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Geosynthetics — Determination of friction characteristics —

Part 1:
Direct shear test

Géosynthétiques — Détermination des caractéristiques de frottement —

Partie 1: Essai de cisaillement direct

Reference number
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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 documents 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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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 221, *Geosynthetics*.

This second edition cancels and replaces the first edition (ISO 12957-1:2005), which has been technically revised. The main changes compared to the previous edition are as follows:

— introduction of the possibility to test the shear between two geosynthetics;

— introduction of the possibility to test soil different from the standard sand.

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 1: Direct shear test

1 Scope

This document specifies an index test method to determine the friction characteristics of geosynthetics in contact with a standard sand as described in EN 196-1, i.e. with a specified density and moisture content, under a normal stress and at a constant rate of displacement, using a direct shear apparatus.

The same testing procedure can be used with any type of soil with the density and moisture content that are required to evaluate the performance under specific conditions or with another geosynthetic under a normal stress and at a constant rate of displacement, using a direct shear apparatus.

The procedure can also be used for testing geosynthetic barriers.

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

3 Terms, definitions and symbols

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

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

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

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

3.1
relative displacement
s
displacement of the sand, soil or other geosynthetic relative to the specimen during shearing

Note 1 to entry: Relative displacement is expressed in millimetres (mm).

3.2
normal force
N
constant vertical force applied to the specimen

Note 1 to entry: Normal force is expressed in kilonewtons (kN).

3.3
shear force
S
horizontal force measured during shearing at a constant rate of displacement

Note 1 to entry: Shear force is expressed in kilonewtons (kN).

3.4
normal stress
σ
normal force (3.2) divided by the contact area of the specimen

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

3.5
shear stress
τ
shear force (3.3) along the sand, soil or other geosynthetic /geosynthetic interface, divided by the contact area of the specimen

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

3.6
maximum shear stress
$\tau_{\max}$
maximum value of *shear stress* (3.5) developed in a shear test

Note 1 to entry: Maximum shear stress is expressed in kilopascals (kPa).

3.7
angle of friction
ϕ
slope of the "best fit regression straight line", through the plot of *maximum shear stress* (3.6)

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

Note 2 to entry: In this document, ϕ_{sg} is used to refer to the angle of friction between geosynthetic and sand, or geosynthetics and specific soil, and ϕ_{gg} is used for the angle of friction between geosynthetic and geosynthetic.

3.8
apparent cohesion
c_{sg}
calculated value of the *shear stress* (3.5) on the "best fit regression straight line" corresponding to zero *normal stress* (3.4)

Note 1 to entry: Apparent cohesion is expressed in kilopascals (kPa).

Note 2 to entry: This term is used between geosynthetic and sand, or geosynthetics and specific soil.

3.9
maximum shear stress in sand or soil alone
$\tau_{\max,s}$
maximum shear stress (3.6) developed during a shear test on sand or soil alone

Note 1 to entry: Maximum shear stress in sand or soil alone is expressed in kilopascals (kPa).

3.10
maximum shear stress sand or soil/support
$\tau_{max,sup}$
maximum shear stress (3.6) developed during the shearing along the sand or soil/support interface without geosynthetic

Note 1 to entry: Maximum shear stress sand or soil/support is expressed in kilopascals (kPa).

3.11
friction ratio
$f_g(\sigma)$
ratio of the *maximum shear stress*, τ_{max} (3.6) to the *maximum shear stress in sand or soil alone*, $\tau_{max,s}$ (3.9) for the same *normal stress* (3.4) σ

3.12
apparent adhesion
a_{gg}
calculated value of the *shear stress* (3.5) on the "best fit regression straight line" corresponding to zero *normal stress* (3.4)

Note 1 to entry: Apparent adhesion is expressed in kilopascals (kPa).

Note 2 to entry: This term is used between geosynthetic and geosynthetic.

4 Principle

A geosynthetic is submitted to direct shear at its contact surface with standard sand, specific soil or another geosynthetic in a shear apparatus or similar apparatus. The angle of friction at the sand/geosynthetic, soil/geosynthetic or geosynthetic/geosynthetic interface is determined.

When geogrids are tested in contact with soil with a rigid support, the results are dependent on the friction with the support and the results are not necessarily realistic. The accuracy of the test should be verified by calibration tests.

5 Test specimens

5.1 Sampling

Take specimens in accordance with ISO 9862.

5.2 Number and dimensions of test specimens

Cut four specimens from the test sample of geosynthetic for each direction to be tested for every sample. 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; four 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 temperature of (20 ± 2) °C and a relative humidity of (65 ± 2) %, until the change in mass between successive readings made at intervals of not less than two hours does not exceed 0,25 % of the mass of the test specimens.

Conditioning and/or testing at a specified relative humidity may be omitted if it can be proven that the results are not affected by this omission.

7 Apparatus

7.1 Shearing apparatus

7.1.1 Constant contact area shear apparatus, schematically represented in Figure 1.

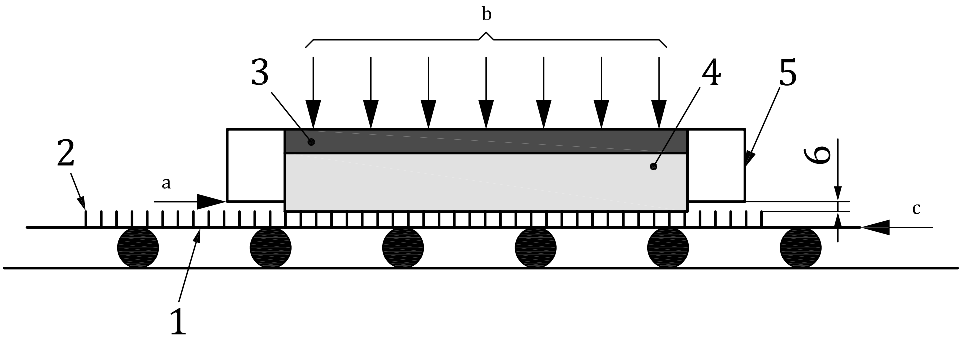
The shear apparatus shall be divided into upper and lower sections. The apparatus shall be sufficiently rigid to resist distortion under the loads applied. It shall be possible to lift the upper part of the shear apparatus from the lower part.

The upper part of the shear apparatus shall have internal dimensions of not less than 300 mm × 300 mm, the width of both parts being not less than 50 % of their length. The box shall be sufficiently deep to accommodate the sand layer and the loading system, or a rigid support to which the upper geosynthetic has to be fixed.

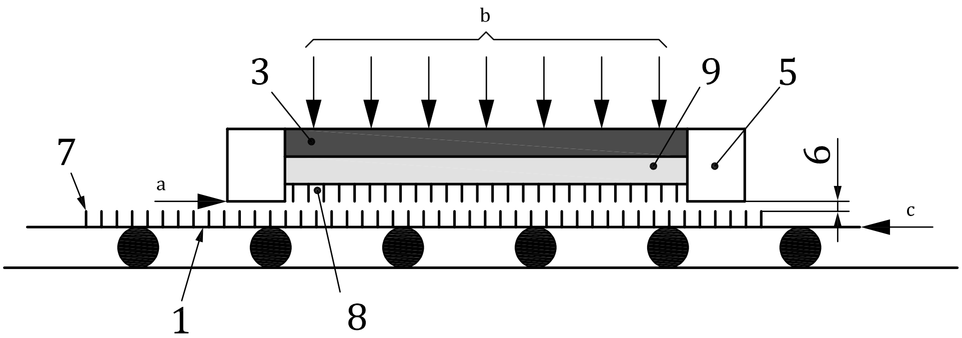
For the testing of geogrids, the minimum dimensions of the shear apparatus shall be such that at least two full longitudinal ribs and three transverse bars are contained within the length of both the upper and lower boxes throughout the test.

The lower part of the shear apparatus shall contain the support of the specimen and any clamping arrangements to prevent the specimen from slipping during the test.

The lower part of the shear apparatus shall be sufficiently long to maintain full contact between specimen and the open area of the upper part over a relative shear displacement of at least 16,5 % of the internal length of the top part.



a) Constant area direct shear test (typical layout) for sand/generic soil — Geosynthetic interface

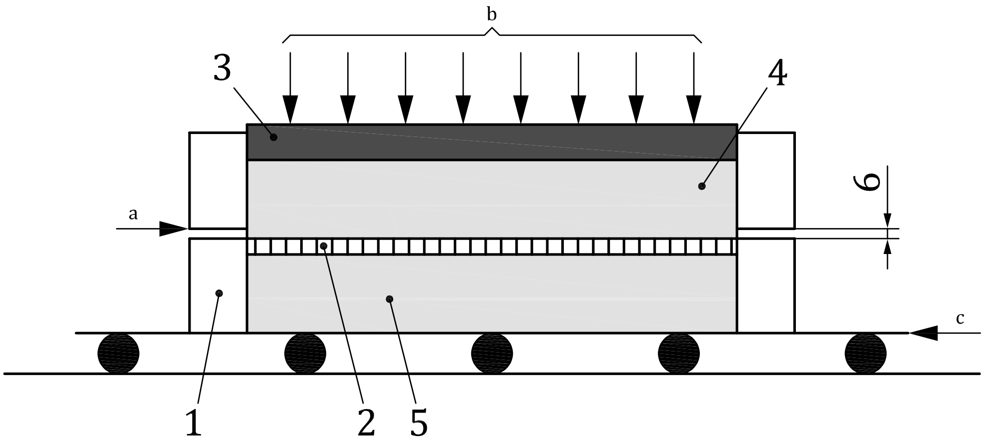


b) Constant area direct shear test (typical layout) for geosynthetic — Geosynthetic interface

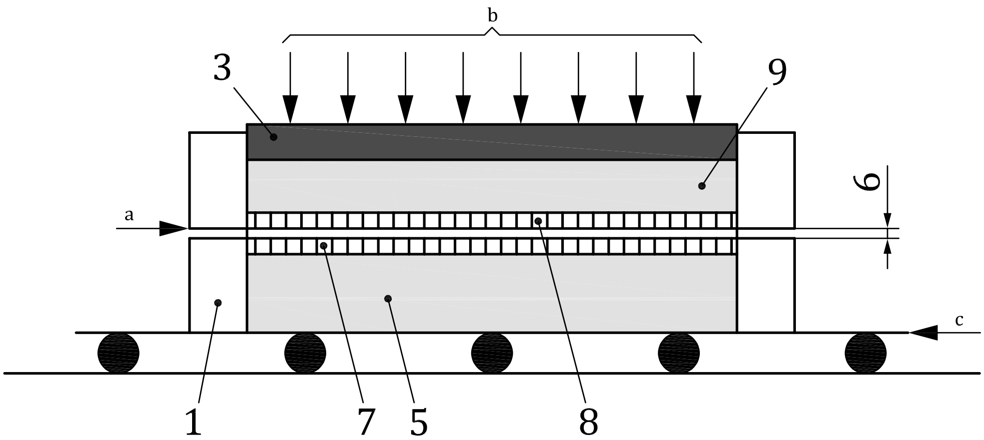
Key

1 rigid base
2 geosynthetic specimen
3 loading system
4 standard sand/generic soil
5 rigid shear box
6 appropriate gap
7 geosynthetic #1 specimen
8 geosynthetic #2 specimen
9 rigid specimen support
a Horizontal reaction.
b Normal load.
c Horizontal force.

Figure 1 — Constant area direct shear test



a) Reducing area direct shear apparatus (typical layout) for sand/generic soil — Geosynthetic interface



b) Reducing area direct shear apparatus (typical layout) for geosynthetic — Geosynthetic interface

Key

1 standard shear apparatus (300 mm × 300 mm)
2 geosynthetic specimen
3 loading system
4 standard sand/generic soil
5 rigid specimen support
6 appropriate gap
7 geosynthetic #1 specimen
8 geosynthetic #2 specimen
9 upper rigid specimen support
a Horizontal reaction.
b Normal load.
c Horizontal force.

Figure 2 — Reducing area direct shear apparatus

7.1.2 Reducing contact area shear apparatus, schematically represented in Figure 2.

Alternatively, a standard soil shear apparatus with equally sized (300 mm × 300 mm minimum) upper and lower halves may be used.

7.2 Specimen support, consisting of a rigid, horizontal support.

The specimen shall be placed on the specimen support in the lower part of the shear apparatus. The specimen shall be fixed to prevent any relative displacement between the specimen and the specimen support. The geosynthetic should be clamped at the front part outside the shear area. Inside the friction area, it should be fixed by gluing or with a standard friction support, e.g. an aluminium oxide abrasive sheet (P 80 type in accordance with ISO 6344-2).

When using a rigid plate as specimen support for geogrids (or geotextiles) with openings, friction tests between sand or soil and the specimen support shall be performed and the maximum shear stress ($\tau_{max,sup}$) related to every normal stress shall be evaluated. For geogrids with large apertures (>15 mm) and a high percentage of openings (>50 % of the overall surface of the specimen), a sand support may be used, i.e. by filling the lower part of the apparatus with standard sand or specific soil at the specified density.

7.3 Rigid carriage, consisting of a machine bed on low friction bearings, which allow movement in the longitudinal direction.

The rigid base of shear apparatus shall be supported on the rigid carriage.

7.4 Loading device, capable of applying a horizontal shear force to the shear apparatus at a constant rate of displacement of (1 ± 0,2) mm/min.

When the test involves soils with a low permeability (d_{10} < 0,007 5 mm), the shear rate shall be determined to ensure the test will be conducted in drained conditions. This can require the use of shear rates much smaller than 1,0 mm/min, i.e. between 0,005 and 1,0 mm/min. When using such shear rate, the precision shall remain ±20 % of the selected value.

7.5 Fluid filled soft membrane or rigid plate ensuring that the normal load is applied uniformly over the whole area of the specimen.

The normal load may be measured to an accuracy of ±2 %.

7.6 Apparatus for the measurement of shear force and displacement

7.6.1 General

The shear force shall be measured to an accuracy of ±2 %.

The relative displacement shall be measured to an accuracy of ±0,02 mm.

The design of the apparatus should allow for the dilatation of the sand, i.e. an appropriate gap should be left between the upper and lower parts of the apparatus.

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. The grading is defined in Table 1.

Table 1 — Grading of EN 196-1 standard sand

Sieve size mm	**Cumulative sieve residue** %
2,00	0
1,60	7 ± 5
1,00	33 ± 5

Table 1 *(continued)*

Sieve size mm	Cumulative sieve residue %
0,50	67 ± 5
0,16	87 ± 5
0,08	99 ± 1

If loss of fine particles is observed during a test, the grading of the sand shall be checked. The amount of sand entrapped shall be determined by re-weighing the specimen and reported.

A visual check can be adequate to verify whether the grading has changed. Water may be added to the sand to avoid particle segregation but the moisture content should not exceed 2 %.

The internal angle of friction of the sand shall be measured in a common direct shear apparatus. The same equipment as used for the friction test may be used if it satisfies the requirements of the common direct shear apparatus.

If the test is performed on a different type of soil, the grain size curve and the internal angle of friction of the soil shall be measured in a common direct shear apparatus.

7.6.2 Rigid confinement system, to be used when testing sand or soil and with which the upper part of the shear apparatus should be fitted to prevent sand particles blocking the space between the upper part of the shear apparatus and the geotextile or geogrid support.

7.6.3 Natural siliceous sand, consisting preferably of particles isometric and rounded in shape and with a silica content of at least 98 %, to be used when testing standard sand in contact with the specimen.

8 Procedure

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

Fix the specimen to the support system. In the reducing contact area apparatus, the top surface of the specimen shall be flush with the lower part of the shear apparatus.

Assemble the upper section of the apparatus.

Any possible friction force between the two halves of the apparatus has to be avoided by executing a preliminary series of tests without any material at the interface. In case a friction force is measured, this has to be deducted from the force measured during the test.

When testing geosynthetic/soil interface, fill the upper part of the shear apparatus with the standard sand or with a specific soil.

The thickness of the soil layer shall be at least 5 times the maximum particle size diameter of the soil tested, or 25 mm, whichever is greater.

The sand shall be compacted to a dry density of 1 750 kg/m^3 (±5 %); the specific soil shall be compacted to the water content and density specified. Fill the upper part of the apparatus with a pre-weighed mass of sand or soil, such that, when compacted, the material has the required density and occupies the required volume.

When testing geosynthetic/geosynthetic interface, fix the upper geosynthetic to a rigid support, a water bag, an airbag or a soil layer, and insert the support into the upper part of the shear apparatus, with the geosynthetic downward.

Assemble the loading devices and displacement measuring devices (transducers or dial gauges). Apply the normal force to obtain one of the following pressures: 50 kPa, 100 kPa or 150 kPa when testing standard sand, or the specific pressures required when testing other soil or geosynthetic/geosynthetic interface.

Measurements of the shear force shall be taken continuously or at intervals which correspond to displacements of 0,2 mm or 12 s time intervals. The actual relative displacement shall be recorded at the same time, and the plate (used to apply the vertical load) lift and rotation should be measured at the end of the test.

The test is terminated when the relative displacement reaches 50 mm for a shear surface length of 300 mm (or 16,5 % of the shear surface length in other cases).

Dismantle the apparatus, carefully remove the sand, soil or upper support with the geosynthetic fixed, inspect the specimen and record any stretching, wrinkles or damage.

Carry out the test twice for the 100 kPa normal stress and repeat, if required, for the different sides or directions of the sample. A new specimen shall be used for each test.

When testing soils other than the standard sand described in Table 1, the test conditions shall be adapted to ensure that the test results will be meaningful. This may include change to the compaction and consolidation strategy, control of water content, shear rate, normal stresses and minimum relative displacement.

9 Calculations

Calculate the normal stress, σ, for each set of readings as:

$$\sigma = \frac{N}{A}$$

where

σ is the normal stress, in kilopascals (kPa);

N is the normal force, in kilonewtons (kN);

A is the the contact area, in square metres (m^2), corrected for each calculation if using the reducing area apparatus.

Calculate the shear stress, τ, for each set of readings as:

$$\tau = \frac{S}{A}$$

where

τ is the shear stress, in kilopascals (kPa);

S is the measured shear force, in kilonewtons (kN);

A is the contact area of the specimen, in square metres (m^2).

Plot the test results as graphs (shear stress versus relative displacement). Determine the maximum shear stress as defined in 3.6.

Plot the maximum shear stress against the normal stress for all four specimens. Draw the best fit regression straight line through the plotted points. The angle between the best fit regression straight line and the horizontal axis is ϕ_{sg}, the peak angle of friction between geosynthetic and sand or specific soil, or ϕ_{gg}, the peak angle of friction between geosynthetic and geosynthetic; c_{sg} (apparent cohesion) is the intercept of the line for a geosynthetic-sand or geosynthetic-soil test with the vertical axis and a_{gg} (apparent adhesion) is the intercept of the line for a geosynthetic-geosynthetic test.

Calculate the friction ratio $fg(\sigma)$ for displacements in the range of 0 % to 10 % of the length of the sheer surface for each of the four tests, as:

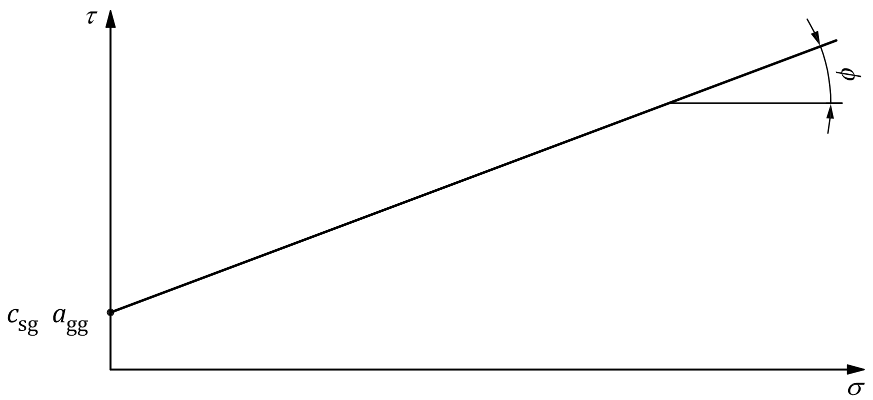
$$f_g(\sigma) = \frac{\tau_{max}(\sigma)}{\tau_{max,s}(\sigma)}$$

where

$\tau_{max}(\sigma)$ is the maximum shear stress under the normal stress σ, in a sand/geosynthetics or specific soil/geosynthetics direct shear test, as defined in 3.6;

$\tau_{max,s}(\sigma)$ is the maximum shear stress under the normal stress σ, in a direct shear test on sand or specific soil alone, as defined in 3.9.

NOTE When testing soils other than the standard sand described in Table 1, it can be necessary to determine the properties at large displacement (residual) as well as the peak shear strength, for each normal stress.



Key

τ shear stress, in kilopascals

c_{sg} apparent cohesion, in kilopascals

ϕ angle of friction, in degrees (°)

σ normal stress, in kilopascals

a_{gg} apparent adhesion, in kilopascals

Figure 3 — Example of straight line of maximum shear stress vs normal stress

10 Test report

The test report shall include following information:

a) number and date of this document, i.e. ISO 12957-1:2018

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, upper or bottom surface) of the specimens;

f) graph of shear stress against relative displacement, showing the maximum shear stress used in calculation;

g) graph of maximum shear stress against normal stress;

h) graph of shear stress against displacement for the direct shear test on sand;

i) graph of maximum shear stress, $\tau_{max}(\sigma)$, against normal stress, σ, for the direct shear test on sand under similar conditions (density, moisture, normal stress);

j) graph of the friction ratio, $f_g(\sigma)$, against normal stress, σ;

k) the angle of friction, ϕ_{sg} or ϕ_{gg}, and the apparent cohesion c_{sg} for the sand/geosynthetic or the specific soil/geosynthetic interface or the apparent adhesion a_{gg} for the geosynthetic/geosynthetic interface;

l) the angle of internal friction, ϕ, for the sand or for the specific soil used;

m) if necessary (see 7.2), a graph of maximum shear stress, τ_{max}, against normal stress, σ, for the sand or other soil versus friction support;

n) observations of any damage of the specimen or unusual behaviour during testing;

o) description of the "post peak" behaviour observed in each test (e.g. constant shear stress, strain hardening, strain softening);

p) any deviation from this procedure.

Graphs f), g), h), i), j), should be produced for each face and direction tested, i.e. a maximum of 5 sets of graphs.

Bibliography

[1] ISO 554, *Standard atmospheres for conditioning and/or testing — Specifications*

[2] ISO 6344-2, *Coated abrasives — Grain size analysis — Part 2: Determination of grain size distribution of macrogrits P12 to P220*

[3] EN 196-1, *Methods of testing cement — Part 1: Determination of strength*

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