INTERNATIONAL STANDARD

ISO 11277

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Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation

Qualité du sol — Détermination de la répartition granulométrique de la matière minérale des sols — Méthode par tamisage et sédimentation

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International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11277 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 5, *Physical methods.*

Annexes A and B form an integral part of this International Standard. Annex C is for information only.

Introduction

The physical and chemical behaviour of soils is controlled in part by the amounts of mineral particles of different sizes in the soil. The subject of this International Standard is the quantitative measurement of such amounts (expressed as a proportion or percentage of the total mass of the mineral soil), within stated size classes.

The determination of particle size distribution is affected by organic matter, soluble salts, cementing agents (especially iron compounds), relatively insoluble substances such as carbonates and sulfates, or combinations of these. Some soils change their behaviour to such a degree upon drying, that the particle size distribution of the dried material bears little or no relation to that of the undried material encountered under natural conditions. This is particularly true of soils rich in organic matter, those developed from recent volcanic deposits, some highly weathered tropical soils, and soils often described as "cohesive" [6]. Other soils, such as the so-called "sub-plastic" soils of Australia, show little or no tendency to disperse under normal laboratory treatments, despite field evidence of a large clay content.

The procedures given in this International Standard recognize these kinds of differences between soils from different environments, and the methodology presented is designed to deal with them in a structured manner. Such differences in soil behaviour can be very important, but awareness of them depends usually on local knowledge. Given that the laboratory is commonly distant from the site of the field operation, the information supplied by field teams becomes crucial to the choice of an appropriate laboratory procedure. This choice can be made only if the laboratory is made fully aware of this background information.

All procedures in this International Standard should be carried out by competent, trained persons, with adequate supervision. Attention is drawn to certain known hazards, but it is essential that users follow safe working practices. If in any doubt, seek professional advice.

It is essential that users of this International Standard read all of it before commencing any operation, as failure to note certain points will lead to incorrect analysis, and could be dangerous.

Soil quality — Determination of particle size distribution in mineral soil material — Method by sieving and sedimentation

1 Scope

This International Standard specifies a basic method of determining particle size distribution applicable to a wide range of mineral soil materials, including the mineral fraction of organic soils. It also offers procedures to deal with the less common soils mentioned in the introduction. This International Standard has been developed largely for use in the field of environmental science, and its use in geotechnical investigations is something on which professional advice might be required.

A major objective of this International Standard is the determination of enough size fractions to enable the construction of a reliable particle size distribution curve.

This International Standard does not apply to the determination of the particle size distribution of the organic components of soil, i.e. the more or less fragile, partially decomposed, remains of plants and animals. It should also be realized that the chemical pretreatments and mechanical handling stages in this International Standard could cause disintegration of weakly cohesive particles that, from field inspection, might be regarded as primary particles, even though such primary particles could be better described as aggregates. If such disintegration is undesirable, then this International Standard should not be used for the determination of the particle size distribution of such weakly cohesive materials.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 565:1990, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings.*

ISO 3310-1:1990, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth.*

ISO 3310-2:1990, *Test sieves — Technical requirements and testing — Part 2: Test sieves of perforated metal plate.*

ISO 3696:1987, *Water for analytical laboratory use — Specification and test methods*.

ISO 11464:1994, *Soil quality — Pretreatment of samples for physico-chemical analyses.*

3 Terminology and symbols

3.1 Terminology

Particles within particular size ranges or classes are commonly described as cobbles, gravel, coarse sand, silt, etc. The meaning of such trivial names differs between countries, and in some cases there are no exact translations of such words from one language to another; for example, the Dutch word "zavel" has no equivalent in English. The only fraction for which there appears to be common agreement is clay, which is defined as material of less than 0,002 mm equivalent spherical diameter [1, 6]. Such trivial names shall not be used in describing the results of particle size determination according to this International Standard. Phrases such as "..passing a 20 mm aperture sieve..." or "...less then 0,063 mm equivalent spherical diameter..." shall be used instead. If trivial names must be used, for example to cross-reference to another (inter-)national standard, then the trivial name should be defined explicitly, so as to remove any doubt as to the meaning intended, e.g. silt (0,063 mm to 0,002 mm equivalent spherical diameter) (clause 4 and, for example, [3]). Further, it is common to use the word 'texture' to describe the results of particle size distribution measurements, e.g. 'the particle size of this soil is of clay texture'. This is incorrect as the two concepts are different, and the word 'texture' shall not be used in the test report (clause 10) to describe the results obtained by use of this International Standard.

It is common to refer to sieves as having a particular mesh-size or mesh number. These are not the same as the sieve aperture, and the relationship between the various numbers is not immediately obvious. The use of mesh numbers as a measurement of particle size is difficult to justify, and shall not be used in reporting the results of this International Standard.

3.2 Symbols

The following symbols are found throughout the text and, where appropriate, units and quantities are as given below (SI convention is followed for common units e.g. g = gram; m = metre; mm = millimetre; s = second, etc.).

Mg megagram (10^6 g)

mPa millipascal

t is the settling time, in seconds, of a particle of diameter d_p;

η is the dynamic viscosity of water at the test temperature (see Table B.2), in millipascals per second;

h is the sampling depth, in centimetres;

ρ_s is the mean particle density, in megagrams per cubic metre (taken as 2,65; note in clause 4);

ρ_w is the density of the liquid containing the soil suspension, in megagrams per cubic metre (taken as 1,00; note in clause 4);

g is the acceleration due to gravity, in centimetres per second squared (taken as 981);

d_p is the equivalent spherical diameter of the particle of interest, in millimetres;

4 Principle

Particle size distribution is determined by a combination of sieving and sedimentation, starting from air-dried soil [6] (see note below). A method for undried soil is given in Annex A. Particles not passing a 2 mm aperture sieve are determined by dry sieving. Particles passing such a sieve, but retained on a 0,063 mm aperture sieve, are determined by a combination of wet and dry sieving, whilst particles passing the latter sieve are determined by sedimentation. The pipette method is preferred. A hydrometer method is given in Annex B. A combination of sieving and sedimentation enables construction of a continuous particle size distribution curve.

The key points in this procedure are summarized as a flow chart in Figure 2. This International Standard requires that the proportions of fractions separated by sedimentation and sieving be determined from the masses of such fractions obtained by weighing. Other methods of determining the mass of such fractions rely on such things as the interaction of particles with electromagnetic radiation or electrical fields [1]. There are often considerable difficulties in relating the values obtained by different methods, one to another, for the same sample. It is one of the intentions of this International Standard that close adherence to its details should help minimize interlaboratory variation in the determination of the particle size distribution of mineral soils. Therefore the proportions of fractions shall be determined only by weighing. If this is not the method used, then compliance with this International Standard cannot be claimed in the test report (clause 10).

Both the pipette and hydrometer methods assume that the settling of particles in the sedimentation cylinder is in accordance with Stokes' Law [1, 6, 9], and the constraints that this implies, namely:

a) the particles are rigid, smooth spheres;

b) the particles settle in laminar flow i.e. the Reynolds Number is less than about 0,2. This constraint sets an upper equivalent spherical particle diameter (below) slightly greater than 0,06 mm for Stokesian settling under gravity [1];

c) the suspension of particles is sufficiently dilute to ensure that no particle interferes with the settling of any other particle;

d) there is no interaction between particle and fluid;

e) the diameter of the suspension column is large compared to the diameter of the particle, i.e. the fluid is of 'infinite extent';

f) the particle has reached its terminal velocity;

g) the particles are of the same relative density.

Thus, the diameter of a particle is defined in terms of the diameter of a sphere whose behaviour in suspension matches that of the particle. This is the concept of *equivalent spherical diameter*. It is the principle upon which the expression of the diameter of particles, as derived from sedimentation, is based in this International Standard.

Stokes' Law can be written, for the purposes of this International Standard, in the form:

$$t = 18\eta h/[(\rho_s - \rho_w) g d_p^2]$$

where

t is the settling time, in seconds, of a particle of diameter d_p (below);

η is the dynamic viscosity of water at the test temperature (Table B.2), in millipascals per second;

h is the sampling depth, in centimetres;

ρ_s is the mean particle density, in megagrams per cubic metre (taken as 2,65; see note);

ρ_w is the density of the liquid containing the soil suspension, in megagrams per cubic metre (taken as 1,00; see note);

g is the acceleration due to gravity, in centimetres per second squared (taken as 981);

d_p is the equivalent spherical diameter of the particle of interest, in millimetres;

NOTE — It is realized that there are considerable differences between the densities of soil particles, but for the purposes of this International Standard it is assumed that the mean particle density is that of quartz, i.e. 2,65 Mg/m^3 [10], as this is the commonest mineral in a very wide range of soils. The density of water is 0,9982 Mg/m^3 and 0,9956 Mg/m^3 at 20 °C and 30 °C, respectively [8]. Given the effect of the addition of a small amount of dispersant (8.3.2), the density of water is taken as 1,0000 Mg/m^3 over the permitted temperature range of this International Standard (8.2.2). Further, for routine use, it is recommended that the sampling times be converted to minutes and/or hours, as appropriate, to lessen the risk of error (Table 3).

5 Field sampling

The mass of sample taken in the field shall be representative of the particle size distribution, especially if the amount of the larger particles is to be determined reliably. Table 1 gives recommended minimum masses.

6 Sample preparation

Samples shall be prepared in accordance with the methods given in ISO 11464.

NOTE — For many purposes, particle size distribution is determined only for the fraction of the soil passing a 2 mm aperture sieve. In this case, the test sample (8.5) may be taken either according to the procedures in ISO 11464 or from the material passing a 2 mm aperture sieve according to 7.2.

7 Dry sieving (material > 2 mm)

7.1 General

The procedure specified in this clause applies to material retained on a 2 mm aperture sieve. Table 2 gives the maximum mass which shall be retained on sieves of different diameters and apertures. If more than this amount of material is retained, then it shall be subdivided appropriately, and resieved.

7.2 Apparatus

7.2.1 Test sieves, with apertures which comply with ISO 565, and with well-fitting covers and receivers.

The full range of sieves appropriate to the largest particle(s) present should be used (Table 1; note in 7.2.3). The apertures chosen shall be stated in the test report (clause 10). The accuracy of the sieves shall be verified monthly against a set of master sieves kept for this purpose, using an accepted method such as particle reference materials, microscopy etc. [1] depending on the sieve aperture. Tolerances shall meet the requirements of ISO 3310-1 and ISO 3310-2. Sieves that do not meet these specifications shall be discarded. A record shall be kept of such testing.

Brass sieves are particularly liable to splitting and distortion, and steel sieves are strongly recommended for the larger apertures.

Special care shall be taken to ensure that covers and receivers do not leak. Sieves shall be inspected weekly when in regular use, and on every occasion if used less often. A record shall be kept of such inspections. Round-hole sieves shall not be used.

7.2.2 Balance, capable of weighing to an accuracy of within ± 0,5 g.

7.2.3 Mechanical sieve shaker

NOTE — It is usually impracticable to sieve mechanically at sieve apertures much greater than 20 mm, unless very heavy-duty equipment is available. Mechanical sieve shaking is essential to sieve efficiency at smaller apertures.

7.2.4 A **sieve brush** and a **stiff brush.**

7.3 Procedure

Weigh the dry test sample, prepared in accordance with ISO 11464, to the nearest 0,5 g (m_1). Place the weighed material on the 20 mm sieve, and by brushing the material gently over the sieve apertures with the stiff brush (to remove any adhering soil), sieve the material. Take care not to detach any fragments from the primary particles. Sieve the retained material on the nest of sieves of selected apertures (7.1.1), and record the amount retained on each sieve to the nearest 0,5 g. Do not overload the sieves (Table 1), but sieve the material in portions if necessary.

Weigh the material passing the 20 mm aperture sieve (m_2), or a suitable portion of it (m_3) (Table 2) obtained by an appropriate subsampling method (clause 6), and place this on a nest of sieves, the lowermost having an aperture of 2 mm. Shake the sieves mechanically until no further material passes any of the sieves (see note). Record the mass of material retained on each sieve and the mass passing the 2 mm aperture sieve.

The total mass of the fractions should be within 1 % of m_2 or m_3, as appropriate. If it is not, then check for sieve damage, and discard sieves as appropriate (note in 7.2.3).

Sieve equipment performance should be verified against a suitable test material, e.g. standard particle reference materials, ballotini, at intervals of one month. The results of this check shall be recorded.

NOTE — For practical purposes, it is usual to choose a standard sieve shaking time which gives an acceptable degree of sieving efficiency with a wide range of soil materials. The minimum recommended period is 10 min.

Table 1 — Mass of soil sample to be taken for sieving

Maximum size of material forming >10% of the soil (given as test sieve aperture, in mm)	**Minimum mass of sample to be taken for sieving** kg
63	50
50	35
37,5	15
28	6
20	2
14	1
10	0,5
6,3	0,5
5	0,2
2 or smaller	0,1

Table 2 — Maximum mass of material to be retained on each test sieve at the completion of sieving

Test sieve aperture mm	**Maximum mass** kg **Sieve diameter** mm		
	450	300	200
50	10	4,5	
37,5	8	3,5	
28	6	2,5	
20	4	2,0	
14	3	1,5	
10	2	1,0	
6,3	1,5	0,75	
5	1,0	0,5	
3,35			0,3
2			0,2
1,18			0,1
0,6			0,075
0,425			0,075
0,3			0,05
0,212			0,05
0,15			0,04
0,063			0,025

7.4 Calculation and expression of results

For the material retained by the 20 mm and larger aperture sieves, calculate the proportion by mass retained by each sieve as a proportion of m_1. For example:

proportion retained on the 20 mm sieve = $[m(20\text{ mm})]/m_1$

For the material passing the 20 mm sieve, multiply the mass of material passing each sieve by m_2/m_3, and calculate this as a proportion of m_1. For example:

proportion retained on the 6,3 mm sieve = $m(6{,}3\text{ mm})[(m_2/m_3)/m_1]$

Present the results as a table showing, to two significant figures, the proportion by mass retained on each sieve, and the proportion passing the 2 mm sieve. The data shall also be used to construct a cumulative distribution curve (Figure 1).

8 Wet sieving and sedimentation (material < 2 mm)

8.1 General

This clause specifies the procedure (see figure 2) for the determination of the particle size distribution of the material passing the 2 mm aperture sieve down to <0,002 mm equivalent spherical diameter (see note). In order to ensure that primary particles are measured rather than loosely bonded aggregates, organic matter and salts are removed, especially sparingly soluble salts such as gypsum which would otherwise prevent dispersion and/or promote flocculation of the finer soil particles in suspension (8.6), and a dispersing agent is added (8.8). These procedures are required in this International Standard, and their omission shall invalidate its application. Sometimes iron oxides, and carbonates, especially of calcium and/or magnesium, are also removed. Preferred procedures for the removal of these compounds are given in the note in 8.7. The removal of any compound shall be recorded in the test report (clause 10).

NOTE — Gravitational sedimentation can give a value for the total amount of material <0,002 mm equivalent spherical diameter. However, the method cannot be used to divide this class further with reliability, as particles less than about 0,001 mm equivalent spherical diameter can be kept in suspension almost indefinitely by Brownian motion [1].

8.2 Apparatus

The apparatus specified hereafter is sufficient to deal with one sample. Clearly it is more efficient to work in batches. Experience has shown [9] that one operator can process up to 36 samples in a batch at a time given sufficient apparatus and space, especially if calculations are dealt with by a computer.

8.2.1 Sampling pipette of a pattern similar to that in Figure 3 [4], the chief requirement being that the smallest practicable zone of sedimenting suspension shall be sampled. The pipette shall be of not less than 10 ml volume and shall be held in a frame so that it can be lowered to a fixed depth within a sedimentation tube (Figure 4).

NOTE — Experience suggests that a pipette with an upper volume of 50 ml is more than sufficient for most purposes. A 25 ml volume pipette is a convenient compromise for routine analysis, but a smaller volume pipette will be found sufficient for soils with down to about 10 % mass fraction <0,063 mm equivalent spherical diameter. Below this amount, greater precision is likely to be obtained with a larger volume pipette.

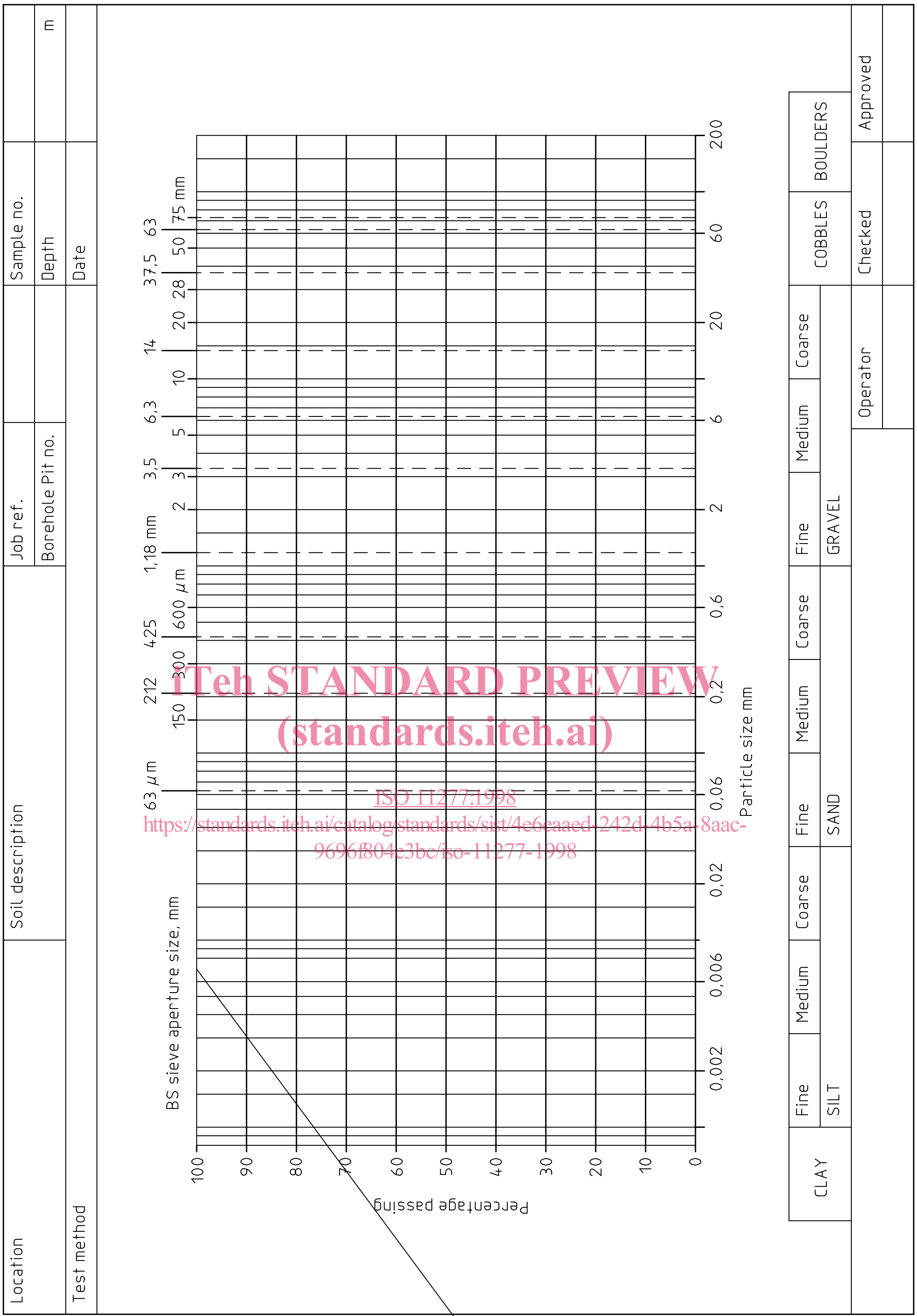

Figure 1 — Particle size distribution chart

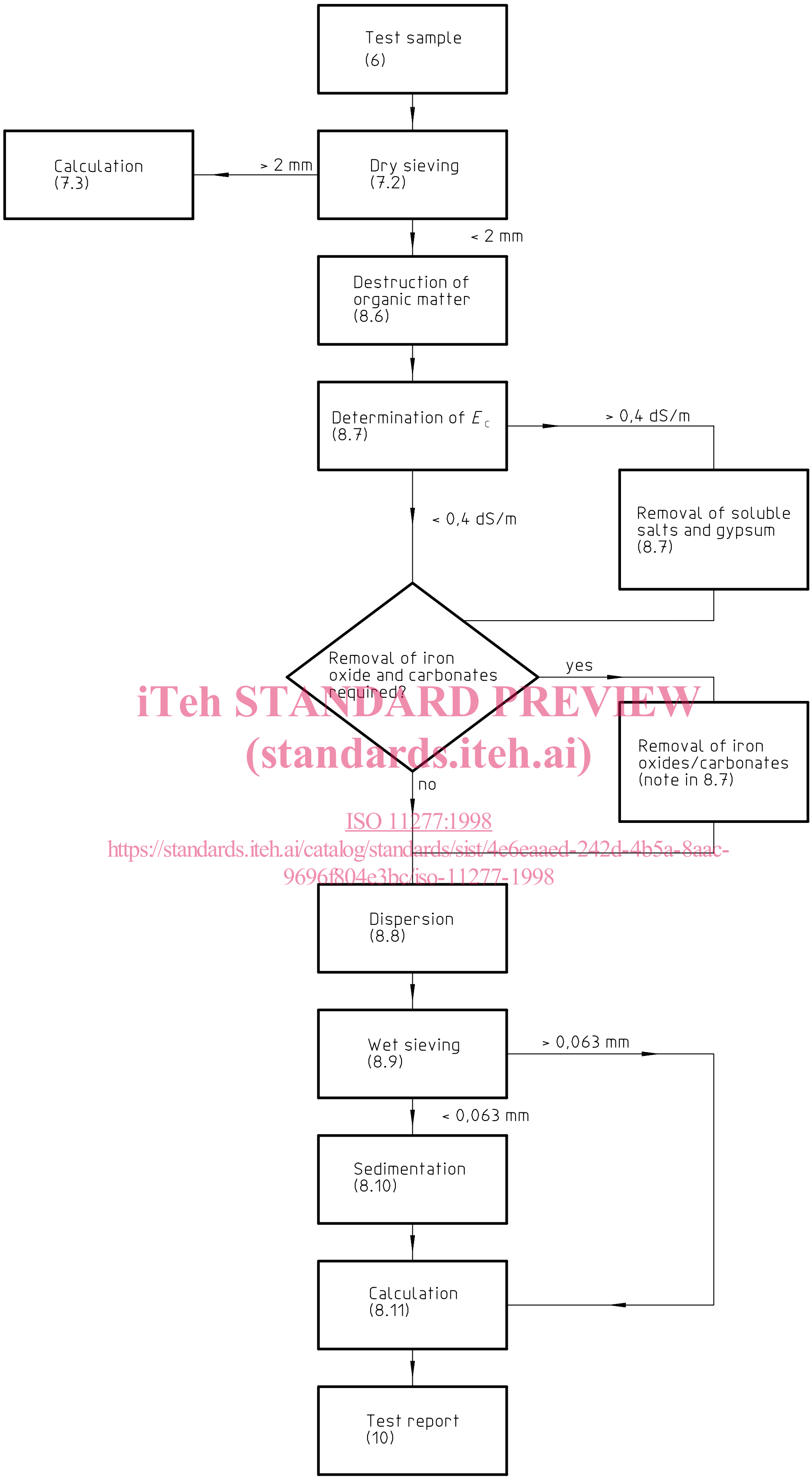

Figure 2 — Flow chart