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Soil quality — Measurement of the stability of soil aggregates subjected to the action of water

Qualité du sol — Mesure de la stabilité d'agrégats de sols soumis à l'action de l'eau

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Foreword

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The main task of technical committees is to prepare International Standards. 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.

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ISO 10930 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 3, *Chemical methods and soil characteristics*.

Introduction

The purpose of the method specified in this International Standard is to provide a realistic analysis of the structural stability of soil aggregates when subjected to the action of weather, cultivation, etc. and to enable the soils to be classified on the basis of the stability of their aggregates.

The methodology is, to a great extent, based on Hénin and Combeau's structural stability test (1958)[1]. However, it also includes certain aspects of other methods [Yoder (1936)[2], Emerson (1954)[3], Grieve (1980)[4], Kemper and Rosenau (1986)[5], Matkin and Smart (1987)[6]], as well as the results from Le Bissonnais (1988)[7], Le Bissonnais *et al.* (1989)[8], Le Bissonnais and Le Souder (1995)[9], and Le Bissonnais (1996)[10].

The aim of the set of three treatments specified in this International Standard is to provide a means of predicting the behaviour of soil, with respect to its structural stability, for different conditions of soil wetting by water, which simulate different climatic, hydraulic and mechanical conditions that might be encountered in the field. It is therefore recommended that the three treatments be used in order to provide scientific information on the different mechanisms which can destroy soil aggregates. However, the use of the fast wetting test only, which is less time-consuming, can prove sufficient for a simple sample comparison.

The treatments were chosen for the following purposes:

— to distinguish between the various mechanisms;

— to distinguish between the disaggregation phase and the measurement of the result of the disaggregation;

— to express the results in a form that can be easily interpreted by comparison with physical soil behaviour *in situ*.

Following the method proposed in Reference [1], this method recommends the use of ethyl alcohol to ensure that disaggregation is well controlled on the one hand and, on the other hand, to limit the reaggregation of the particles on drying.

Soil quality — Measurement of the stability of soil aggregates subjected to the action of water

1 Scope

This International Standard specifies the treatments for the measurement of the stability of soil aggregates. It can be applied to a wide range of materials originating mainly from the tilled horizons of cultivated soils. It can, however, also apply to any soil profile horizon, whether it is cultivated or not. Aggregates ranging from 3 mm to 5 mm are measured.

However, the presence of gravel in the 2 mm to 5 mm fraction can distort the results. If the percentage of gravel is between 10 % and 40 %, the $>$ 2 mm fraction of the gravel obtained from the tests should be washed and a mean weighted diameter (MWD, see 6.1) calculated with and without gravel. If the percentage of gravel is $>$ 40 %, the structural stability tests are not significant. The method does not apply to unstructured materials, as they are not sufficiently cohesive to form millimetric aggregates.

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 3310-1:2000, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth*

3 Terms and definitions

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

3.1
aggregate
semi-permanent structural unit comprising small particles and associated matter bonded together

3.2
mean weighted diameter
MWD
sum of the product of the mean diameter multiplied by the percentage by mass of the particles in each of the seven size classes (according to 6.1) divided by 100

NOTE This diameter is expressed in millimetres.

4 Reagent and equipment required for stability tests

4.1 Ethyl alcohol [95 % (V/V) ethanol].

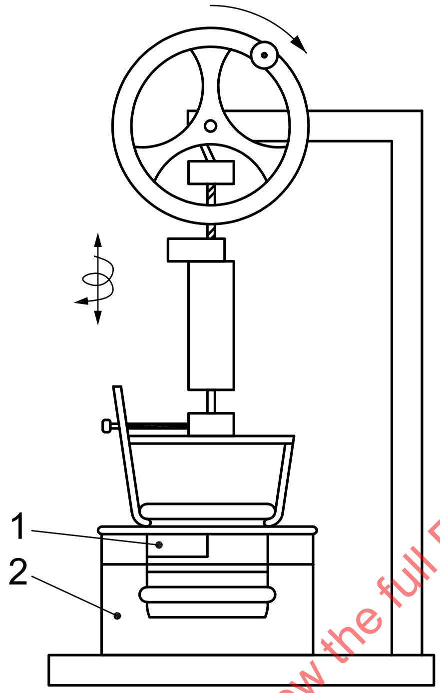
4.2 Sieving device producing a helical movement.

- Diameter of the vessel: 200 mm.
- Height of the vessel: 90 mm.
- Diameter of the sieve: 100 mm.
- Rotation about the centre line: horizontal rotation angle = 0° to 180°.

— Rinse and fall: 45 mm vertically.

Hénin-Féodoroff's device is recommended for this purpose.

Figure 1 shows an example of a sieving device.



Key

1 50 µm sieve

2 vessel filled with ethyl alcohol

Figure 1 — Example of a sieving device

4.3 Balance, with an accuracy of 1 mg.

4.4 Oven.

4.5 Beakers, nominal volume 250 ml.

4.6 Erlenmeyer flasks with stoppers, nominal volume 250 ml.

4.7 Evaporation dishes, nominal volume 60 ml.

4.8 Sieves, stainless steel, square mesh, 100 mm in diameter, 45 mm high, sizes (mm): 5,0, 3,0, 2,0, 1,0, 0,5, 0,2, 0,1, 0,05, respectively, in accordance with ISO 3310-1.

NOTE A 3,15 mm sieve can be used instead of a 3,0 mm sieve.

4.9 Sieve, stainless steel, 0,05 mm square mesh, 100 mm in diameter, 60 mm high, in accordance with ISO 3310-1.

4.10 Plastic angled-spout wash bottles, nominal volume 500 ml.

4.11 Vessel, with a capacity of approximately 3 l, used for sieving in ethyl alcohol.

4.12 Flat vessel, approximately 8 cm high with a capacity of approximately 8 l, which is able to contain the permeable plastic block (4.14).

4.13 Pipette, nominal volume 50 ml, and inherent soft plastic-like rubber pear-shaped bulb.

4.14 Permeable plastic block, 30 mm thick, sufficient in area and shape to almost cover the bottom of the flat vessel (4.12) (e.g. synthetic foam, 30 kg/m^3).

NOTE If no suitable plastic block is available, a 30-mm-thick bed of fine or medium sand may be used.

4.15 Filter papers, with a retention capacity of 2 µm.

4.16 Rigid plastic or **metal containers**, for the field samples.

4.17 Sampling tools: shovel or spade.

5 Procedures

5.1 General

The sequence of operations is illustrated in Annex A.

5.2 Field sampling

Take a sample of approximately 1 kg of soil from the layer of soil to be analysed, if possible under moderately humid conditions (between the field moisture capacity and the wilting point), for example in the case of cultivated soils, the conditions under which seed beds can be prepared or a maximum yield of aggregates obtained from the sample (yield = ratio between a 3 mm to 5 mm mass of aggregates and an initial sample of soil). In the event of crusting or litter on the surface of the soil, take the sample from below. The soil's structural stability may vary cyclically throughout the year. It is therefore recommended that soil samples always be taken at the same time of year to ensure better comparison. Samples shall be transported from the field to the laboratory in such a way that no significant damage occurs to the aggregates. In most cases, a rigid container is required.

Samples shall be restrained from movement within their containers.

5.3 Preparation of the soil sample

Prepare the aggregates as soon as possible after sampling, otherwise some changes may occur during the process, affecting the stability. Immediately after samples reach the laboratory, they shall be spread out in flat containers in a temperate (about 20 °C) well-ventilated atmosphere to be air-dried. If this is not possible, store the boxes in a fridge at 4 °C to minimize biologic activity and avoid changes in temperature.

If necessary, samples may at this stage be reduced in size using any recognized method to produce a representative subsample for the test.

During the drying period, oversize aggregates shall be manually broken under optimum humid conditions until the whole sample, except for stones, passes through a 5 mm sieve. The mass of stones rejected shall be recorded. Care shall be taken that excessive diminution of the aggregates does not occur.

After all of the aggregates have been passed through a 5 mm sieve, undersized aggregates and other materials shall be separated by use of a 3 mm sieve. The dry mass of the undersized material shall be recorded. Aggregates passing through a 5 mm sieve and retained by a 3 mm sieve shall be retained for further testing. Immediately before testing, the aggregates shall be oven-dried at 40 °C for 24 h and cooled in a desiccator, so that, as far as possible, the aggregates are always subjected to the same treatment (5.4).

5.4 Treatment methods

5.4.1 Treatment 1: fast wetting by immersion in water

This treatment is used to test the behaviour of dry materials subjected to sudden wetting, such as irrigation by submersion or heavy rain (spring and summer storms), although in the latter case, the impact of the raindrops also plays a part.

The treatment is as follows:

— weigh 5 g to 10 g of aggregates measuring 3 mm to 5 mm (initial mass) (the larger the percentage of gravel, the larger the test portion);

— pour 50 ml of deionized water into a beaker (4.5);

— carefully pour the aggregates into the beaker;

— allow to rest for 10 min (visually observe slaking);

— remove the water using a pipette (4.13);

— transfer the aggregates to a 0,05 mm sieve (4.9) immersed in ethyl alcohol (4.1), using a wash bottle (4.10) filled with ethyl alcohol.

Then proceed as specified in 5.5.

5.4.2 Treatment 2: slow wetting by capillarity

This treatment is used to test the behaviour of dry materials subjected to moderate rain. It is less destructive than fast wetting and is therefore used to discriminate between soils that are not stable.

The treatment is as follows:

— weigh 5 g to 10 g of aggregates measuring 3 mm to 5 mm (initial mass) (the larger the percentage of gravel, the larger the test portion);

— place the foam (4.14) in the flat vessel (4.12), then add water in the vessel up to a height of 2,5 cm (to create a depression of 0,5 cm);

— put the filter paper (4.15) on the foam (4.14) and wait for it to become humid;

— arrange the aggregates on the filter paper (4.15);

— wait until the aggregates have been rewetted by capillarity (for 60 min);

— transfer the aggregates to the 0,05 mm sieve (4.9) immersed in ethyl alcohol (4.1), using a wash bottle (4.10) filled with ethyl alcohol.

Then proceed as specified in 5.5.

5.4.3 Treatment 3: mechanical disaggregation by shaking after immersion in ethyl alcohol

This treatment is used to test the behaviour of wet materials. The purpose of previously immersing the materials in ethyl alcohol (4.1) is to allow their cohesion to be tested when they are wet, avoiding the phenomenon of slaking. Rewetting without slaking can be ensured either by rewetting under vacuum or by immersion in a low-polarity water-miscible liquid. Ethyl alcohol (4.1) is suitable.

The treatment is as follows:

— Weigh 5 g to 10 g of aggregates measuring 3 mm to 5 mm (initial mass) (the larger the percentage of gravel, the larger the test portion);

— pour 50 ml of ethyl alcohol (4.1) into a beaker (4.5);

- immerse the aggregates in ethyl alcohol (4.1) for 30 min;
- remove the ethyl alcohol using a pipette (4.13);
- pour 50 ml of deionized water into an Erlenmeyer flask (4.6);
- transfer the aggregates into the Erlenmeyer flask, using a wash bottle (4.10) containing deionized water;
- make the deionized water up to 200 ml, pouring with the wash bottle against the side of the Erlenmeyer flask;
- manually shake the Erlenmeyer flask (4.6) vigorously, turning it upside down 10 times at 1 s per cycle and with forearms-length amplitude, or shake the Erlenmeyer flask by an end-over-end shaker with a frequency of 1 r/s;
- allow to rest for 30 min;
- remove the excess water using a pipette (4.13);
- transfer the aggregates to the 0,05 mm sieve (4.9) immersed in ethyl alcohol (4.1), using a wash bottle (4.10) filled with ethyl alcohol.

Then proceed as specified in 5.5.

5.5 Measurement of the size distribution of the remaining aggregates

The three measurement steps are as follows.

Step 1: Apply five cycles of the helical movement at 1 s per cycle, using the sieving device (see Figure 1) with the 0,05 mm sieve (4.9) immersed in ethyl alcohol (4.1), on which the disaggregated sample has been placed, in order to carry out an initial granulometric separation. The mesh should remain immersed in alcohol to avoid air bubbles beneath the sieve.

NOTE If no sieving device is available, the same type of movement can be performed manually, imitating the helical movement as closely as possible.

Step 2: Recover the fraction > 0,05 mm in an evaporation dish (4.7), using the wash bottle (4.10) filled with ethyl alcohol (4.1), and dry at 40 °C for 48 h.

Step 3: Then transfer the fraction > 0,05 mm in its dry state to a column of six sieves of 2 mm, 1 mm, 0,5 mm, 0,2 mm, 0,1 mm and 0,05 mm (4.8). Shake the sieve column gently by hand or mechanically to allow the aggregates to spread out across the sieve before weighing the oversize aggregates.

The fraction < 0,05 mm is obtained by subtraction from the initial mass and the percentage of each fraction with respect to initial mass can therefore be calculated.

6 Calculation

6.1 General

Then calculate the mean weighted diameter (MWD) after disaggregation (between 0,025 mm and 3,5 mm) according to Equation (1).

$$\begin{aligned}\text{MWD} &= \sum \left(\bar{d} \times w\right) \Big/ 100 \\ &= \left(3{,}5 \times \left[\% > 2\ \text{mm}\right]\right) + \left(1{,}5 \times \left[\%\ 1\ \text{mm to}\ 2\ \text{mm}\right]\right) + \left(0{,}75 \times \left[\%\ 0{,}5\ \text{mm to}\ 1\ \text{mm}\right]\right) \\ &\quad + \left(0{,}35 \times \left[\%\ 0{,}2\ \text{mm to}\ 0{,}5\ \text{mm}\right]\right) + \left(0{,}15 \times \left[\%\ 0{,}1\ \text{mm to}\ 0{,}2\ \text{mm}\right]\right) \\ &\quad + \left(0{,}075 \times \left[\%\ 0{,}05\ \text{mm to}\ 0{,}1\ \text{mm}\right]\right) + \left(0{,}025 \times \left[\% < 0{,}05\ \text{mm}\right]\right) / 100\end{aligned} \qquad (1)$$

where

$\bar{d}$ is the mean diameter between two sieves;

w is the weighted percentage of the particles retained on the sieve.

The result is expressed in the form of histograms representing the size distribution of the particles for each test or as MWD (see Annex B). Other indices can be calculated from the results obtained for each class. It is also possible to find the mean of the three MWDs to obtain a synthetic value, or to calculate the relationship between the MWDs obtained from different tests to determine the respective share of each mechanism. Numerical histograms or graphical cumulative histograms (similar to those used for particle size distributions) can also be used.

6.2 Corrected MWD for soils with gravels

The presence of gravel in the 2 mm to 5 mm fraction can distort the results. If the percentage of gravel is between 10 % and 40 %, the fraction > 2 mm obtained from the tests should be washed, the gravels retained on the 2 mm sieve after the stable “aggregates” retained on that sieve have been broken down should be weighted and a corrected mean weighted diameter (MWD) without gravel should be calculated. If the percentage of gravel is > 40 %, the structural stability tests are not significant.

7 Additional treatment for dispersible soils

The soils affected by physicochemical dispersion generally exhibit the same particle size distribution for the three treatments with a predominant fraction < 0,05 mm.

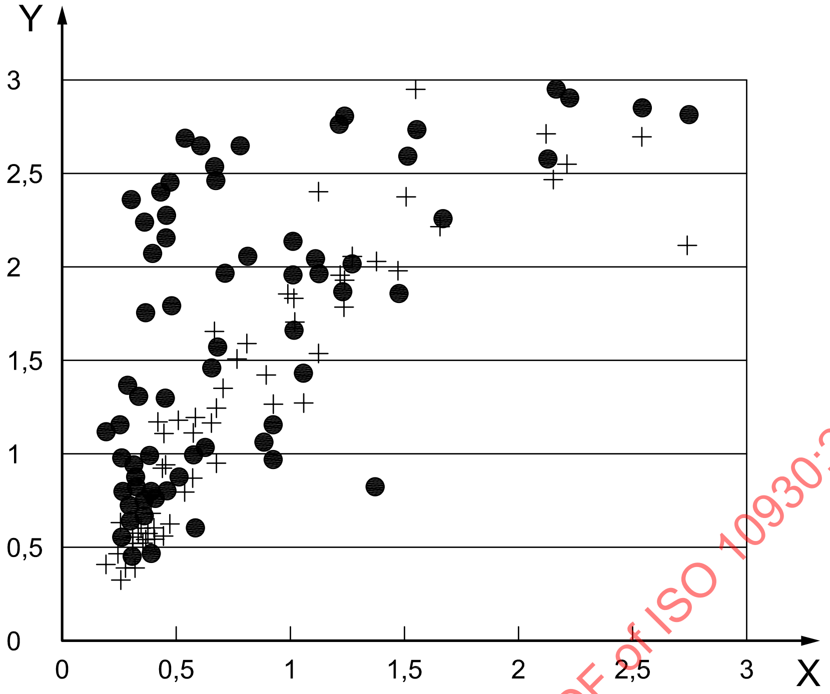
NOTE In this case, it can be useful to measure more accurately the dispersion rate of the material on the suspension obtained for one of the three tests using the pipette method [11] [12] or by laser diffraction analysis.

8 Interpretation of the results

As each of the three treatments corresponds to specific hydric, wetting-speed and applied energy conditions, either the result of one of these treatments or a combination of the three treatments can be used, depending on the context of the analysis.

The values of the MWD from each treatment can be interpreted from Table 1. A high MWD indicates good soil stability and a limited surface crusting and water erosion risk.

NOTE A good correlation was observed between the results of this method and the water erosion measurements [13][14]. Although the results of the three treatments are often intercorrelated (see Figure 2), different classifications of the sets of soils used for the three tests indicate that these soils behave differently depending on the soil/water contact conditions simulated by the three tests.



Key

X mean weighted diameter (MWD) of the test by immersion (fast wetting), in millimetres (mm)

Y mean weighted diameter (MWD) of other tests, in millimetres (mm)

+ slow wetting

● mechanical disaggregation

Figure 2 — Example of results of slow-wetting and mechanical-disaggregation tests compared with the immersion test for different cultivated soils of various soil types from temperate and Mediterranean climates (after References [13] and [14])

Furthermore, due to threshold effects, it is possible that only one of the treatments discriminates well between the samples from a given set of soils. Figure 2 compares the test results. It shows that, in the case of stable soils (MWD > 1,5 obtained from the test by immersion), the range of MWDs is wider than for the other two tests, whereas in the lower stability range (MWD < 1,5 obtained from the test by immersion), the other two tests give a wider spread of values and therefore discriminate better between the soils.

Although the best and easiest way of comparing soils is to calculate the MWD (Table 1), it is sometimes useful to compare certain fractions if specific interpretations are required. For example, 200 µm/250 µm is often considered to be a limit between micro- and macro-aggregates with different properties [15].

Table 1 — Stability classes, surface crusting and water erosion, depending on the MWD after disaggregation

MWD	Stability	Surface crusting	Runoff and interrill erosion
< 0,4 mm	Highly unstable	Systematic	High permanent risk under all topographic conditions
0,4 mm to 0,8 mm	Unstable	Very frequent	Frequent risk in all situations
0,8 mm to 1,3 mm	Moderately stable	Frequent	Variable risk, depending on climatic and topographic parameters
1,3 mm to 2,0 mm	Stable	Occasional	Limited risk
> 2,0 mm	Highly stable	Very rare	Very low risk

9 Test report

The test report shall contain the following information:

a) a reference to this International Standard;

b) a complete identification of the sample;

c) the treatment method used, in accordance with 5.4;

d) the results of the measurements;

e) an interpretation of the results obtained in accordance with Clause 8 and Table 1;

f) any details not specified in this International Standard or which are optional, as well as any factor which may have affected the results.

Annex A
(informative)

Flow diagram of the measurement of aggregate stability

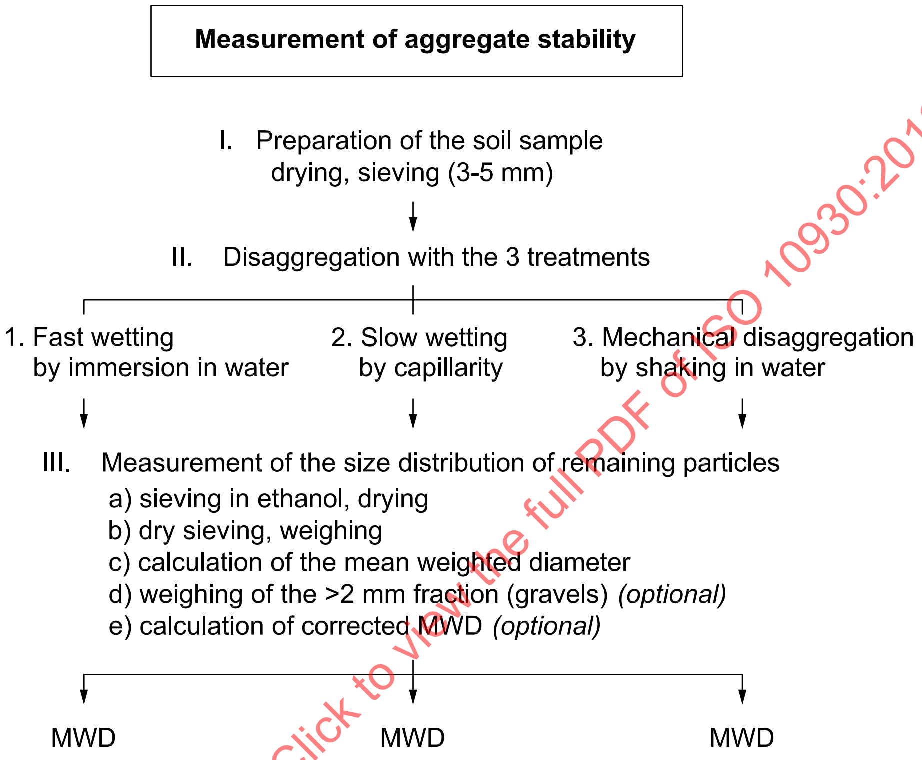
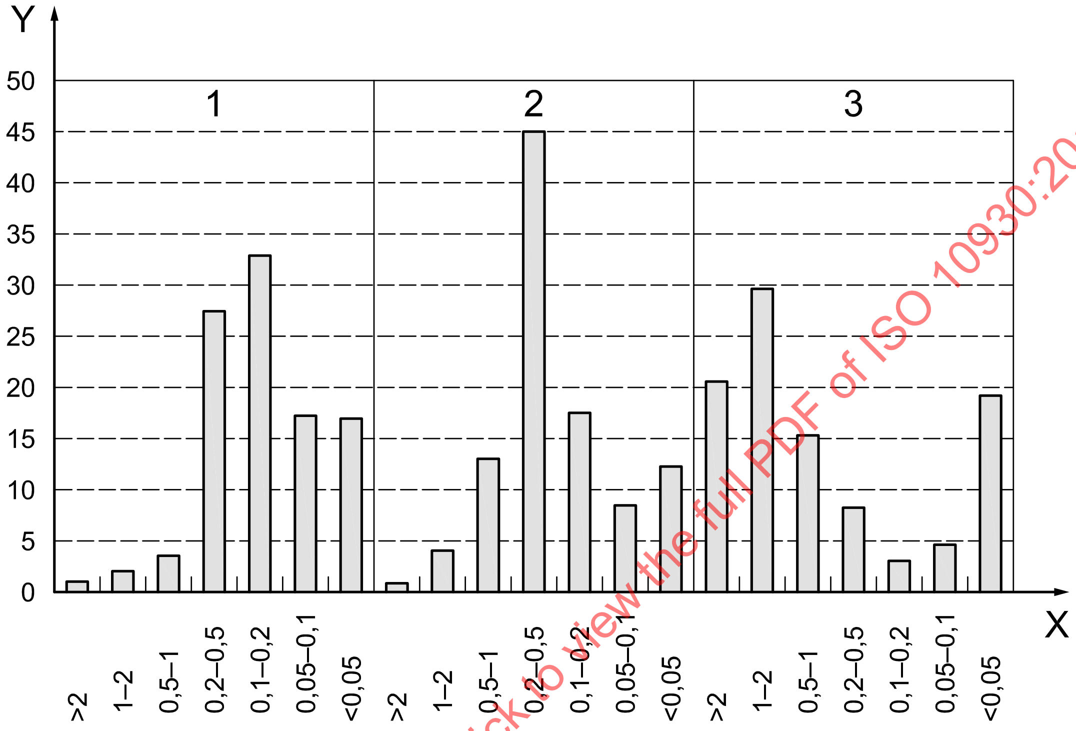


Figure A.1 — Flow of the measurement of aggregate stability

Annex B
(informative)

Examples of the presentation of the test results on the same sample



Key

1 fast wetting
2 slow wetting
3 mechanical disaggregation
X size of particles, in millimetres (mm)
Y weighted particle sizes, as a percentage (%)

Figure B.1 — Detailed test results