



**International
Standard**

ISO 12957-2

**Geosynthetics — Determination of
friction characteristics —**

**Part 2:
Inclined plane test**

*Géosynthétiques — Détermination des caractéristiques de
frottement —*

Partie 2: Essai sur plan incliné

**Second edition
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Foreword

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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).

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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 second edition cancels and replaces the first edition (ISO 12957-2:2005) which has been technically revised.

The main changes are as follows:

- minor modifications, notably in the terms and definitions;
- improvement of figures.

A list of all parts in the ISO 12957 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.

Geosynthetics — Determination of friction characteristics —

Part 2: Inclined plane test

1 Scope

This document specifies a method to determine the friction characteristics of geosynthetics (geotextiles and geotextile-related products, geosynthetic barriers) in contact with soils or another geosynthetic, at low normal stress, using an inclining plane apparatus.

This test method is primarily intended as a performance test to be used with site specific soils but is also used as an index test with standard sand. It is also possible to measure the displacement of the interface over time (creep phenomenon) without necessarily reaching the slippage failure.

NOTE Test data obtained for geogrids tested with a rigid support are not necessarily realistic as the results depend on the friction support.

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 6344-2, *Coated abrasives — Determination and designation of grain size distribution — Part 2: Macrogrit sizes P12 to P220*

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

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

3 Terms and definitions

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

normal force

N

constant vertical force applied to the specimen

Note 1 to entry: Normal force is expressed in newtons (N).

Note 2 to entry: Normal force is calculated from, firstly, the mass of materials, *W*, expressed in kilograms (kg), which is applied onto the contact area of the specimen, and secondly, the acceleration of gravity, *g*, expressed in metres per second squared (m/s²), whose value is taken equal to 9,81 m.s⁻².

3.2

normal stress

σ_n
normal force (3.1) divided by the specimen area that supports the weight of the materials applied onto it (contact area)

Note 1 to entry: The normal stress is expressed in kilopascals (kPa).

Note 2 to entry: The normal stress with the plane in horizontal position is noted $\sigma_{n,0}$ and the calculated normal stress at slippage failure at *angle of slipping* (3.4) β is noted $\sigma_{n,\beta}$.

3.3

angle of friction

φ
angle of the tested interface defined as the average of the values recorded in the test

Note 1 to entry: The angle of friction is expressed in degrees (°).

Note 2 to entry: The angle of friction between soil and geosynthetic is noted $\varphi_{s,GSY}$ and the angle of friction between geosynthetic and geosynthetic is noted $\varphi_{GSY,GSY}$.

3.4

angle of slipping

β
angle between the plane and an horizontal line at which the box's displacement attains 50 mm

Note 1 to entry: The angle of slipping is expressed in degrees (°).

3.5

force to restrain the empty upper box

$fr(\beta)$
force required to restrain the empty upper box, supported by rails, when the plane is inclined at the *angle of slipping* (3.4) β

Note 1 to entry: The force to restrain the empty upper box is expressed in newton (N).

3.6

shear stress

τ
shear force along the sand, soil or other geosynthetic or geosynthetic interface, divided by the contact area of the specimen

Note 1 to entry: The shear stress is expressed in kilopascal (kPa).

4 Principle

The angle of friction is determined by measuring the angle at which a soil filled box (with possible additional weights) slides when the base supporting the geosynthetic is gradually inclined at a constant speed.

NOTE Variations to the test described in this document are used to measure friction properties of geosynthetics in non-standard conditions, e.g.:

- a second layer of geosynthetic is fitted in the upper part of the shear box to measure geosynthetic on geosynthetic friction;
- normal pressures different from the standard values are applied to simulate actual site conditions;
- the test method is also used to measure the displacement of the interface over time (creep phenomenon) without necessarily reaching the slippage failure. In this case, the test does not give a measurement of the angle of friction as depicted in this document.

5 Test specimens

5.1 Sampling and preparation of test specimen

Sampling and preparation of test specimens shall be made in accordance with ISO 9862.

5.2 Number and dimensions of test specimens

Cut three specimens from the test sample, for each direction to be tested. The size of the specimens shall suit the dimensions of the apparatus.

If the two faces of the sample are different, both faces shall be tested. Three specimens shall be tested for each face.

6 Conditioning

Condition the test specimens and conduct the tests in the standard atmosphere for testing, in accordance with ISO 554, i.e. at a relative humidity of $(65 \pm 2) \%$ and a temperature of $(20 \pm 2) ^\circ\text{C}$ until the change in mass between two successive readings made at intervals of not less than two hours does not exceed 0,25 % of the mass of the test specimens.

NOTE Conditioning or testing, or both, at a specified relative humidity are omitted if it is shown that the results are not affected by this omission.

7 Apparatus

7.1 General

Two types of apparatus are possible, one with the upper box supported by rollers, the other without support of the box. A diagrammatic representation of suitable equipment is shown in [Figures 1, 2, 3 and 4](#). [Figures 1 and 2](#) illustrate an apparatus with a rigid support for the geosynthetic. [Figure 3](#) illustrates an apparatus in which the geosynthetic is supported by a lower box filled with soil. [Figure 4](#) gives the minimum dimensions of the upper sliding box to be used with both methods.

7.2 Rigid base apparatus

7.2.1 Rigid base

The inclined plane apparatus consists of a rigid smooth plate hinged at one end ([Figures 1 and 2](#)). The rigid plate has a minimum length of 350 mm and a minimum width of 300 mm. The apparatus shall be fitted with a mechanism which allows the plane to be raised smoothly at a rate of $(3 \pm 0,5) ^\circ/\text{min}$. The inclined plane apparatus shall be horizontal in all directions at the start of each test. Spirit levels shall be fitted to allow checking of the inclination before each test.

The mechanism used to raise the inclined plane shall be fitted with a trip-switch which will automatically stop the raising of the plane when the displacement of the upper soil filled box exceeds 50 mm.

The inclined plane apparatus shall be fitted with an angle measurement system which enables measurement of the inclination angle of the plane to the horizontal with a precision of $\pm 0,5^\circ$.

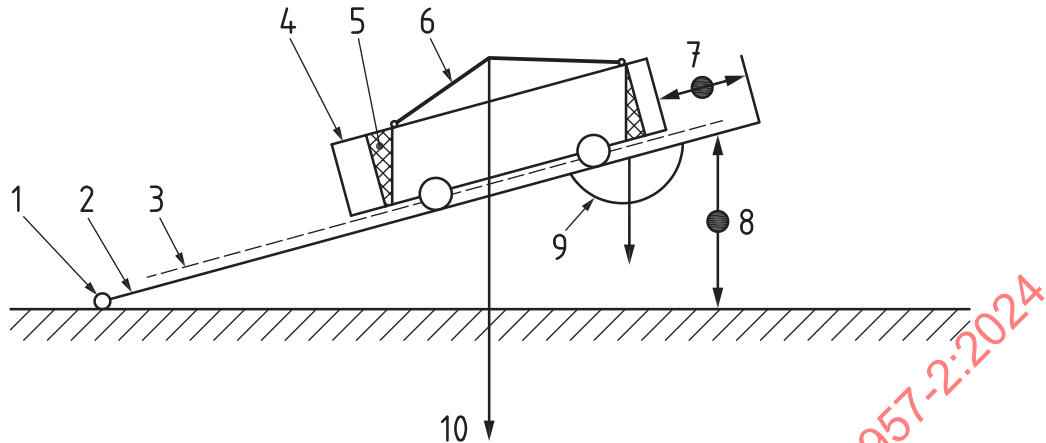
The geosynthetic shall be fixed to the inclined plane apparatus to limit any relative displacement between the geosynthetic and the plane.

NOTE This is obtained by one of the following techniques:

- stitching or gluing;
- use of a rough high friction support;

— anchoring the geosynthetic outside the contact area.

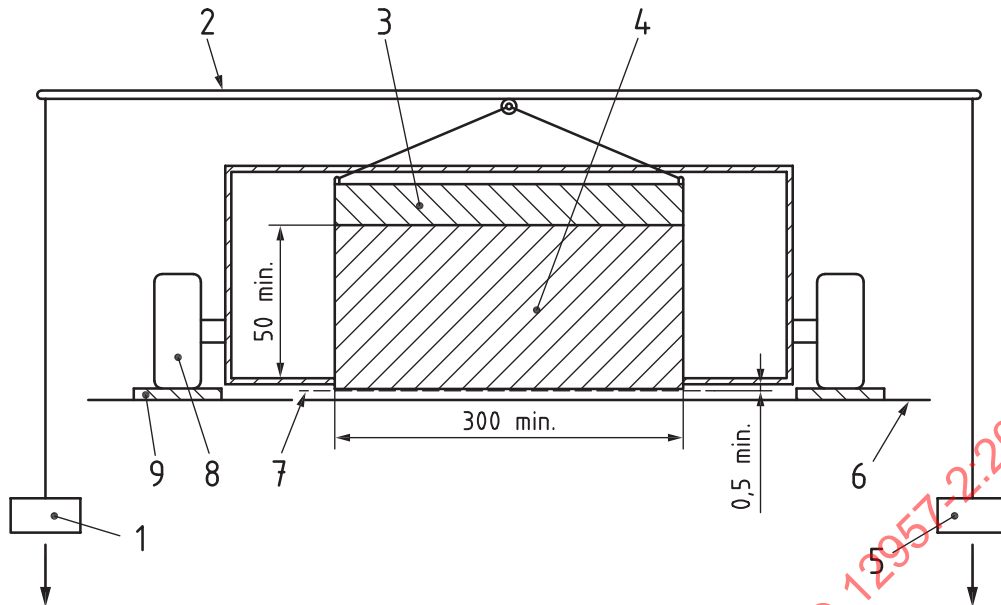
For geogrids and geotextiles with open structures, the support used shall be either soil or an emery cloth abrasant P 100 in accordance with ISO 6344-2 (in case of testing with a rigid support).



Key

- 1 pivot
- 2 rigid base
- 3 specimen
- 4 soil box supported on rollers
- 5 wedges inside box to ensure correct alignment or normal force (wedges 1 on 2)
- 6 loading frame for normal load
- 7 displacement gauge and trip switch
- 8 lifting device
- 9 inclination measurement device
- 10 load

Figure 1 — Inclined plane test

**Key**

- 1 load
- 2 loading frame for normal load
- 3 normal load distribution pack
- 4 soil
- 5 load
- 6 rigid lower tilting base
- 7 specimen
- 8 adjustable or fixed rollers
- 9 runners

NOTE "min." means minimum.

Figure 2 — Cross-section of a typical test apparatus

7.2.2 Upper soil box

The upper soil box shall be of rigid construction with the following minimum internal dimensions ([Figure 4](#)):

- length: 300 mm;
- width: 300 mm;
- depth: soil depth $H_s > 7 \times D'_{max} > 50$ mm, where:
 - H_s : depth of soil in the box, in millimetres;
 - D'_{max} : maximum particle size of soil being used in the test, in millimetres.

When testing geogrids, the minimum size of the apparatus shall be such that not less than two full ribs and three full longitudinal members are contained within the area of the box.

In addition, the upper box shall be able to accommodate a system of weights possibly used to apply the normal load to the soil. The upper box shall assure that the line of action of the normal force passes through

the centre of gravity of the upper box when the apparatus is tilted, e.g. by wedges or inclinable walls. The standard shall be set at an angle of 27°.

NOTE Other angles are used for interfaces with an angle β significantly outside the range of 20° to 35°.

The upper box may be fitted with rollers which bear on runners set outside of the geosynthetic specimen. In this case, the inside of the upper box shall be lined with smooth steel or a low friction surface to reduce friction between the soil and the sides of the box. In the case where the upper box is not fitted with rollers, shims shall be used to ensure a gap between the geosynthetic and the box; the shims are removed prior to inclining the apparatus. When shims are used, the friction between the soil and the upper box shall be sufficient to prevent the upper box from settling onto the specimen during the test. The gap between the base of the upper box and the geosynthetic shall be adjustable or set so that the upper box does not bear upon the specimen. The gap shall be between 0,5 mm and 1,5 mm to minimize the loss of soil during the test. The displacement of the upper box shall be measured during the test to a precision of $\pm 0,05$ mm. Displacement readings shall be taken at intervals not exceeding 30 s.

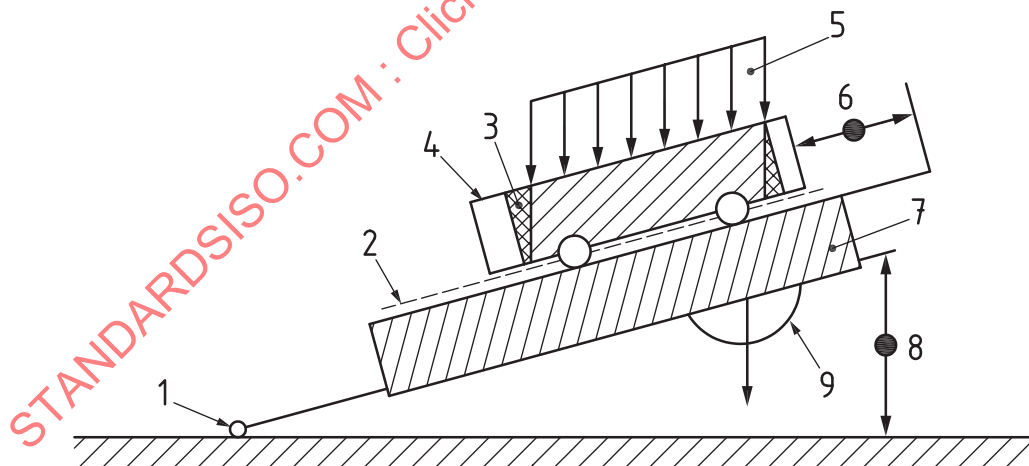
7.3 Soil filled base apparatus

7.3.1 Lower soil box

The lower box filled with soil (Figure 3) shall be a rigid box with the following minimum internal dimensions:

- length: 400 mm;
- width: 325 mm;
- depth: $H_s > 7 \times D_{\max} > 50$ mm, where:
 - H_s : depth of soil in the box, in millimetres;
 - $D_{\max}$: maximum particle size of soil being used in the test, in millimetres.

The inclined plane apparatus shall be fitted with an angle measurement system which enables measurement of the inclination angle of the lower soil box to the horizontal with a precision of $\pm 0,5^\circ$.

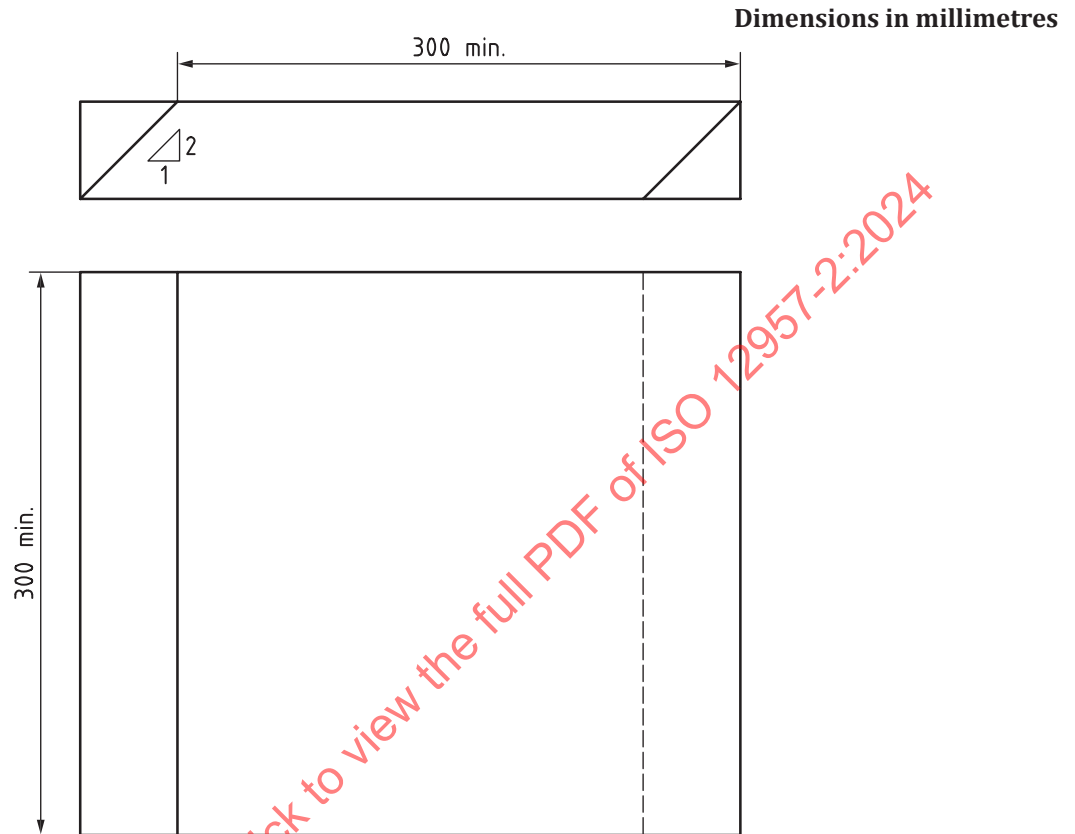


Key

- 1 pivot point
- 2 specimen
- 3 internal wedges (set 1 on 2)
- 4 upper box supported on rollers or with a 0,5 mm air gap
- 5 load to give required normal stress
- 6 displacement gauge and trip switch

- 7 soil filled lower box
- 8 lifting device
- 9 inclination gauge

Figure 3 — Inclined plane test with a soil filled lower box



NOTE "min." means minimum.

Figure 4 — Dimensions of the upper shear box

7.3.2 Upper soil box

See [7.2.2](#).

7.4 Application of the normal force (for both types of apparatus)

The normal force shall be applied by any method ensuring an even distribution of the pressure over the tested area of the specimen (contact area).

NOTE A rigid steel plate covering the tested area or a fluid filled soft membrane are adequate solutions to obtain an even pressure distribution.

If the upper box is not supported on rollers, the weight of the upper box and the soil shall be included in the calculation of normal stress. It shall be ensured that the box makes no contact with the base.

The normal force applied shall be such that the normal stress is $(5 \pm 0,1)$ kPa.

The normal stress shall be measured to a precision of ± 2 %.

7.5 Soil

Soil from the site shall be used to fill the apparatus or, alternatively, shall be selected by the parties involved. The preparation and compaction of the soil shall be agreed before the start of the tests.

In the case where the test is carried out with a standard sand, the sand shall be a natural siliceous sand, consisting preferably of rounded particles and with a silica content of at least 98 %. The moisture content, determined as the loss of mass after 2 h drying at 105 °C, shall be less than 0,2 %, expressed as a percentage by mass of the dried sample (see also [Table 1](#)).

Table 1 — Grading of standard sand

Sieve size mm	Cumulative sieve residue %
2,00	0
1,60	7 ± 5
1,00	33 ± 5
0,50	67 ± 5
0,16	87 ± 5
0,08	99 ± 1

If a visual check indicates the probability of fine particles lost during the test, the grading shall be checked before reusing the sand. The amount of sand entrapped shall be determined by reweighing the specimen and reported.

7.6 Calibration of the apparatus

When using the apparatus with the upper box supported on rollers, the apparatus shall be calibrated prior to carrying out a set of tests on a sample. To ensure that roller friction is not significant, the empty upper box shall start to move when the plane is raised to an angle not exceeding 5°.

The force to restrain the empty upper box shall be measured in the range of 10° to 45° with 5° increments of the inclined plane. The recorded values shall be used to determine the value of $f_r(\beta)$ for the individual calculations of the angle of friction φ .

8 Procedure

The specimen shall be flat, free from folds and wrinkles.

Assemble the apparatus. Fix the specimen to the rigid inclined plane or fill the lower box with soil compacted in accordance with the agreed procedure. Fix or lay one of the specimens on the base or on the soil in the lower box.

Assemble the upper soil box and align the box in the starting position.

Fill the upper box with the required soil to a compacted thickness of not less than 50 mm. If standard sand is being used, the sand shall be compacted to a density of 1 750 kg/m³.

Assemble the loading devices, the displacement measuring devices (transducers or dial gauges) and the automatic trip device. Apply the normal force selected to give the required normal stress of 5 kPa.

Incline the plane at the specified rate and record the angle at which the automatic trip device stops the test. [Figure 5](#) shows a typical graph.

It is also possible to measure the displacement at a given angle of inclination. To do so, incline the plane at the specified rate and maintain the plane at the specified angle of inclination. Record the displacement of the upper box during the whole specified period.

Dismantle the apparatus, remove the specimen and record any signs of damage.