International Standard

ISO 10319

Fourth edition
2024-10

Geosynthetics — Wide-width tensile test

Géosynthétiques — Essai de traction des bandes larges

Reference number
ISO 10319:2024(en)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 221, *Geosynthetics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 189, *Geosynthetics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 10319:2015), which has been technically revised.

The main changes are as follows:

— the term “load” changed to “force” in all instances;

— difference between strain and elongation clarified in Clause 3 and Figure 1 modified accordingly;

— difference between tensile strength at first and second peak clarified in Clause 3 and 9.2;

— illustration of suitable jaws and grips introduced in Figure 3;

— testing of metallic products limited to woven steel wire meshes in 6.4.6;

— testing products narrower than 200 mm introduced in 6.4.7;

— testing at lower or higher temperatures introduced, with the related conditioning in 7.3 and the related procedure added in Annex A;

— formulae for strain calculation introduced in 9.1;

— formulae for tensile strength of products narrower than 200 mm introduced in 9.2;

— test report requirements updated in Clause 10.

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

Geosynthetics — Wide-width tensile test

1 Scope

This document specifies an index test method for the determination of the tensile properties of geosynthetics (polymeric, glass and metallic), using a wide-width strip. This document is applicable to most geosynthetics, including woven geotextiles, nonwoven geotextiles, geocomposites, knitted geotextiles, geonets, geomats and metallic products. It is also applicable to geogrids and similar open-structure geotextiles, but specimen dimensions will possibly need to be altered. It is not applicable to polymeric or bituminous geosynthetic barriers, but it is applicable to clay geosynthetic barriers.

This document specifies a tensile test method that covers the measurement of tensile force, elongation characteristics and includes procedures for the calculation of secant stiffness, maximum load per unit width and strain at maximum force. Singular points on the tensile force-extension curve are also indicated.

Procedures for measuring the tensile properties of both conditioned and wet specimens are included in this document.

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 554, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 9862, *Geosynthetics — Sampling and preparation of test specimens*

ISO 9863-1, *Geosynthetics — Determination of thickness at specified pressures — Part 1: Single layers*

ISO 10318-1, *Geosynthetics — Part 1: Terms and definitions*

ISO 10321, *Geosynthetics — Tensile test for joints/seams by wide-width strip method*

EN 10223-3, *Steel wire and wire products for fencing and netting — Part 3: Hexagonal steel wire mesh products for civil engineering purposes*

3 Terms and definitions

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

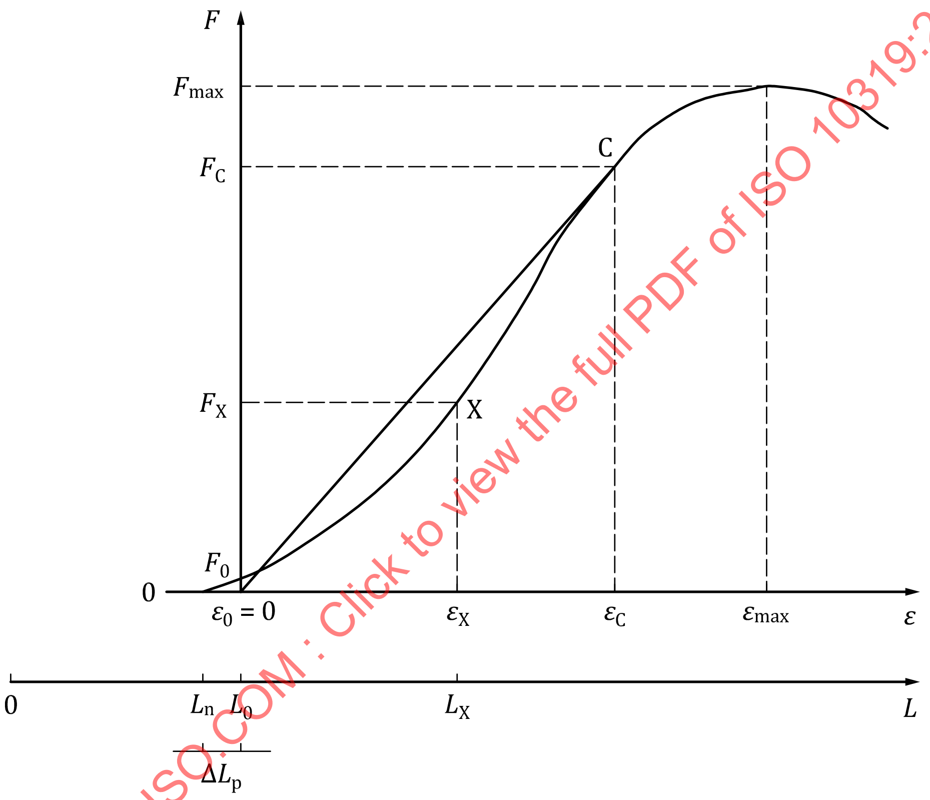
— IEC Electropedia: available at https://www.electropedia.org/

3.1
nominal gauge length
L_n
initial distance between two reference points located on the specimen parallel to the applied force direction

Note 1 to entry: The nominal gauge length is normally 60 mm (30 mm on either side of the specimen symmetrical centre).

3.2
elongation at pre-tension force
ΔL_p
measured increase in gauge length (mm) corresponding to an applied pre-tension force of 1 % of the expected *maximum tensile force* (3.4)

Note 1 to entry: The elongation at pre-tension force is indicated in Figure 1.



Key

F	tensile force, in kN
F_{max}	maximum tensile force, in kN
F_0	pre-tension force, in kN
F_c	tensile force for secant stiffness calculation at point C
F_x	tensile force at strain ε_x
C	selected point for the stiffness calculation
ε	tensile strain, in per cent
ε_0	tensile strain at pre-tension force set as the origin of the abscissa, in per cent
ε_{max}	tensile strain at maximum tensile force, in per cent
ε_x	tensile strain corresponding to the generic length L_x, in per cent
ε_c	tensile strain for secant stiffness calculation at point C, in per cent
L	length, equal to the distance between the two reference points measured during the test, in mm
L_n	nominal gauge length, in mm

L_0 true gauge length, in mm

L_x generic length measured during the test, in mm

ΔL_p elongation at pre-tension force, in mm

Figure 1 — Typical tensile force–strain curve

3.3
true gauge length
L_0
nominal gauge length (3.1) in millimetres plus the *elongation at pre-tension force* (3.2) in millimetres

3.4
maximum tensile force
F_{max}
maximum value obtained during a test

Note 1 to entry: The maximum tensile force is expressed in kilonewtons (kN).

3.5
tensile strain
ε
increase in *true gauge length* (3.3) of a specimen during a test divided by true gauge length

Note 1 to entry: Tensile strain is expressed as a percentage of the true gauge length.

3.6
tensile strain at maximum tensile force
ε_{max}
tensile strain (3.5) exhibited by the specimen under *maximum tensile force* (3.4)

Note 1 to entry: Tensile strain at maximum tensile force is expressed in per cent.

3.7
tensile strain at nominal tensile strength
ε_{nom}
value at the nominal *tensile strength* (3.9) as defined by the manufacturer

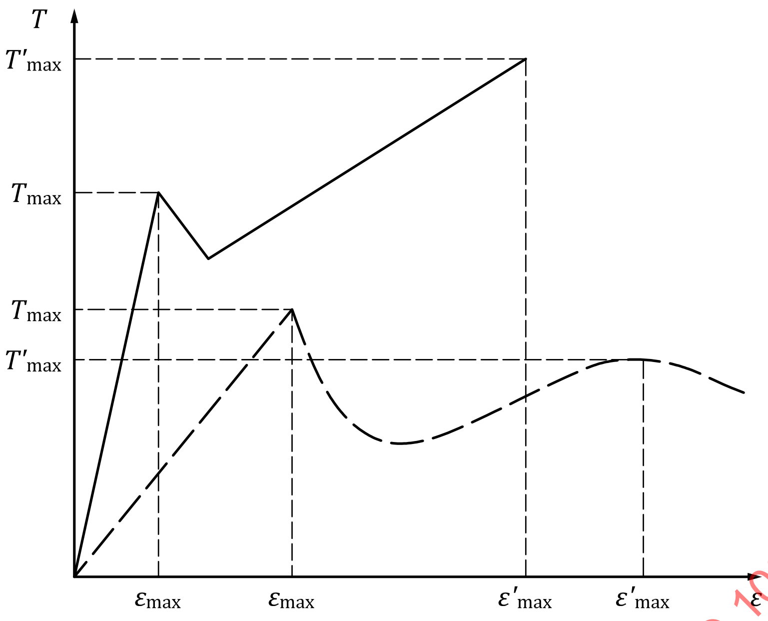
3.8
secant tensile stiffness
J
ratio of tensile force per unit width to an associated value of strain

Note 1 to entry: Secant tensile stiffness is expressed in kilonewtons per metre (kN/m).

3.9
tensile strength
T_{max}
maximum force per unit width observed during a test in which the specimen is stretched to rupture

Note 1 to entry: Tensile strength is expressed in kilonewtons per metre (kN/m).

Note 2 to entry: For products exhibiting a second peak on the tensile force per unit width-strain curves, the tensile strength is defined as the highest value between the two peaks, as shown in Figure 2.



Key

T_{max} tensile strength at first peak, in kN/m

ε_{max} tensile strain at first peak, in per cent

T'_{max} tensile strength at second peak (kN/m)

ε'_{max} tensile strain at second peak, in per cent

Figure 2 — Typical tensile force per unit width-strain curves of two geosynthetics showing a second peak

3.10
strain rate
strain at maximum force, divided by the duration of the test, i.e. the time to attainment of *maximum tensile force* (3.4) from pre-tension force

Note 1 to entry: Strain rate is expressed in percentage per minute.

3.11
tensile strength at second peak
T'_{max}
maximum force per unit width observed during a test in which the specimen is stretched to rupture, at the second peak observed on the tensile force per unit width–strain curve, occurring at a higher strain than that corresponding to the first peak

Note 1 to entry: Tensile strength at second peak is expressed in kilonewtons per metre (kN/m).

3.12
tensile strain at second peak
ε'_{max}
tensile strain (3.5) exhibited by the specimen at the second peak observed on the tensile force per unit width–strain curve, occurring at a higher strain than that corresponding to the first peak

Note 1 to entry: Tensile strain at second peak is expressed in per cent.

3.13
pre-tension force
F_0
tensile force equal to 1 % of the expected *maximum tensile force* (3.4), applied at the beginning of the test

Note 1 to entry: The pre-tension force is expressed in kilonewtons (kN).

3.14
tensile strain at pre-tension force
ε_0
tensile strain (3.5) corresponding to the pre-tension force, set as the origin of the abscissa in Figure 1, in per cent

Note 1 to entry: Tensile strain at pre-tension force is equal to zero based on Formulae (1) and (2), as shown in Figure 1.

4 Principle

A specimen is held across its entire width in a set of clamps or jaws (see Figure 3) of a tensile testing machine operated at a constant cross-head speed. A longitudinal force is applied to the specimen until the specimen ruptures. The type of jaws used are selected according to the type and tensile strength of the tested product; compressive hydraulic jaws [Figure 3 a), c), d)] and capstan grips [Figure 3 b), e), f)] may be used. For capstan grips, it can be useful to wind the specimen in an “S-shape” scheme around the capstan clamps or in a “B-shape” scheme, as shown in Figure 3 f).

The tensile properties of the specimen are calculated from machine scales, dials, autographic recording charts or an interfaced computer. A constant test speed is selected so as to give a strain rate of (20 ± 5) % per minute in the true gauge length of the specimen, except for products that exhibit a low strain, i.e. less than or equal to 5 %. For these products, e.g. glass, the speed is reduced so that the specimen breaks in (30 ± 5) s.

The basic distinction between the current method and other methods for measuring tensile properties of products is the width of the specimen. In the current method, the width is greater than the length of the specimen, as some geosynthetics have a tendency to contract (neck down) under tensile force in the gauge length area [see Figure 3 c)].

Greater width reduces the contraction effect of such products and provides a relationship closer to the expected product behaviour in the field, as well as a standard for comparison of geosynthetics.

For information on strain, extension measurements are made by means of an extensometer, which follows the movement of two reference points on the specimen. These reference points are situated on the specimen symmetry axis, which is parallel to the applied tensile force, and are separated by a distance of 60 mm (30 mm on each side of the specimen symmetry centre). This distance can be adapted for some types of geosynthetics, like geogrid, in order to include at least one row of nodes or internal junctions.

5 Reagents

The usual laboratory apparatus and, in particular, the following shall be used.

— Use only reagents of recognized analytical grade and only distilled water or water of equivalent purity.

— Distilled water, for wet specimens only, conforming to Grade 3 of ISO 3696.

— Non-ionic wetting agent, for wet specimens only.

— The wetting agent used shall be a general purpose polyoxyethylene glycol alkyl ether at 0,05 % volume.

6 Apparatus

The usual laboratory apparatus and, in particular, the following shall be used.

6.1 Tensile testing machine (constant cross-head speed), conforming to ISO 7500-1, Class 1 or better, in which the rate of increase of specimen length is uniform with time, fitted with a set of clamps or jaws which are sufficiently wide to hold the entire width of the specimen and equipped with appropriate means to limit slippage or damage.

NOTE 1 It is useful if one clamp is supported by a free swivel or universal joint to compensate for uneven distribution of force across the specimen.

Compressive jaws or capstan grips should be selected according to the type and tensile strength of the tested product.

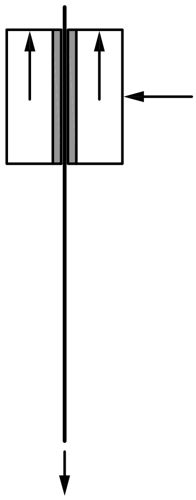
Jaw faces that limit slippage of the specimen shall be chosen, especially in stronger geosynthetics. Examples of jaws that have been found satisfactory are shown in Figure 3.

NOTE 2 The type of selected clamp can affect the obtained results.

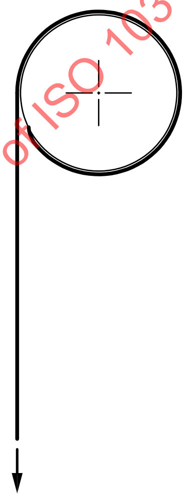
6.2 Extensometer, capable of measuring the distance between two reference points on the specimen without any damage to the specimen or slippage. Care should be taken to ensure that the measurement represents the true movement of the reference points.

NOTE Suitable extensometers are mechanical, optical, infrared or other types, all with an electrical output.

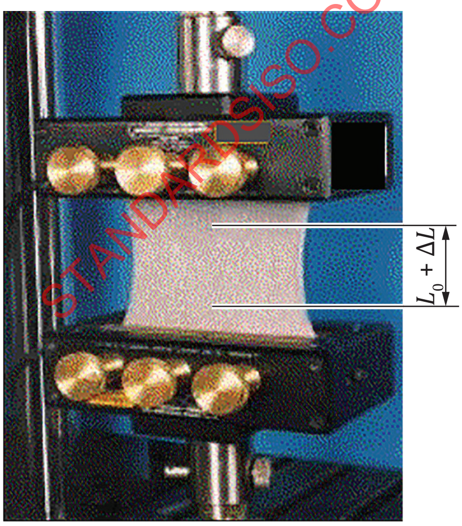
The extensometer shall be capable of measuring to an accuracy of ±2 % of the indicated reading. If any irregularity of the stress-strain curve due to the extensometer is observed, this result shall be discarded and another specimen shall be tested.



a) Friction by lateral pressure (hydraulic or mechanic compressive jaws)

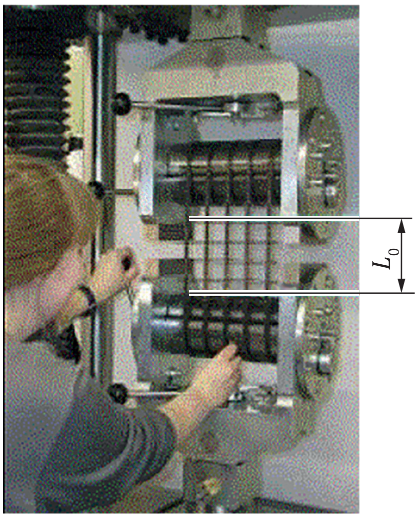


b) Capstan or roller clamps friction on circular tube

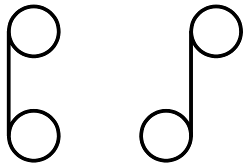


c) Example of hydraulic jaws for low-strength products

d) Example of hydraulic jaws for high-strength products



e) Example of capstan grips



f) “B-shape” scheme and “S-shape” scheme for capstan grips

Figure 3 — Examples of jaws for tensile testing of geosynthetics — Test specimens

6.3 A minimum of five test specimens, cut in both machine direction (MD) and cross-machine direction (CMD).

For strip products like prefabricated vertical drains, geostrips, and strips of geocells, testing in only the longitudinal direction is suitable.

Sample and prepare the test specimens in accordance with ISO 9862.

6.4 Dimensions

6.4.1 Nonwoven geotextiles, knitted geotextiles, geonets, geomats, clay geosynthetic barriers, geocomposite drains, geospacers, geoblankets and other products wider than 200 mm and without an open structure.

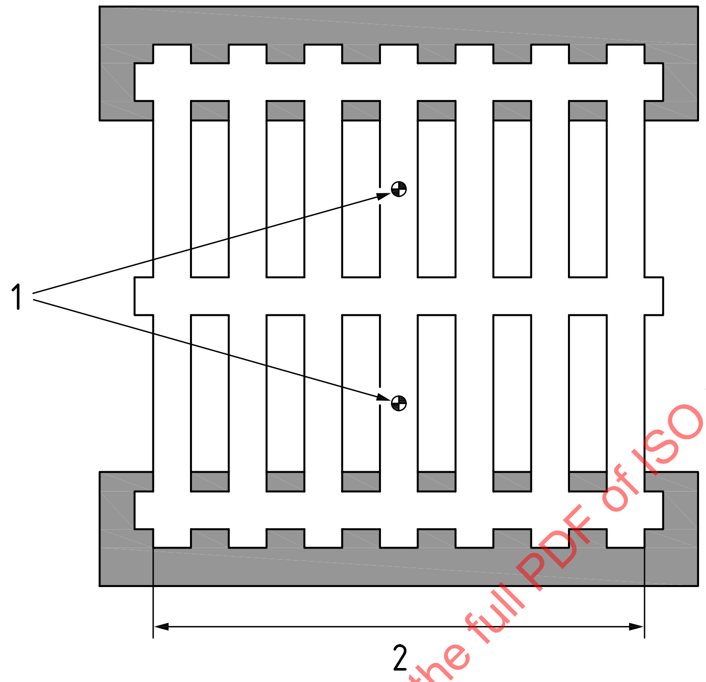
Prepare each finished test specimen to a nominal width of 200 mm ± 1 mm and of sufficient length to ensure 100 mm between the jaws, with the length dimension being designated and parallel to the direction in which the tensile force is applied. For some materials, the use of a cutting knife or scissors can affect the structure. In such cases, thermal cutting or other techniques can be used. If used, this shall be included in the test report (see Clause 10). For monitoring any slippage, and where appropriate, draw two lines at the edge of jaws running the full width of the test specimen jaw faces, perpendicular to the length dimension and separated by 100 mm [except for capstan grips, see Figure 3 b)].

6.4.2 Woven geotextiles, with each specimen cut approximately 220 mm wide and fringes made by removing an equal number of threads from each side to obtain the 200 mm ± 1 mm nominal specimen width.

This helps to maintain the specimen integrity during the test. When the specimen integrity is not affected, the specimens can be initially cut to the finished width.

6.4.3 Geogrids with tensile elements along one axis. The tensile test is carried out only in the direction of the tensile elements, either MD or CMD.

Prepare each specimen at least 200 mm wide and sufficiently long to ensure at least 100 mm between the jaws. Cut all ribs at least 10 mm from any node. Where the nodes are not separated by at least 10 mm, the specimens should be prepared two ribs wider than required for the test and, after clamping in the jaws, the outer rib on each side of the specimen should be severed. The test result (strength) shall be based on the unit of width associated with the number of intact ribs. The test specimen shall contain at least one row of nodes or cross-members, excluding the nodes of cross-members held in the jaws (see Figure 4). Products of pitch [i.e. the distance between the start of one rib (tensile element) and the start of the next rib] less than 75 mm shall contain at least four complete tensile elements (ribs) in the width direction. Products of pitch greater than 75 mm and less than 120 mm shall contain at least two complete tensile elements in the width direction. For products of pitch greater than 120 mm, single ribs may be tested.



Key

1 gauge marks for elongation measurement ≥60 mm

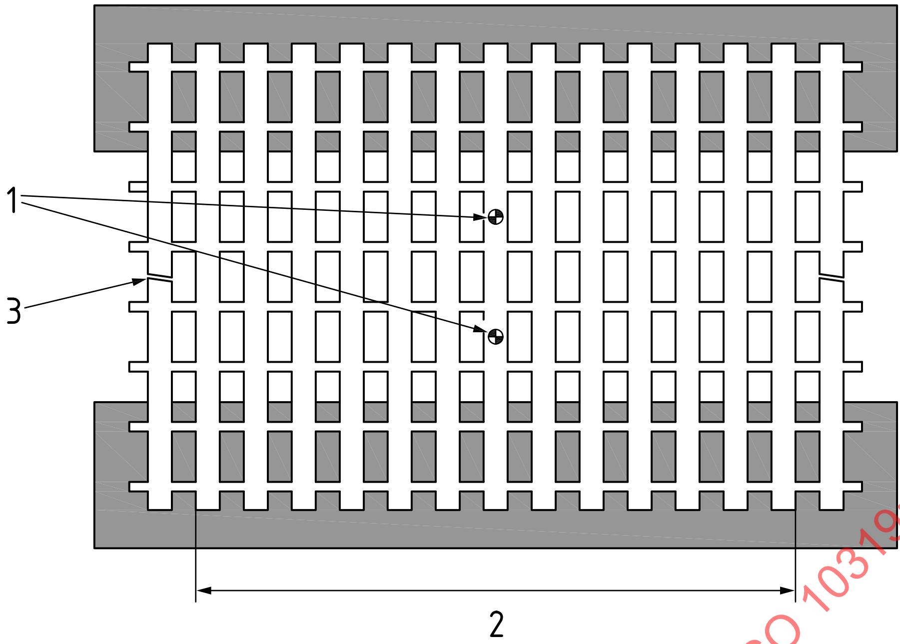
2 number of tensile elements, n_s

Figure 4 — Typical geogrid with tensile elements along one axis

The reference points for the extensometer shall be marked on a central row of tensile elements that will be subjected to testing and shall be at least 60 mm apart. The reference points shall be marked at the centre point of a rib and shall be separated by at least one node or cross-member. Where necessary, the two reference points may be separated by more than one row of nodes or cross-members, in order to achieve the minimum separation of 60 mm apart. In this case, the requirement to mark the reference points at mid-rib shall be maintained and the gauge length shall then be an integral number of pitches of the grid. Measure the nominal gauge length to an accuracy of ±1 mm.

6.4.4 Geogrids with tensile elements along two or four axes. The tensile test is carried out in both directions, MD and CMD.

Prepare each specimen at least 200 mm wide and sufficiently long to ensure at least 100 mm between the jaws. Cut all ribs at least 10 mm from any node. The test specimen shall contain at least one row of nodes or cross-members, excluding the nodes of cross-members held in the jaws (see Figure 5 and Figure 8).



Key

1 gauge marks for elongation measurement ≥60 mm

2 number of tensile elements, n_s

3 exterior elements cut before loading

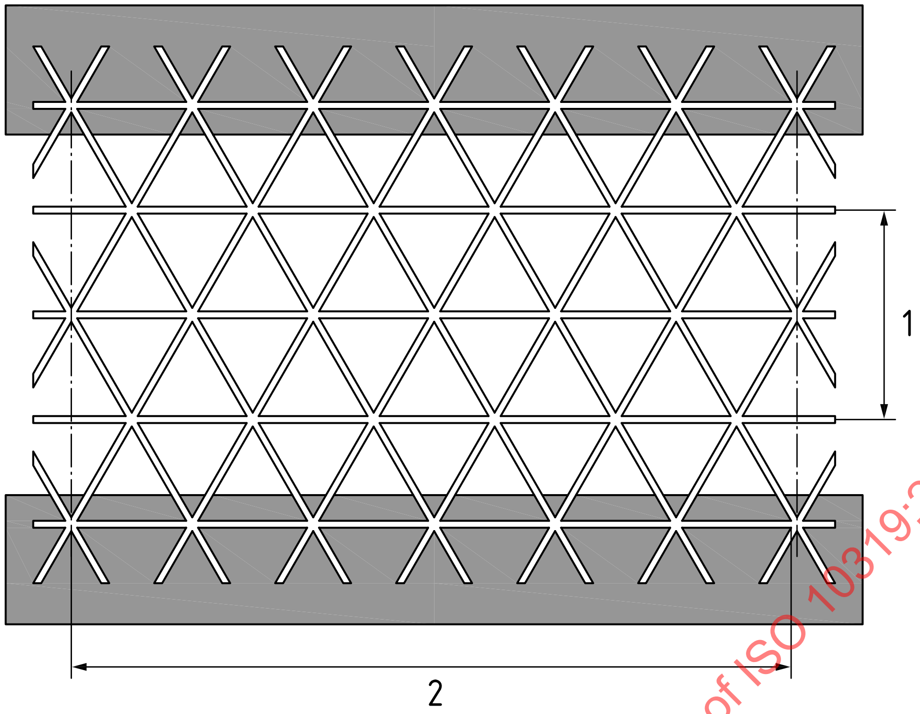
Figure 5 — Typical geogrid with tensile elements along two axes

Products of pitch less than 75 mm shall contain at least four complete tensile elements (ribs) in the width direction. Products of pitch greater than 75 mm and less than 120 mm shall contain at least two complete tensile elements in the width direction. For products of pitch greater than 120 mm, single ribs may be tested.

The reference points for the extensometer shall be marked on a central row of tensile elements that will be subjected to testing and shall be at least 60 mm apart. The reference points shall be marked at the centre point of a rib and shall be separated by at least one node or cross-member. Where necessary, the two reference points may be separated by more than one row of nodes or cross-members, in order to achieve the minimum separation of 60 mm apart. In this case, mark the reference points at mid-rib or on nodes and the gauge length shall then be an integral number of pitches of the grid. Measure the nominal gauge length to an accuracy of ±1 mm.

6.4.5 Geogrids with tensile elements along three axes. The tensile test is carried out in both directions, MD and CMD, but not in diagonal directions.

Prepare each specimen at least 200 mm wide and sufficiently long to ensure at least 100 mm between the jaws. The specimens are cut and the width of the specimen is measured as shown in Figure 6 and Figure 7.

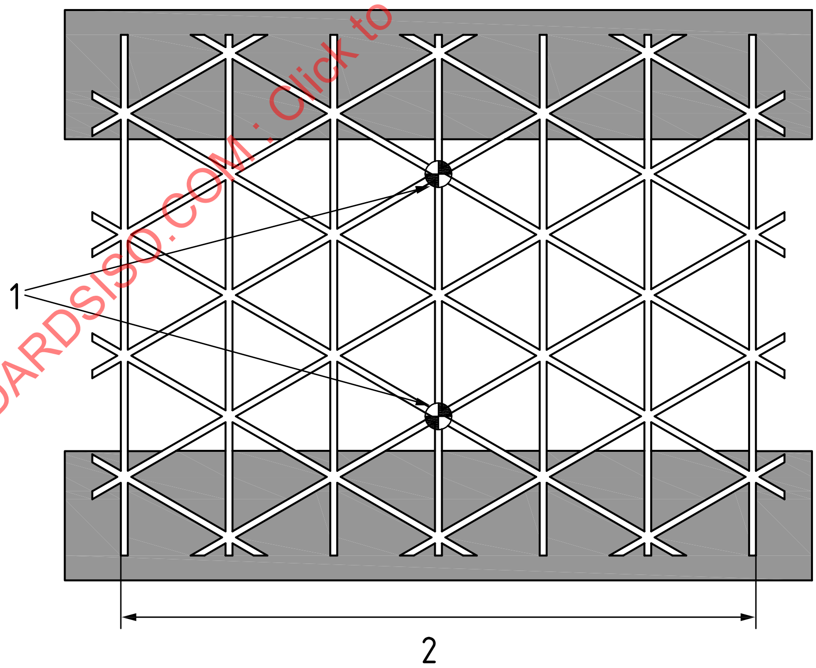


Key

1 gauge marks for elongation measurement ≥60 mm

2 width in mm ≥ 200 mm

Figure 6 — Example of geogrid with tensile elements along three axes, specimen size, widths and gauge length MD



Key

1 gauge marks for elongation measurement ≥60 mm

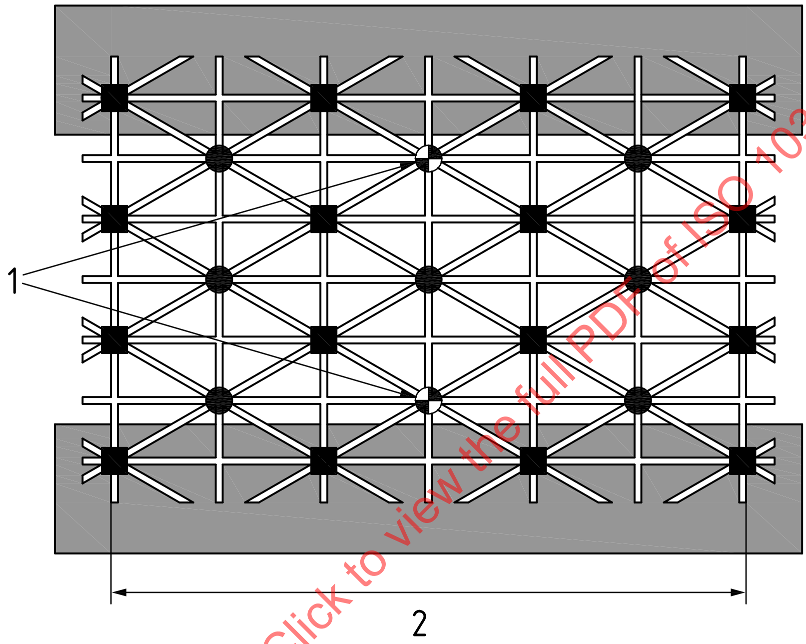
2 number of tensile elements, n_s

Figure 7 — Example of geogrid with tensile elements along three axes, specimen size, width and gauge length CMD

The reference points for the extensometer shall be marked at the centre point of a node and shall be separated by at least one node or cross-member. Where necessary, the two reference points may be separated by more than one row of nodes or cross-members, in order to achieve the minimum separation of 60 mm apart. In this case, the requirement to mark the reference points at mid-rib shall be maintained and the gauge length shall then be an integral number of pitches of the grid. Measure the nominal gauge length to an accuracy of ±1 mm.

6.4.6 Woven steel wire mesh products. The sample shall be tested in accordance with EN 10223-3, except for the extension, which shall be measured using an extensometer.

The reference points for the extensometer shall be marked at the centre point of the double twists and shall be separated by a distance of at least 60 mm. Measure the nominal gauge length to an accuracy of ±1 mm (see Figure 9).

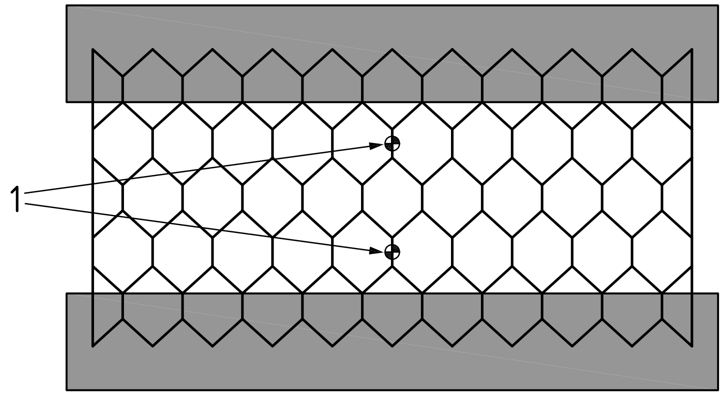


Key

1 gauge marks for elongation measurement >60 mm

2 number of tensile elements, n_s

Figure 8 — Example of geogrid with tensile elements along four axes, specimen size, width and gauge length, MD and CMD



Key

1 gauge marks for elongation measurement at distance ≥ 60 mm

Figure 9 — Typical woven steel wire mesh specimen mounted in clamps

6.4.7 Products narrower than 200 mm. For geostrips, prefabricated vertical drains, single strips of geocells and any other geosynthetic produced with a narrower width than 200 mm, prepare each specimen to full width and of sufficient length to ensure 100 mm between the jaws, with the length dimension being designated and parallel to the direction in which the tensile force is applied.

Specimens of single strips of geocells shall be cut is such a way that no junction is located between the clamps.

6.4.8 Width for seam and joint strength test

When the test is used as a reference test for the seam and joint strength test, as specified in ISO 10321, the specimen width shall be the same for both sets of tests (with and without the seam or joint in the middle).

6.4.9 Testing wet specimen

When the values of both the wet tensile strength and the dry tensile strength are required, cut each test specimen to at least twice as long as is typically required. Number each test specimen and then cut each specimen crosswise into two halves, one for determining the dry tensile strength, and the other for determining the wet tensile strength. Each portion shall be marked with the specimen number. Thus, each paired break is performed on a test specimen containing the same threads.

For geosynthetics which shrink excessively when wet, the tensile strength shall be determined from the maximum tensile force, in wet conditions, and the initial width shall be measured to an accuracy of ±1 mm, after conditioning but before wetting (see Clause 7).

7 Conditioning atmosphere

7.1 General

The test specimens shall be conditioned and tested in the standard atmosphere for testing (20 ± 2 °C) at (65 ± 5 % RH) as specified in ISO 554.

Specimens are considered conditioned when the change in mass in successive weighing made at intervals of not less than 2 h does not exceed 0,25 % of the mass of the test specimen.

Conditioning or testing, or both, in a standard atmosphere may be omitted when it can be shown that results obtained for the same specific type of product (both structure and polymer type) are not affected by changes in temperature and humidity exceeding the limits. This information shall be included in the test report.

7.2 Conditioning for testing in wet condition

Specimens to be tested in wet condition shall be immersed in distilled water maintained at a temperature of (20 ± 2) °C. The time of immersion shall be at least 24 h and shall be sufficient to wet the test specimens thoroughly, as indicated by no significant change in maximum force or strain following a longer period of immersion. To obtain thorough wetting, it can be necessary to add up to a maximum of 0,05 % of a non-ionic neutral wetting agent (see Clause 5) to the water.

7.3 Conditioning for testing at lower or higher temperatures

When the tensile test is required at lower or higher temperatures, the procedure in Annex A shall be followed.

8 Test procedure

8.1 Setting up the tensile testing machine

Adjust the distance between the jaws at the start of the test to (100 ± 3) mm, except for geosynthetics mounted on capstan grips and for geogrids. Select the force range of the testing machine such that the break can be measured to an accuracy of 10 N.

For geosynthetics with a strain ε_{max} in excess of 5 %, set the machine at a constant cross-head speed so as to induce a strain rate of (20 ± 5) % per minute in the gauge length.

For geosynthetics with a strain less than or equal to 5 %, select a constant cross-head speed such that the average time to break of the test specimens is 30 ± 5 s.

For wet specimens, carry out the test within 3 minutes of removal from the water.

If capstan grips are used, the separation between the centres of the capstans at the beginning of each test shall be kept to a minimum, or for geogrids to a representative length. The use of capstan grips and the distance between the centres of the capstans shall be recorded in the test report.

8.2 Insertion of the test specimen in the jaws

Mount the test specimen centrally in the jaws. Ensure that, in both the MD and CMD tests, the specimen length is parallel to the direction of the force applied. Where appropriate, do this by having the two lines, which were previously drawn 100 mm apart across the width of the test specimen (see 6.4.1), positioned as closely as possible adjacent to the inside edges of the jaws.

8.3 Installation of the extensometer

Fix the gauge marks on the specimen 60 mm apart (30 mm on each side of the symmetry centre of the specimen) and set the extensometer. For all geogrids, see Clause 6. If a contacting extensometer is used, no damage shall be caused to the specimen. Also ensure that there is no slippage of the reference points during the test.

8.4 Measurement of tensile properties

Start the tensile testing machine and apply a pre-tension force of 1 % of the estimated maximum tensile force to define the starting point for the measurement of strain; continue running until the specimen ruptures. Stop the machine, record and report the maximum tensile force to the nearest 10 N and strain to the first decimal place; reset to the initial gauge position.

Only nonwoven geotextiles shall be tested without any pre-tension force. The decision to discard the results from a specimen shall be based on observation of the specimen during the test, on the inherent variability of the geosynthetic and on the provision of 6.2. In the absence of other criteria for rejecting a jaw break, any break occurring within 5 mm of the jaws, which results in a value below 50 % of the average value of all other breaks, shall be discarded. No other break results shall be discarded, unless the test is proven to be faulty.

It is difficult to determine the precise reason why certain specimens break near the edge of the jaws. If a jaw break is caused by damage to the test specimen by the jaws, the results should be discarded. If, however, it is merely due to randomly distributed weaknesses in the test specimen, it is a legitimate result. In some cases, it can also be caused by a concentration of stress in the area adjacent to the jaws because they prevent the test specimen from contracting in width as the load is applied. In these cases, a break near the edge of the jaws is inevitable and should be accepted as a characteristic of the particular method of test.

Special procedures are required for the testing of specimens made from specific materials (e.g. glass fibre or carbon fibre) to minimize any damage that can be caused by the jaws. If a test specimen slips in the jaws, or if more than one quarter of the specimens break at a point within 5 mm of the edge of the jaw, then:

a) the jaws may be padded;

b) the test specimen may be coated under the jaw-face area; or

c) the jaw face may be modified.

If any of these modifications listed are used, state the method of modification in the test report.

8.5 Measurement of strain

Strain is the increase in true gauge length, L_0, (nominal gauge length plus the increase in gauge length at pre-tension force) of a specimen during the test, expressed as a percentage of the true gauge length (see Figure 1).

Measure the length of the test specimen between the two reference points at any specified tensile force by means of an extensometer and calculate the strain using Formulae (1) and (2).

9 Calculations

9.1 Strain

Calculate the tensile strain, ε_x, expressed in per cent, at any point X during the test, directly from the measurement of the distance L_x between the two reference points obtained from the extensometer (see Figure 1), using Formulae (1) and (2).

$$L_0 = L_n + \Delta L_p \quad (1)$$

$$\varepsilon_x = 100 \cdot (L_x - L_0)/L_0 \quad (2)$$

where

L_n is the initial gauge length (mm);

L_0 is the true gauge length (mm);

ΔL_p is the elongation at pre-tension force (mm);

L_x is the length measured at generic point X (mm);

ε_x is the tensile strain at generic point X (per cent).

9.2 Tensile strength

Calculate the tensile strength, T_x, expressed in kilonewtons per metre (kN/m), at any point X during the test, directly from the data obtained from the tensile testing machine (see Figure 1), using Formula (3).

$$T_x = F_x \cdot c \qquad (3)$$

where

F_x is the recorded tensile force, in kilonewtons (kN);

c is obtained from Formula (5), Formula (6) or Formula (7), as appropriate.

Plot the F–ε curve as shown in Figure 1, and the T–ε curve as shown in Figure 2. If curve fitting is applied, the measured point shall also be plotted.

Calculate the tensile strength, T_{max}, expressed in kilonewtons per metre (kN/m), directly from the data obtained from the tensile testing machine (see Figure 1), using Formula (4).

$$T_{max} = F_{max} \cdot c \qquad (4)$$

where

F_{max} is the recorded maximum tensile force, in kilonewtons (kN);

c is obtained from Formula (5), Formula (6) or Formula (7), as appropriate.

Record the strength in kN/m to the nearest 0,01 kN/m.

Record the force in kN to the nearest 0,01 kN.

For woven, knitted and nonwoven geotextiles, geonets, geomats, clay geosynthetic barriers, geocomposites and any other product wider than 200 mm and without an open structure:

$$c = 1/B \qquad (5)$$

where B is the nominal width of the specimen, in metres.

For geogrids with one axis, two axes, three axis and four axes (see Figures 4 to 8):

$$c = N_m/n_s \qquad (6)$$

where

N_m is the average number of tensile elements within a 1 m width of the product being tested;

n_s is the number of tensile elements within the test specimen.

For geostrips, prefabricated vertical drains, single strips of geocells and other products narrower than 200 mm:

$$c = N_d \qquad (7)$$

where N_d is the average number of tensile elements within a 1 m width of the product being tested, according to manufacturer or design specification

For woven steel wire mesh products, the tensile strength and strain is obtained in accordance with EN 10223-3.