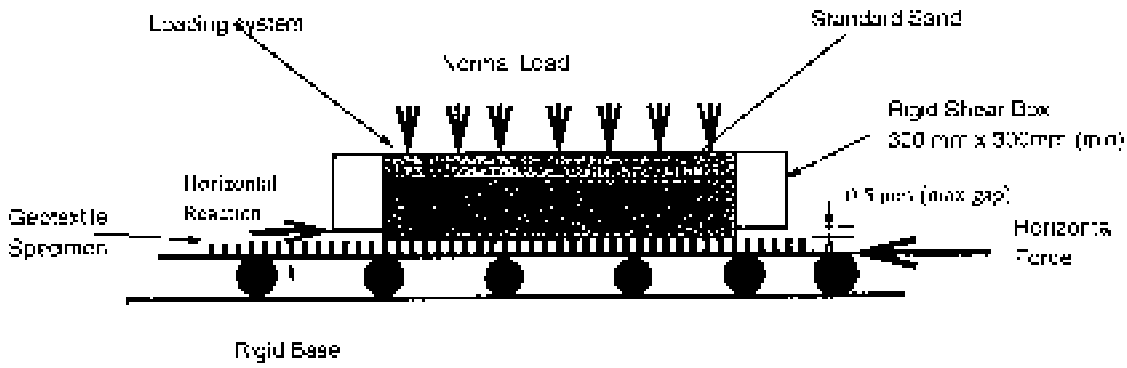
Force vs displacement of abraded (lower lines) to pristine product (upper line)

2.6 Friction properties (EN ISO 12957 : 1998)

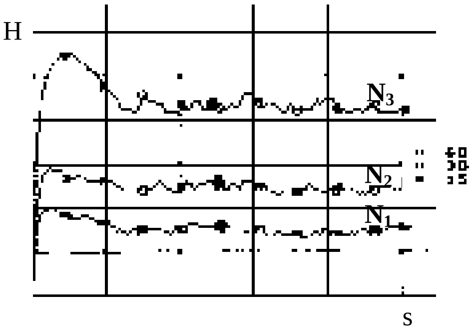
Reinforcing geosynthetics get their tensile load by transferring stresses from the soil to the fabric via friction. The friction ratio to normal stresses is mainly expressed – as common in soil mechanics – as angle of friction. Low normal stresses may be tested by inclined plane test (2.6.2) and higher normal stresses by direct shear ("shear box test" 2.6.1) or by pulling the geosynthetic out of soil (2.6.3).

2.6.1 Direct shear (EN ISO 12957-1)

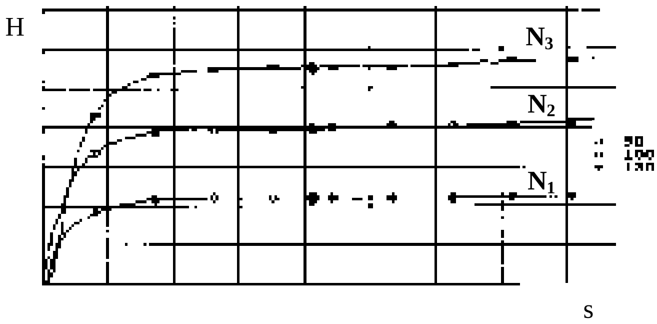
The friction partners are placed one in an upper box, the other in the lower box. The lower box is moved in displacement control (index testing: 1 mm/min) while recording force and displacement. The results for some normal stresses (50, 100, 150 kPa) are plotted, the value of friction angle is calculated. Typical result plot is given below.



Scheme of shearbox test



„Coulomb“ type

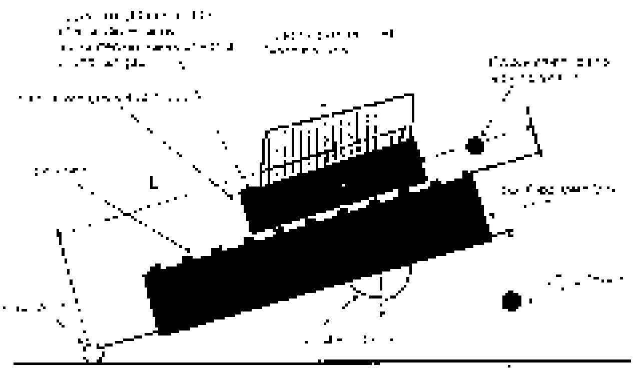


„grease“ type

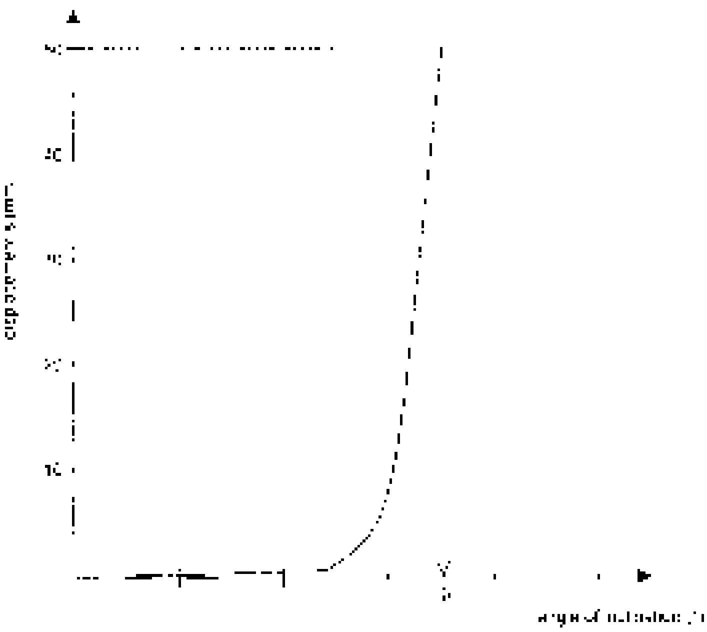
Horizontal force vs shear displacement

2.6.2 Inclined plane test (EN ISO 12957-2)

The friction partners to be tested (geomembrane/geosynthetic; geomembrane/soil; geosynthetic/soil) are set up on a inclinable steel table. Slip of materials and inclination are measured while lifting the table by 3 degrees/min. A movement of 50 mm stops the test and gives the angle of friction for the choosen materials combination. The normal stress must be recalculated for the angle resulting.

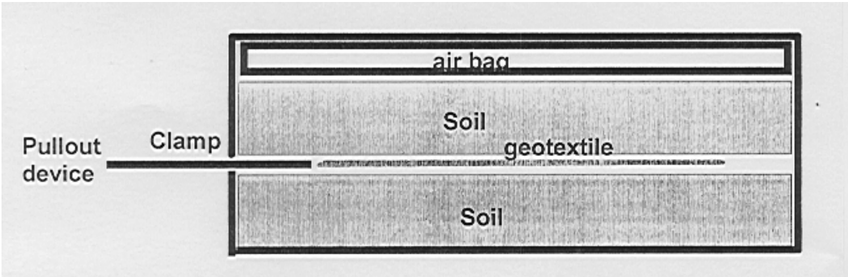


Inclined Plane Shear Test : Soil filled lower base

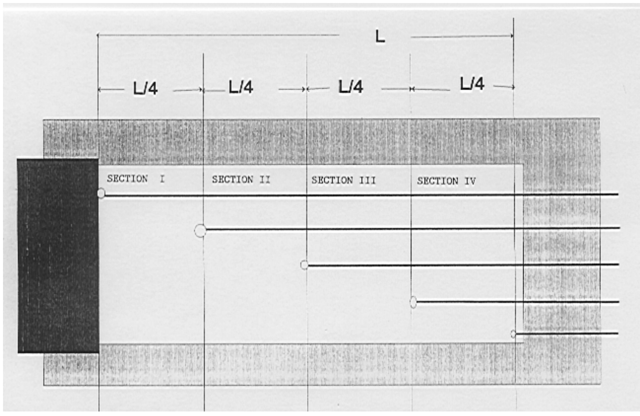


Typical graph inclined plane test

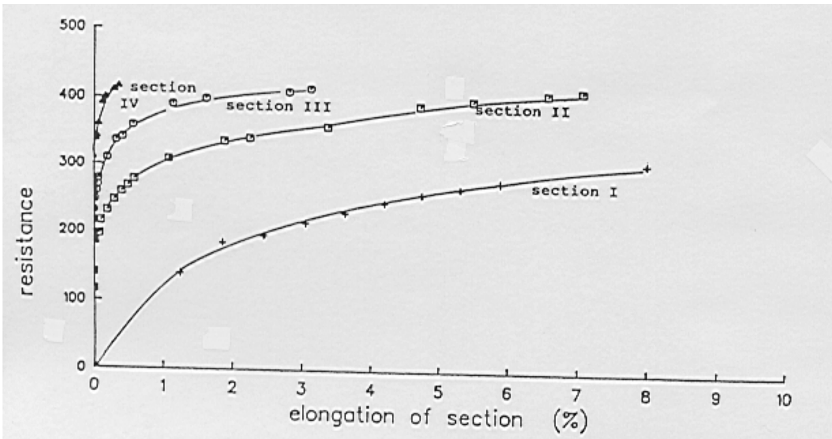
2.6.3 Pullout resistance
A strip of the material (width depending on box width) is pulled out of a soil filled box, where the soil is loaded normal to the geosynthetic by pneumatic, hydraulic or deadweight means.
Force and deformation are recorded for several points of the material inside the box.
Force bypasses at the sleeve must be avoided.



Pullout Box



Plan view and typical gage placement



Pullout resistance versus percent strain of sections of pullout specimen during test

Results may be max force at rupture or slippage or plots of force vs deformation.

2.7 Protection efficiency

The ability of a geotextile to protect a geomembrane is quantified by a test based on german origin. The deformation of a lead platen loaded with nuts as a reproducible material placed on top of a elastomeric pad is calculated from depth and width of the indentations. A photo of glass spheres as load transfer material is given below.

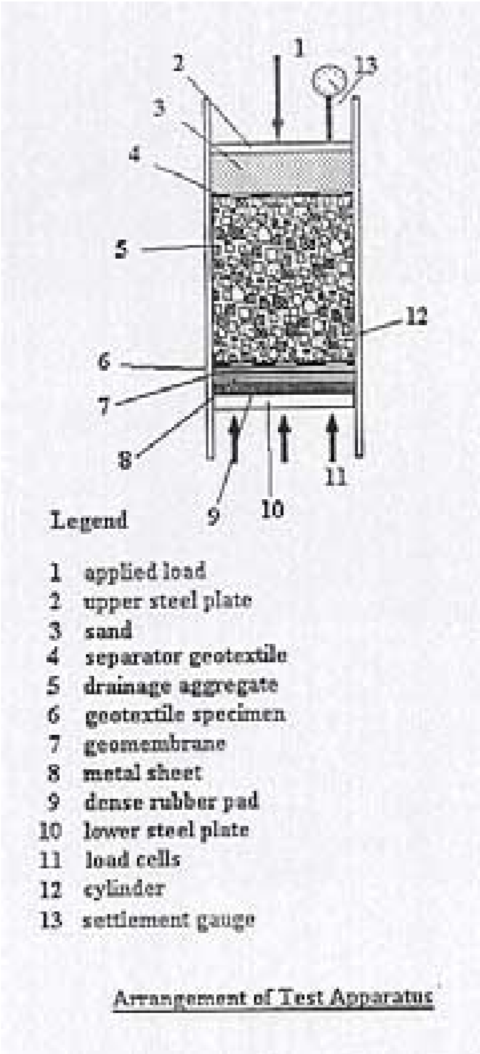
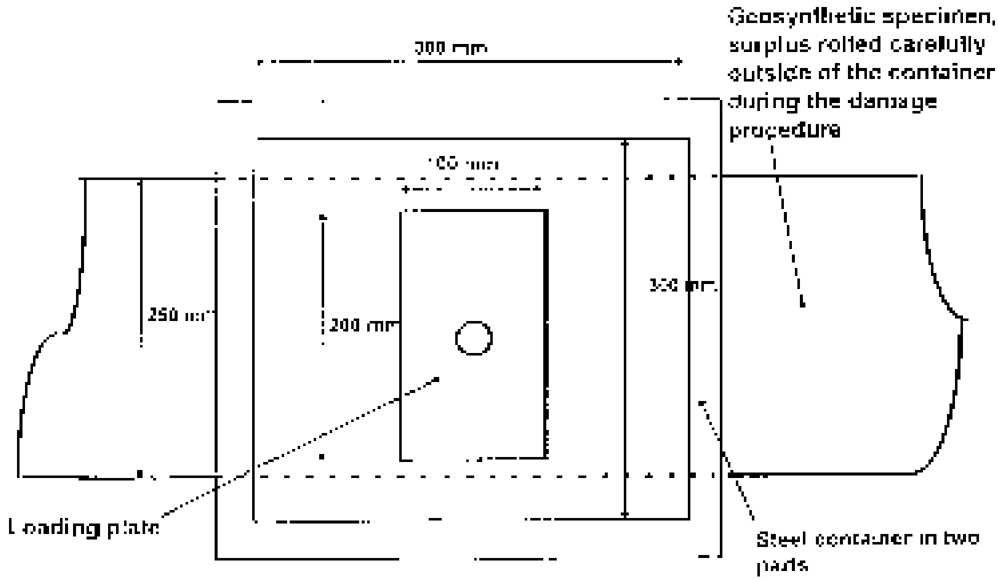


Photo shows the indentations after a similar test (glass-spheres ∅ 22 mm instead of nuts M 16)

2.8 Damage during installation (index) (ENV ISO 10722-1 : 1997)

As the installation can be the most severe attack to geosynthetics during their service life, a estimation of the resistance is to be tested.



Plan on apparatus

Filling Corundum into upper box

Loading of assembly

The CEN-ISO standard applies a cyclic load on a platen (100 x 200) pressing via a layer of corundum aggregat the geosynthetic to be tested.
After 200 cycles between 5 kPa and 900 kPa maximum stress the specimen is exhumed and may be tested for reinforcement on residual strength, for filtration on hydraulic properties. A performance test requires the soil and fill of the site and the equipment to spread and compact the material. Results of the index-test are given below.

Material before (left) and after (right) damage test

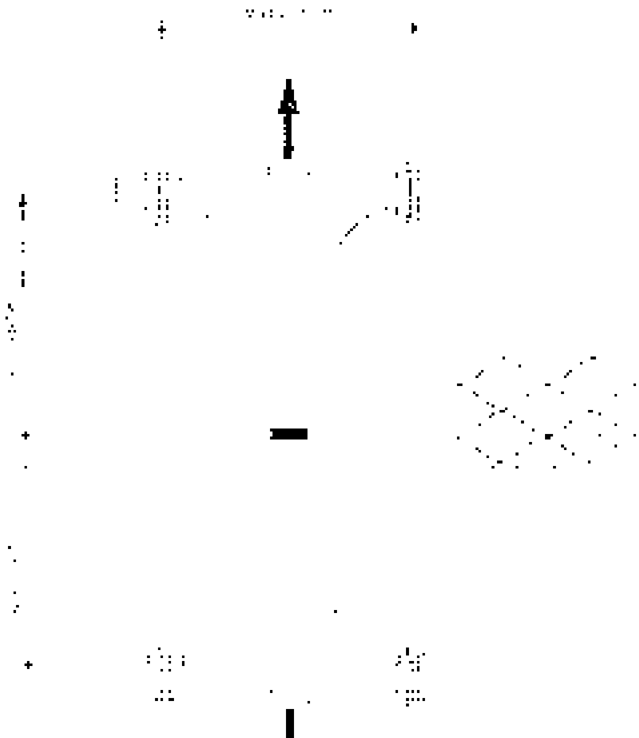
2.9 Geosynthetics or composites internal strength (EN ISO 13426-1)

If a failure of internal junctions may cause failure of a structure, the strength of these junctions shall be tested. CEN WG 3 has 3 parts in progress.

2.9.1 Geocells

The loading of a internal geocell-connection may be of
- a tensile shear type
- a peeling type
- a splitting type

or of combinations.
A typical test scheme for split test is given:



The parts geocomposites and geogrids are in working group discussion.

3 Hydraulic properties

3.1 Water permeability characteristics normal to the plane, without load (EN ISO 11058 : 1999)

When geosynthetics are working as filters, water shall pass the filter and soil shall only pass in grain sizes to create a stable secondary filter in the contact soil zone.
The water flow may be determined at stationary (time independent) conditions i.e. constant flow at constant water head or at instationary conditions, i.e. “falling head”.

3.1.1 Constant head

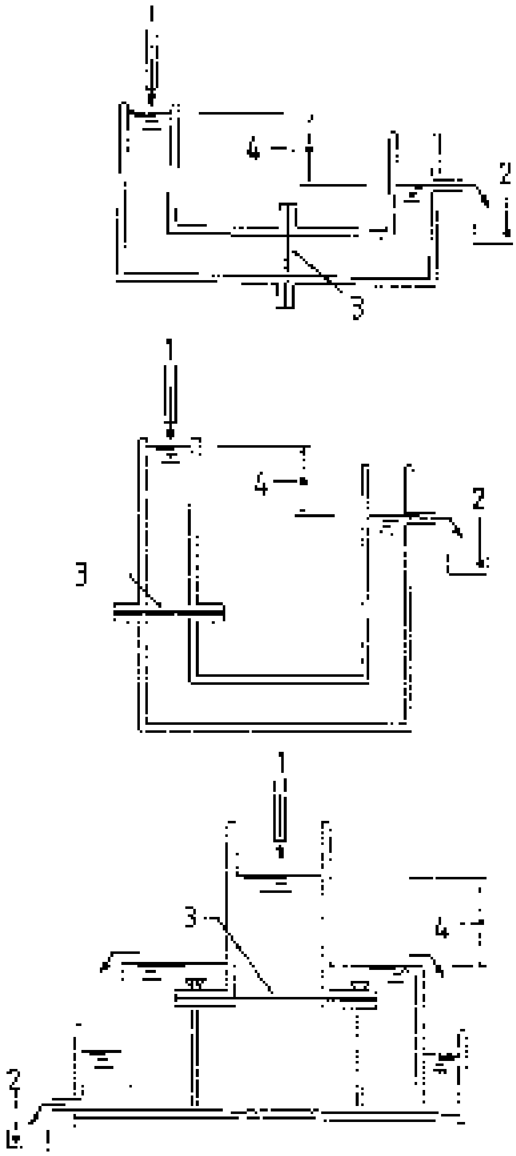
De-aired water passes the specimen charged with normal stresses from top to bottom (multilayer specimen of 20...40 mm are used), flow vs time is measured and expressed as a k_v (k_n)-factor.

a) horizontal

b) vertical

c) open

1 inflow
2 collected outflow
3 specimen
4 head loss (H)



Examples of apparatus for the constant head method

In Darcy’s equation $v = k_v \cdot i$

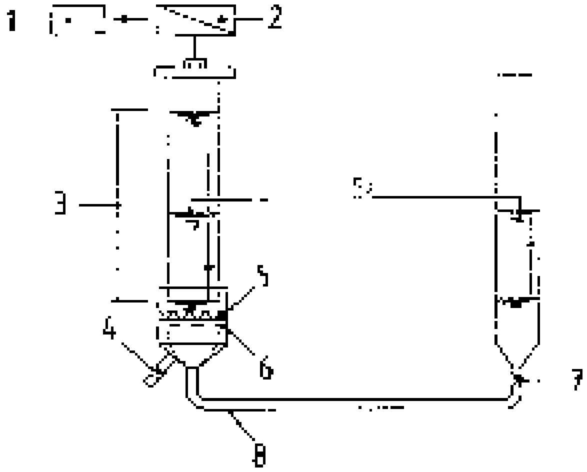
v = speed of flow (m/s)

i = hydraulic gradient = head difference/specimen thickness

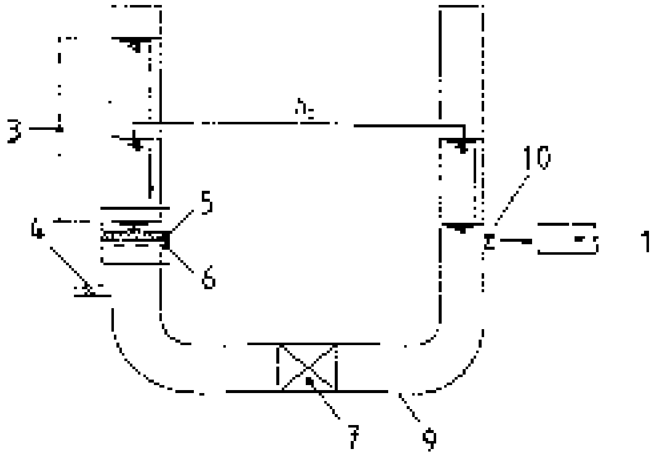
3.1.2 Falling head

The test is mostly done without normal stress on single layer specimen (e.g. contaminated, after soil contact). The test is faster, easier, cheeper.

weighing cell method



pressure gage method

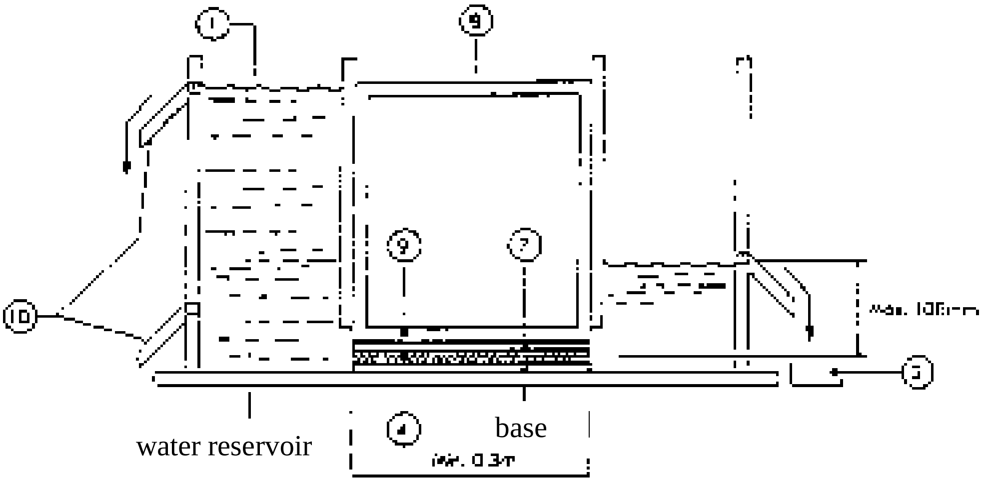


1 analog recorder or computer
2 weighing cell
3 water level difference at the test start
4 release valve
5 specimen
6 support grid
7 main valve
8 flexible connection tube
9 fixed connection tube
10 pressure gauge

Examples of apparatus for the falling head method

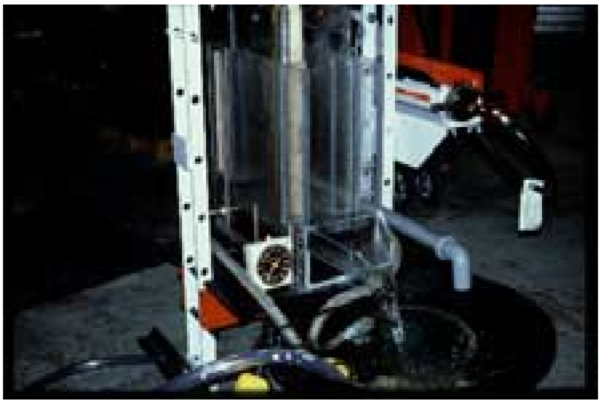
3.2 Water flow capacity in their plane (EN ISO 12958 : 1999)

In drainage applications water is to be transported in the plane of the product. Tests according to EN-ISO or ASTM differ in specimen size, but are genericly identical.



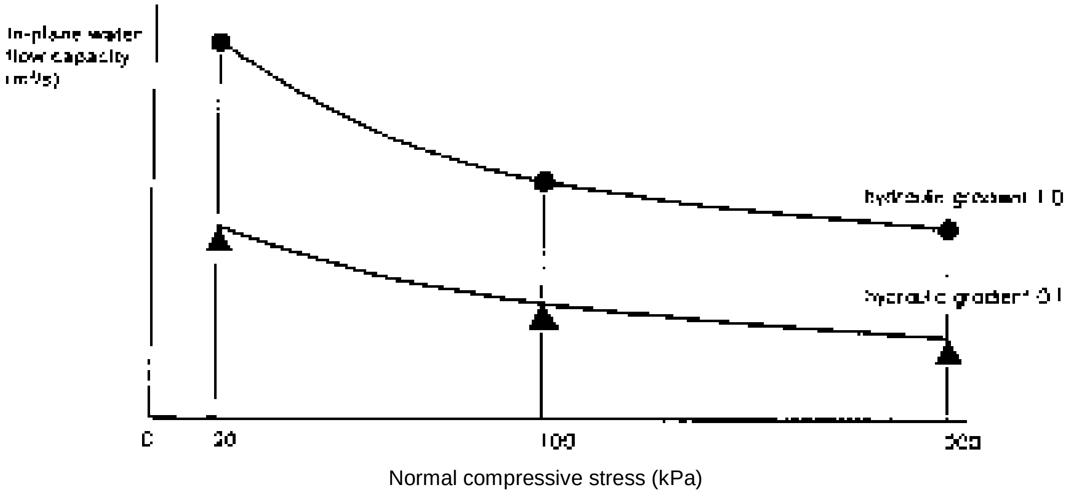
1 water supply
2 water collection
4 specimen
7 foam
8 load
9 loading platen
10 oeverflow weirs at hydraulic gradients 0,1 and 1,0

Typical example of apparatus



CEN-apparatus in plane flow

Specimen in apparatus (cuspated film)
top soft plate, bottom hard plate



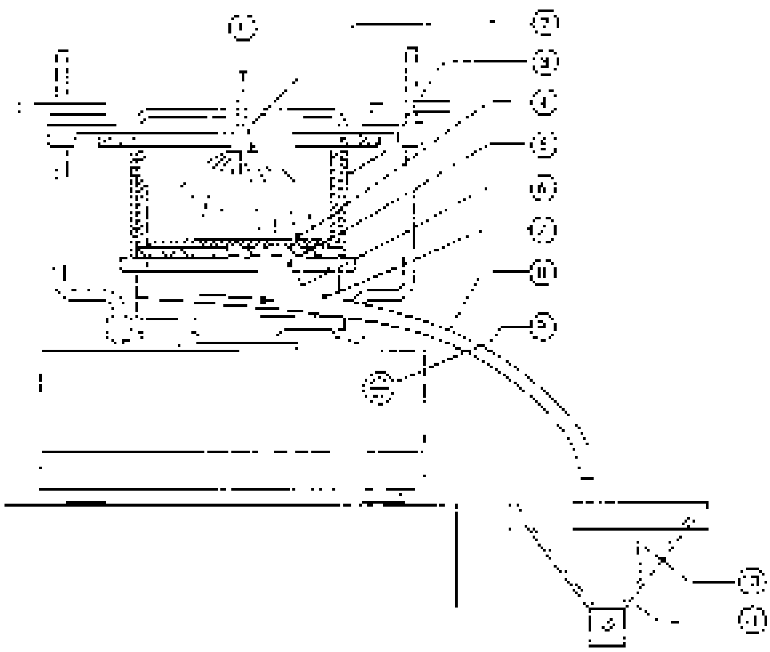
Typical examples of in-plane water flow capacity curves

Flow is measured at constant water head and expressed either as k_H (k_p), unit m/s, or as flow capacity, unit l/s per m width of the product at given gradient. The value is dependent of thickness and thus of time as the materials creep. For a long-term design thickness dependent values have to be measured and matched with compressive creep tests.

3.3 Characteristic opening size (EN ISO 12956 : 1999)

To determine, which grain particle is passing a geosynthetic and which is retained, a wet sieving test is made with a standard “soil”. The material passing is extracted from the water and sieved again. A characteristic value O_{90} is calculated according to EN ISO 12956.

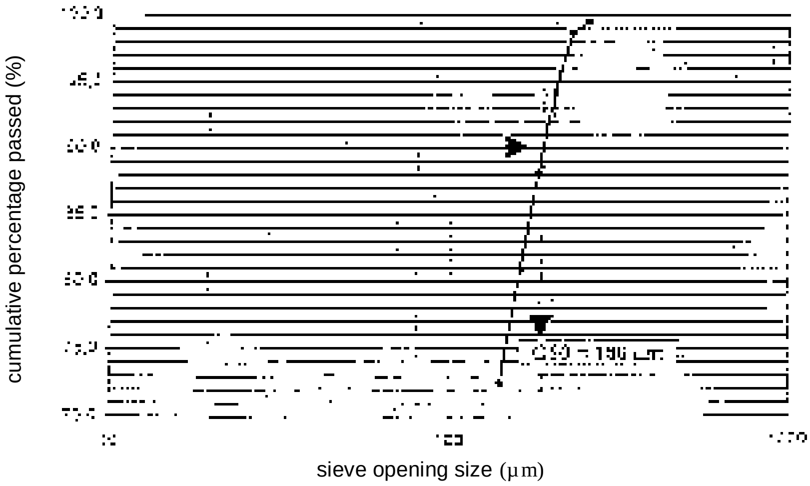
$O_{90} = d_{90}$ of material passing the product



1 water supply	6 support grid
2 spray nozzle(s)	7 pan
3 clamping device	8 connecting tube
4 granular material	9 amplitude regulator
5 specimen	10 filter paper
	11 collection device

Example of sieving device

Tests according to other standards take single grade sand or glass-spheres to measure similar properties.



Cumulative curve of the granular material passed through the specimen and determination of O_{90}

4 Durability properties

Geosynthetics may serve for temporary structures as access roads for construction sites or may be needed temporarily until consolidation of soils. Long-term application is the majority of applications (30 or 60 years are values numbered in UK; more than 120 years are required for landfills in Germany). Therefore durability is an important requirement.

4.1 Resistance to weathering (prEN 12224 : 1996)

Products exposed uncovered to light and products placed without cover-soil for sometime are tested by artificial weathering. Exposition to UV-light of defined emission spectrum and rain at elevated temperature accelerates the test.

Exposition to natural weathering

Tensile tests after exposition and reference to pristine specimen give tensile strength loss in %.

Chamber for artificial weathering

4.2 Resistance to microbiological degradation (ENV 12225 : 1996)

Fungi and bacteria living in soils may attack the polymeric materials used as geosynthetics. (There is no failure reported till now by this). To check the resistance the product to be tested is buried in biologically active soil and after the "soil burial" test residual strength is measured. ENV 12224 gives types of bacteria and environments.

4.3 Resistance to liquids (ENV ISO 12960)

From all chemical attacks two seemed more important to the standards working group. Resistance to hydrolysis for Polyester and resistance to thermal oxidation for Polyolefines.

Immersion of geosynthetics in liquid agents

4.3.1 Resistance to hydrolysis (prEN 12447)

Hydrolysis of Polyester is the reverse action of the evolution by polycondensation and means connecting water molecules or parts to the PET molecules, thus increasing the Carboxyl end group (CEG)-content and decreasing the average molecular weight often expressed as solution viscosity. External hydrolysis by alcaline attak occurs also at low temperatures, internal hydrolysis in neutral environments is relevant at elevated temperatures.
Products are immersed in liquids for times up to 90 days and residual strength and deformation are tested.

4.3.2 Resistance to thermal oxidation (prEN ISO 13430)

To the polyolefine molecules of PE, PP oxygen may be connected creating increased brittleness of the polymers. Stabilizing additives delay this oxidation. For the test the products are exposed to high temperature in an oven.