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Geosynthetics — Determination of friction characteristics —

Part 2: **Inclined plane test**

Géosynthétiques — Détermination des caractéristiques de frottement —

Partie 2: Essai sur plan incliné

Reference number
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Foreword

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ISO 12957-2 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 221, *Geosynthetics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

ISO 12957 consists of the following parts, under the general title *Geosynthetics — Determination of friction characteristics*:

— *Part 1: Direct shear test*

— *Part 2: Inclined plane test*

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Foreword

This document (EN ISO 12957-2:2005) has been prepared by Technical Committee CEN/TC 189 “Geosynthetics", the secretariat of which is held by IBN, in collaboration with Technical Committee ISO/TC 221 “Geosynthetics".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2005, and conflicting national standards shall be withdrawn at the latest by August 2005.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

This document describes a method to determine the friction characteristics of geosynthetics (geotextiles and geotextile-related products, geosynthetic barriers), in contact with soils, 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 may also be used as an index test with standard sand.

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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 554, *Standard atmospheres for conditioning and/or testing – Specifications.*

ISO 6344-2, *Coated abrasives – Grain size analysis – Part 2: Determination of grain size distribution of macrogrits P 12 to P 220.*

ISO 9862, *Geotextiles – Sampling and preparation of test specimens.*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
normal stress ($\sigma_{n,o}$)
normal force (N) divided by the area of the specimen, in kilopascals

$\sigma_{n,o}$ indicates the normal stress with the table in horizontal position; $\sigma_{n,calc}$ indicates the calculated normal stress at slippage failure with angle of slipping (β).

3.2
angle of friction (ϕ_{gp})
angle of friction between geosynthetic and soil, in degrees, defined as the average of the values recorded in the test

3.3
angle of slipping (β)
angle, in degrees, at which the box's displacement attains 50 mm

4 Principle

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

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

a) a second layer of geosynthetic can be fitted in the upper part of the shear box to measure geosynthetic on geomembrane friction;

b) normal pressures different from the standard values can be applied to simulate actual site conditions.

5 Test specimens

5.1 Sampling

Take specimens 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, defined in ISO 554, i.e. at a relative humidity of (65 ± 2) % and a temperature of (20 ± 2) °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 and/or testing at a specified relative humidity may be ommitted if it can be 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 (see Figures 1 and 2)

7.2.1 Rigid base

The inclined plane apparatus consists of a rigid smooth plate hinged at one end. The apparatus shall be fitted with a mechanism which allows the plane to be raised smoothly at a rate of (3 ± 0,5) degrees per minute. 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 table 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 allows to measure the inclination angle of the table to the horizontal with a precision of ± 0,5 degrees.

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

NOTE This may be 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 abradant P 100 according to ISO 6344-2 (in case of testing with a rigid support).

7.2.2 Upper soil box (see Figure 4)

The upper soil box shall be of rigid construction with the following minimum internal dimensions:

- 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 degrees.

NOTE Other angles may be used for geosynthetics with an angle β significantly outside the range of 20 degrees to 35 degrees.

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 ± 0,05 mm. Displacement readings shall be taken at intervals not exceeding 30 s.

7.3 Soil filled base apparatus (Figure 3)

7.3.1 Lower soil box

The lower box 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 allows to measure the inclination angle of the lower soil box to the horizontal with a precision of ± 0,5 degrees.

7.3.2 Upper soil box (see Figure 4)

The upper box shall be a rigid box with the following minimum internal dimensions:

- length: 300 mm;
- width: 300 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.

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 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 inclined (e.g. by wedges or inclinable walls). The standard shall be set at an angle of 27 degrees.

NOTE Other angles may be used for geosynthetics which exhibit an angle of slipping (β) significantly outside the range of 20 degrees to 35 degrees.

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 foreseen 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 inside the range of 0,5 mm to 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 ± 0,05 mm. Displacement readings shall be taken at intervals not exceeding 30 s.

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 whole area of the specimen.

NOTE A rigid steel plate covering the whole 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 ± 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 (in mm)	Cumulative sieve residue (in %)
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 table is raised to an angle not exceeding 5 degrees.

The force to restrain the empty upper box shall be measured in the range of 10 degrees to 45 degrees with 5 degree 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_{gp}).

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.

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

Repeat the test using the other specimens at the same normal stress. Use a new specimen for each test. New specimens shall also be used for testing the other side or another direction of the material.

9 Calculations

9.1 Apparatus with a roller supported upper box

Calculate the normal stress (σ_n) as:

$$\sigma_{n,\beta} = \frac{9{,}81\,W \cos\beta}{1000\,A}$$

where

$\sigma_{n,\beta}$ = normal stress at inclination β, in kPa;

W = mass of the soil, additional weights and any part of the upper box not supported on rollers, in kilograms;

A = area, in square metres;

β = slipping angle of the upper box, in degrees.

Calculate the shear stress (τ) as:

$$\tau = \frac{\left(9{,}81\left(W \sin\beta + f_{r(\beta)}\right)\right)}{1000\,A}$$

where

τ = shear stress, in kPa;

W = mass of soil, additional weights and any part of the upper box not supported on rollers, in kilograms;

β = slipping angle of the upper box, in degrees;

$f_{r(\beta)}$ = the force required to restrain the empty upper box when the table is inclined at an angle ß;

A = contact area, in square metres.

Calculate the angle of friction (ϕ_{gp}) as:

$$\tan\varphi_{gp} = \frac{\tau}{\sigma_{n,\beta}}$$

where

τ = shear stress, in kPa;

$\sigma_{n,\beta}$ = normal stress at inclination β, in kPa;

9.2 Apparatus with an upper box not supported on rollers

The slipping angle (β) is equal to the angle of friction (ϕ_{gp}).

Calculate the normal stress (σ_n) as:

$$\sigma_{n,\beta} = \frac{9{,}81\, W \cos \beta}{1000\, A}$$

where

$\sigma_{n,\beta}$ = normal stress at inclination β, in kPa;

W = mass of soil, of additional weights and of the upper box, in kilograms;

β = slipping angle, in degrees;

A = contact area, in square metres.

10 Test Report

The test report shall include following information:

a) number and date of this document;

b) identification of the sample, date of receipt and date of testing;

c) conditioning atmosphere;

d) temperature at which the test was carried out;

e) orientation (machine or cross machine direction, top or bottom side), of the specimens during the test;

f) type of soil used, the method of soil preparation, the density in use and the moisture content;

g) initial normal stress ($\sigma_{n,o}$) and the normal stress at slippage ($\sigma_{n,\beta}$);

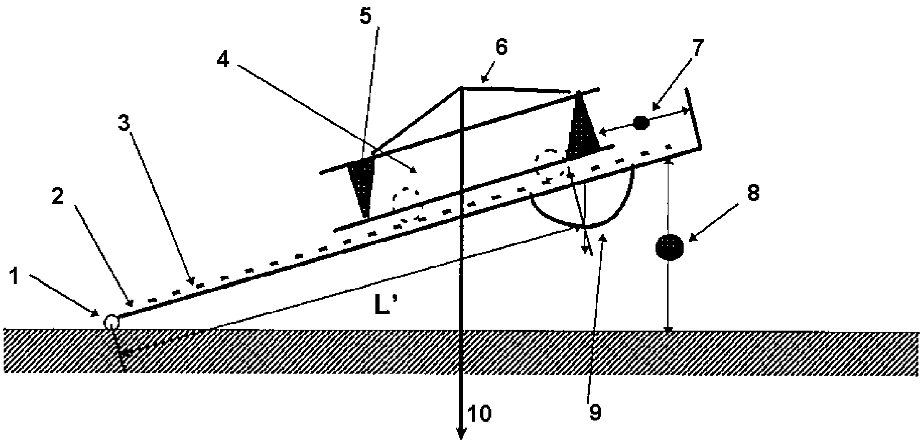
h) mean angle of friction for the soil geosynthetic interface (ϕ_{gp});

i) method of testing used (rigid lower table or soil filled lower box)

j) a displacement versus inclination graph;

k) observations of any damage or unusual behaviour;

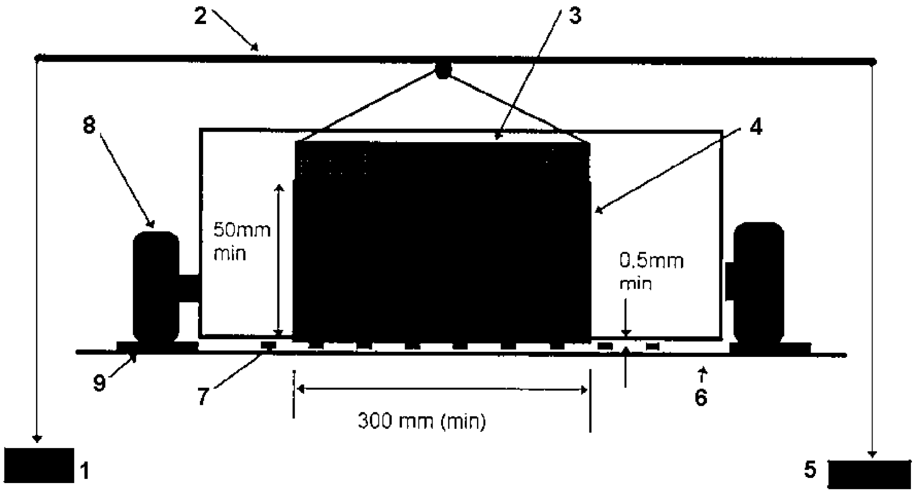
l) any deviation from this procedure.



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

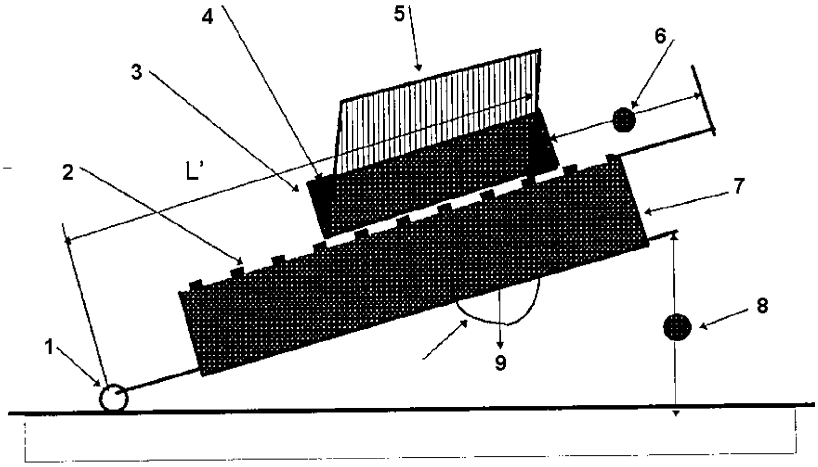
Figure 1 - Inclined plane test



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

Figure 2 - Cross-section of a typical test apparatus



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 with trip switch
7	Soil filled lower box
8	Lifting device
9	Inclination gauge

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

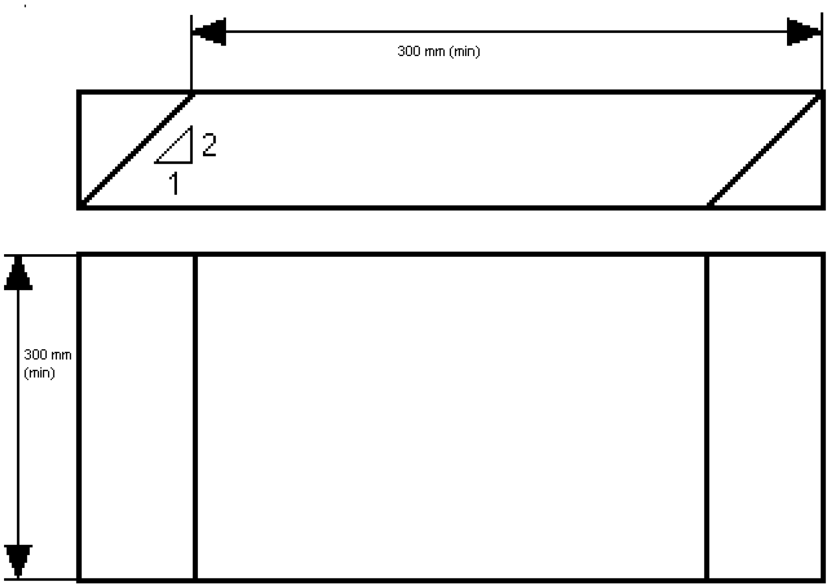
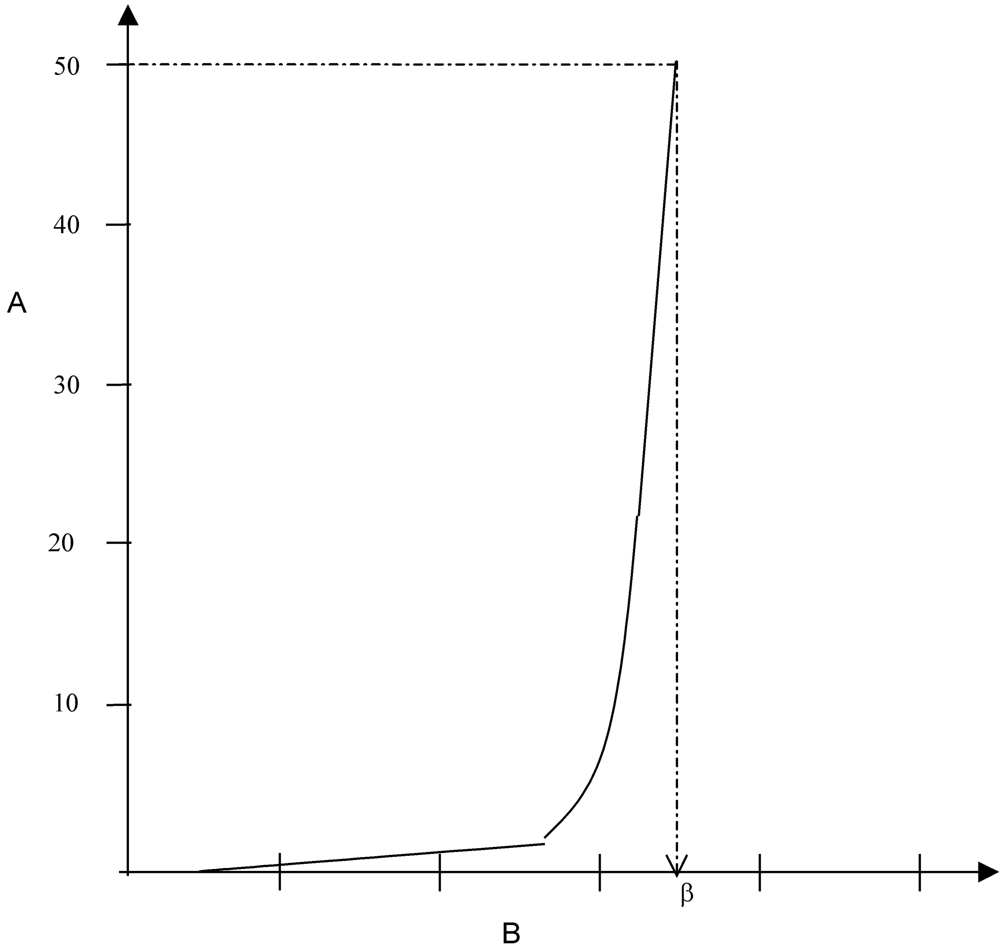


Figure 4 - Dimensions of the upper shear box



Key

A Displacement (mm)

B Angle of inclination (°)

Figure 5 - Typical graph

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