BS EN 933-1:2012

BSI Standards Publication

Tests for geometrical properties of aggregates

Part 1: Determination of particle size distribution — Sieving method

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National foreword

This British Standard is the UK implementation of EN 933-1:2012. It supersedes BS EN 933-1:1997, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/502/6, Test methods.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution - Sieving method

Essais pour déterminer les caractéristiques géométriques des granulats - Partie 1: Détermination de la granularité - Analyse granulométrique par tamisage

Prüfverfahren für geometrische Eigenschaften von Gesteinskörnungen - Teil 1: Bestimmung der Korngrößenverteilung - Siebverfahren

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Foreword

This document (EN 933-1:2012) has been prepared by Technical Committee CEN/TC 154 “Aggregates”, the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by July 2012, and conflicting national standards shall be withdrawn at the latest by July 2012.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 933-1:1997.

EN 933 — Tests for geometrical properties of aggregates, consists of the following parts*:*

Part 1: Determination of particle size distribution — Sieving method;

— *Part 2: Determination of particle size distribution — Test sieves, nominal size of apertures;*

— *Part 3: Determination of particle shape — Flakiness index;*

— *Part 4: Determination of particle shape — Shape index;*

— *Part 5: Determination of percentage of crushed and broken surfaces in coarse aggregate particles;*

— *Part 6: Assessment of surface characteristics — Flow coefficient of aggregates;*

— *Part 7: Determination of shell content — Percentage of shells for coarse aggregates;*

— *Part 8: Assessment of fines — Sand equivalent test;*

— *Part 9: Assessment of fines — Methylene blue test;*

— *Part 10: Assessment of fines — Grading of filler aggregates (air jet sieving);*

— *Part 11: Classification test for the constituents of coarse recycled aggregate.*

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1 Scope

This European Standard describes the reference washing and dry sieving method used for type testing and in case of dispute, for determination of the particle size distribution of aggregates. For other purposes, in particular factory production control, other methods may be used, provided that an appropriate working relationship with the reference method has been established. It applies to all aggregates, including lightweight aggregates, up to 90 mm nominal size, but excluding filler.

NOTE 1 The determination of the grading of fillers is specified in EN 933-10 *Assessment of fines — Grading of filler aggregates (air jet sieving)*.

NOTE 2 Dry sieving without washing may be used for aggregates free from particles which cause agglomeration.

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.

EN 932-2, *Tests for general properties of aggregates — Part 2: Methods for reducing laboratory samples*

EN 932-5, *Tests for general properties of aggregates — Part 5: Common equipment and calibration*

EN 933-2, *Tests for geometrical properties of aggregates — Part 2: Determination of particle size distribution — Test sieves, nominal size of apertures*

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

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

3 Terms and definitions

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

3.1
aggregate
granular material used in construction which may be natural, manufactured or recycled

3.2
test portion
sample used as a whole in a single test

3.3
constant mass
mass determined by successive weighings performed at least 1 h apart and not differing by more than 0,1 %

NOTE In many cases constant mass can be achieved after a test portion has been dried for a pre-determined period in a specified oven (see 5.3) at (110 ± 5) ºC. Test laboratories may determine the time required to achieve constant mass for specific types and sizes of sample dependent upon the drying capacity of the oven used.

4 Principle

The test consists of dividing and separating a material into several particle size classifications of decreasing sizes by means of a series of sieves,. The aperture sizes and the number of sieves are selected in accordance with the nature of the sample and the accuracy required.

The method adopted is washing and dry sieving. When washing can alter the physical properties of a lightweight aggregate, dry sieving shall be used and the procedure specified in 7.1 shall not be applied.

The mass of the particles retained on the various sieves is related to the initial mass of the material. The cumulative percentages passing each sieve are reported in numerical form and, when required, in graphical form (see Annex D).

5 Apparatus

Unless otherwise stated, all apparatus shall conform to the general requirements of EN 932-5.

5.1 *Test sieves*, with apertures as specified in EN 933-2 and conforming to the requirements of ISO 3310-1 and ISO 3310-2.

5.2 *Tightly fitting pan and lid*, for the sieves.

5.3 *Ventilated oven*, thermostatically controlled to maintain a temperature of (110 ± 5) ºC, or other suitable equipment for drying the aggregates, if it does not cause any particle size breakdown.

5.4 *Washing equipment*.

5.5 *Balances or scales*, accurate to ± 0,1 % of test portion mass.

5.6 *Trays*, *brushes*.

5.7 *Sieving machine*, (optional).

6 Preparation of test portions

Samples shall be reduced in accordance with EN 932-2 to produce the required number of test portions.

NOTE It may be necessary to moisten samples containing substantial amounts of fines before reduction to minimise segregation and loss of dust.

The size of each test portion shall be as specified in Table 1.

Table 1 — Minimum size of test portions

Aggregate size D (maximum) mm	**mass of aggregates** kg	**volume of lightweight aggregates (litres)**
90	80	-
32	10	2,1
16	2,6	1,7
8	0,6	0,8
≤ 4	0,2	0,3

NOTE 1 For aggregates of other sizes below 90 mm, the minimum test portion mass may be interpolated from the masses given in Table 1 using the following formulae: $M = (D/10)^2$

where M = minimum mass of test portion in kg

D = aggregate size in mm

NOTE 2 The precision of the test method may be reduced if the test portion size is less than the value in Table 1. In such a case, the test portion size should be stated in the test report (9.2).

NOTE 3 For aggregates of particle density higher than 3,00 Mg/m^3 (see EN 1097-6), an appropriate correction should be applied to the test portion masses given in Table 1 based on the density ratio, in order to produce a test portion of approximately the same volume as those for aggregates of normal density.

NOTE 4 For lightweight aggregates complying with EN 13055, use the volume column to choose the appropriate minimum size of test portions. The volumes for other aggregate sizes may be interpolated.

Sample reduction shall yield a test portion of size larger than the minimum but not of an exact predetermined value.

Dry the test portion by heating at a temperature of (110 ± 5) ºC to constant mass. Allow to cool, weigh and record the mass as M_1.

For some types of aggregate, drying at 110 ºC binds particles together sufficiently strongly to prevent separation of single particles during subsequent washing and/or sieving procedures. For such aggregates the procedure given in Annex B shall be adopted.

For all-in aggregates with D equal to 31,5 mm or larger, the procedure described in Annex A may be used.

7 Procedure

7.1 Washing

Place the test portion in a container and add sufficient water to cover the test portion.

NOTE 1 A storage period of 24 h under water is helpful in breaking down lumps. A dispersion agent may be used.

Agitate the sample with sufficient vigour to result in complete separation and suspension of the fines.

Wet both sides of a 0,063 mm sieve reserved for use in this test only, and fit a guard sieve (e.g. 1 mm or 2 mm) on top. Mount the sieves in such a way that the suspension passing the test sieve can be run to

waste or, when required, collected in a suitable vessel. Pour the contents of the container on to the top sieve. Continue washing until the water passing the 0,063 mm test sieve is clear.

NOTE 2 Care should be taken to prevent overloading, overflowing or damaging the 0,063 mm test sieve or the guard sieve. For some aggregates, it will be necessary to pour only the suspended fines from the container onto the 0,063 mm guarded test sieve, continuing to wash the coarse residue in the container and decanting the suspended fines onto the guard sieve until the water passing the 0,063 mm test sieve is clear.

Dry the residue retained on the 0,063 mm sieve at (110 ± 5) ºC to constant mass. Allow to cool, weigh and record as M_2.

7.2 Sieving

Pour the washed and dried material (or directly the dry sample) into the sieving column. The column comprises a number of sieves fitted together and arranged, from top to bottom, in order of decreasing aperture sizes with the pan and lid.

NOTE 1 Experience has shown that washing does not necessarily remove all the fines. It is therefore necessary to incorporate a 0,063 mm test sieve in the series.

Shake the column, manually or mechanically. Then remove the sieves one by one, commencing with the largest aperture size opening. Shake each sieve manually ensuring no material is lost by using a pan and lid for example.

NOTE 2 The effectiveness of mechanical sieving is influenced by the aggregate type, the sieving time, the loading on the sieve and the parameters of the shaking movement such as amplitude and frequency. The mechanical sieving time should hence be carefully chosen.

Transfer all the material which passes each sieve onto the next sieve in the column before continuing the operation with that sieve. Sieve overloading shall be avoided.

NOTE 3 To avoid overloading of sieves, the fraction of normal weight aggregates retained at the end of the sieving operation on each sieve (expressed in grams) should not exceed:

$$\frac{A \times \sqrt{d}}{200}$$

where

A is the area of the sieve, in square millimetres;

d is the aperture size of the sieve, in millimetres.

If overloading occurs, one of the following procedures shall be used:

a) divide the fraction into smaller portions and sieve these one after the other.

b) divide the portion of the sample passing the next largest sieve with the aid of a sample divider or by quartering, and continue the sieve analysis on the reduced test portion, making due allowance in subsequent calculations for the reductions.

The sieving process shall be considered as finished when additional sieving does not lead to a change of mass of the retained material on any sieve by more than 1,0 % by mass.

NOTE 4 Depending on the aggregate characteristics, the sieving process may be considered completed when the retained material does not change more than 1,0 % during 1 min.

NOTE 5 For lightweight aggregates, no more than one layer of particles should be retained on each sieve at the end of the sieving operation.

7.3 Weighing

Weigh the retained material for the sieve with the largest aperture size and record its mass as R_1.

Carry out the same operation for the sieve immediately below and record the mass retained as R_2.

Continue with the same operation for all the sieves in the column, in order to obtain the masses of the various lots of retained materials and record these masses as R_3, R_4, R_i, R_n.

Weigh the screened material, if any, remaining in the pan and record its mass as P.

8 Calculation and expression of results

8.1 Calculations

Record the various masses on a test data sheet, an example of which is given in Annex C.

Calculate the mass retained on each sieve as a percentage of the original dry mass M_1.

Calculate the cumulative percentage of the original dry mass passing each sieve down to the 0,063 mm sieve exclusive.

Calculate the percentage of fines f passing the 0,063 mm sieve in accordance with the following equation:

$$f = \frac{(M_1 - M_2) + P}{M_1} \times 100$$

where

M_1 is the dried mass of the test portion, in kilograms;

M_2 is the dried mass of the residue retained on the 0,063 mm sieve, in kilograms;

P is the mass of the screened material remaining in the pan, in kilograms.

For dry sieving $f = \frac{100\,P}{M_1}$

8.2 Validating the results

If the sum of the masses R_i and P differs by more than 1 % from the mass M_2, the test shall be repeated.

8.3 Precision

The following precision values have been issued from the document "*The proposed CEN method for the determination of the particle size distribution of aggregates. Sieve test on sand. Results of the 1996/7 Cross-Testing Experiment*" of the European Project No. 134.

The repeatability r_1 and reproducibility R_1 values have been determined on the basis of two repetitions of tests carried out on each of the three fine aggregate fractions, a 0/0,4 and two 0/2 mm fractions, in 17 laboratories from nine European countries. Each laboratory has prepared (using a riffle box) and successively tested two different masses of samples, 200 g and 30 g.

For any sieve size of the basic set comprised between 0,063 and 4 mm, the precision values can be stated as follows:

$$r_1 = 0{,}042 \sqrt{\{X\,(100{,}0 - X)\}}$$

$$R_1 = 0{,}086 \sqrt{\{X\,(100{,}0 - X)\}}$$

where

X represents the average of the cumulative percent passing the actual sieve size.

It is highlighted that precision is highly dependent on the loading of individual sieves, overloaded sieves leading to degraded precision data and lightly loaded sieves leading to better precision data.

9 Test report

9.1 Required data

The test report shall include the following information:

a) reference to this European Standard;

b) identification of the sample;

c) identification of the laboratory;

d) sample reception date;

e) method of analysis (washing and sieving or dry sieving);

f) cumulative percentage of the mass of the test portion passing each of the sieves to the nearest single decimal place for the 0,063 mm sieve and to the nearest whole number for other sieves.

9.2 Optional data

The test report may include the following information:

a) name and location of the sample source;

b) description of the material and of the sample reduction procedure;

c) graphical presentation of results (see Annex D);

d) sampling certificate;

e) size of test portion;

f) date of test.

Annex A
(normative)

Alternative test method for all-in aggregate with $D \geq 31,5$ mm

A.1 Principle

This alternative test method uses washing and dry sieving in the same way as the procedure described in Clause 7, but an alternative procedure is used to prepare the test portion.

The test portion is first divided using a 16 mm size test sieve before it is dried. The dry subsample retained on the 16 mm size test sieve is then washed on the 0,063 mm size and the 16 mm size test sieves, then dried and sieved again.

The subsample passing the 16 mm size test sieve is also dried and any particles in the 0,063/16 mm size fraction from the first subsample are added to it. The amount of dry particles passing the 16 mm size test sieve is then reduced in size. This reduced subsample is then washed on the 0,063 mm size test sieve, dried and sieved again.

Modified calculations are used to allow for the additional stages.

NOTE 1 This alternative method introduces additional steps to the main method, but reduces the amount of smaller size material that has to be washed, dried and sieved.

NOTE 2 This method should not be used as an alternative to the 'dry sieving without washing' method.

A.2 Apparatus

The apparatus shall be as specified in Clause 5, with the following addition:

A.2.1 *Perforated plate test sieve*, 16 mm size, used to divide the initial test portion before drying.

A.3 Procedure

A.3.1 Preparation of the initial test portion

Reduce the size of the laboratory sample using the procedures in Clause 6 to prepare an initial test portion with a size as specified in Table 1.

Separate the initial test portion using the 16 mm size test sieve. If necessary, wash the sieve to ensure that particles are not lost at this stage.

NOTE The separation stage should be carried out with the aggregate in the 'as received' condition. However, it may be appropriate to allow some drying of the laboratory sample to remove excess water.

Dry the particles retained on the 16 mm size test sieve (*MC*) to constant mass, as specified in Clause 6. Allow to cool, weigh and record the mass as MC_1.

Dry the particles passing the 16 mm size test sieve (*MF*) to constant mass, as specified in Clause 6. Allow to cool, weigh and record the mass as MF_1.

A.3.2 First washing stage – particles retained on the 16 mm size test sieve

Wash the dried particles retained on the 16 mm size test sieve (*MC*) using the 16 mm size test sieve, a 0,063 mm size test sieve and the procedures specified in 7.1.

Dry the washed particles retained on the 16 mm size test sieve to constant mass, as specified in 7.1. Allow to cool, weigh and record the mass as MC_2.

Dry the washed particles passing the 16 mm size test sieve and retained on the 0,063 mm size test sieve to constant mass, as specified in 7.1. Allow to cool, weigh and record the mass as MC_3.

A.3.3 First dry sieving stage – particles retained on the 16 mm size test sieve

Dry sieve the dried particles retained on the 16 mm size test sieve (with mass MC_2) using the procedures in 7.2. Use the 16 mm size test sieve; the appropriate test sieves larger than 16 mm size; and a pan.

Record the mass of material retained on the 16 mm size test sieve and the larger test sieves, as specified in 7.3.

Retain any particles that pass the 16 mm size test sieve and record their mass as MC_4.

A.3.4 Preparation stage – dry subsample passing the 16 mm size test sieve

Add the particles in the 0,063/16 mm size fraction from the particles initially retained on the 16 mm size test sieve (with mass MC_3 and mass MC_4) to the particles from the initial test portion that passed the 16 mm size test sieve (*MF*). Mix, weigh and record the total mass as MF_2.

NOTE Mass MF_2 should not be more than 10 g different from mass (MF_1 + MC_3 + MC_4).

Reduce the combined dry subsample to at least the size specified in Table 1 for aggregate size *D* equals 16 mm. Record the mass of the reduced subsample as MF_3.

A.3.5 Second washing stage – reduced subsample passing the 16 mm size test sieve

Wash the dried particles passing the 16 mm size test sieve (with dry mass MF_3) using a 0,063 mm size test sieve and the procedures specified in 7.1.

Dry the washed particles retained on the 0,063 mm size test sieve to constant mass, as specified in 7.1. Allow to cool, weigh and record the mass as MF_4.

A.3.6 Second dry sieving stage – reduced subsample passing the 16 mm size test sieve

Dry sieve the dried particles in the 0,063/16 mm size fraction (with dry mass MF_4) using the procedures in 7.2.

Record the mass of material retained on each test sieve as specified in 7.3, using the notation RF_3, RF_4, RF_n,; and the mass passing the 0,063 mm test sieve as *PF*.

A.4 Calculation and expression of results

A.4.1 Original dry mass

Use the values recorded in A.3.1 to calculate the initial dry mass M_1 using the following equation:

$$M_1 = MC_1 + MF_1 \quad (1)$$

where

M_1 is the dried mass of the initial test portion;

MC_1 is the dried mass of the initial test portion retained on the 16 mm size test sieve;

MF_1 is the dried mass of the initial test portion passing the 16 mm size test sieve.

A.4.2 Mass retained on the sieves at the first dry sieving stage

Use the values recorded in A.3.3 to calculate the mass retained on each sieve R_n as a percentage of the initial dry mass M_1.

A.4.3 Mass retained on the sieves at the second dry sieving stage

Use the values recorded in A.3.6 to calculate the equivalent masses in the initial dried test portion using the following equations:

$$P = PF \times MF_2/MF_3 \quad (2)$$

and

$$R_n = RF_n \times MF_2/MF_3 \quad (3)$$

where

MF_2 is the dried mass of the initial test portion passing the 16 mm size test sieve;

MF_3 is the dried mass of the reduced subsample passing the 16 mm size test sieve;

P is the equivalent dried mass of sieved material retained in the pan;

PF is the dried mass of sieved material retained in the pan;

R_n is the equivalent dried mass of sieved material retained on each sieve;

RF_n is the dried mass of sieved material retained on each sieve.

A.4.4 Mass of fines passing the 0,063 mm sieve

Use the values recorded in A.3.1 and A.3.2 to calculate the mass of fines from the particles initially retained on the 16 mm size test sieve FC_1 using the following equation:

$$FC_1 = MC_1 - (MC_2 + MC_3) \quad (4)$$

where

FC_1 is the mass of fines from the particles initially retained on the 16 mm size test sieve;

MC_1 is the dried mass of the initial test portion retained on the 16 mm size test sieve;

MC_2 is the dried mass of the particles retained on the 16 mm size test sieve after the first washing stage;

MC_3 is the dried mass of the particles passing the 16 mm size test sieve after the first washing stage.

Use the values recorded in A.3.4 and A.3.5 to calculate the equivalent mass of fines from the particles initially passing the 16 mm size test sieve FF_1 using the following equation:

$$FF_1 = MF_2/MF_3 \times (MF_3 - MF_4) \quad (5)$$

where

FF_1 is the mass of fines from the particles initially retained on the 16 mm size

MF_2 is the dried mass of the initial test portion passing the 16 mm size test sieve;

MF_3 is the dried mass of the reduced subsample passing the 16 mm size test sieve;

MF_4 is the dried mass of the particles after the second washing stage.

Calculate the total equivalent mass of fines f using the following equation:

$$f = FC_1 + FF_1 + P \quad (6)$$

where

f is the total equivalent mass of fines

A.4.5 Particle size distribution

Use the values of mass and equivalent mass retained on each sieve from A.4.2 and A.4.3 to calculate the cumulative percentage of the initial dry mass (M_1) passing each sieve.

Use the value of the total equivalent mass of fines from A.4.4 to calculate the percentage of fines as a percentage of the initial dry mass M_1.

A.4.6 Validating the results

If the sum of the masses R_n and f differs by more than 1 % from the initial dry mass M_1 the test shall be repeated.

Annex B
(normative)

Test method for aggregates unsuitable for oven-drying

For aggregates unsuited to oven drying at 110 ºC the required number of test portions shall be obtained in duplicate and their masses recorded. The moisture content of one of each duplicate pair of test portions shall be determined by oven drying at (110 ± 5) ºC.

The other test portion shall be tested by the washing and sieving method without pre-drying. The initial dry mass of this second test portion shall be calculated on the assumption that the duplicate test portions have identical moisture contents and recorded as M_1'.

Annex C
(informative)

Example of test data sheet

PARTICLE SIZE DISTRIBUTION – SIEVING METHOD EN 933-1	**Laboratory:**
Identification of the sample	Sample reception Date : Operator :
Method used: washing and sieving / dry sieving (delete as appropriate)	

Total dry mass, M_1 = (or M_1' = see Annex B)

Dry mass after washing, M_2 =

Dry mass of fines removed by washing, $M_1 - M_2$ =

Sieve aperture size mm	**Mass of material retained R_i** kg	**Percentage of material retained $100 \times R_i/M_1$** (% by mass)	**Cumulative percentages passing $100 - \Sigma (100 \times R_i/M_1)$** (% by mass)
	R_1 R_2		(to nearest whole number)
Material in the pan	P		

Percentage fines passing the 0,063 mm sieve, $f = \dfrac{(M_1 - M_2) + P}{M_1} \times 100$

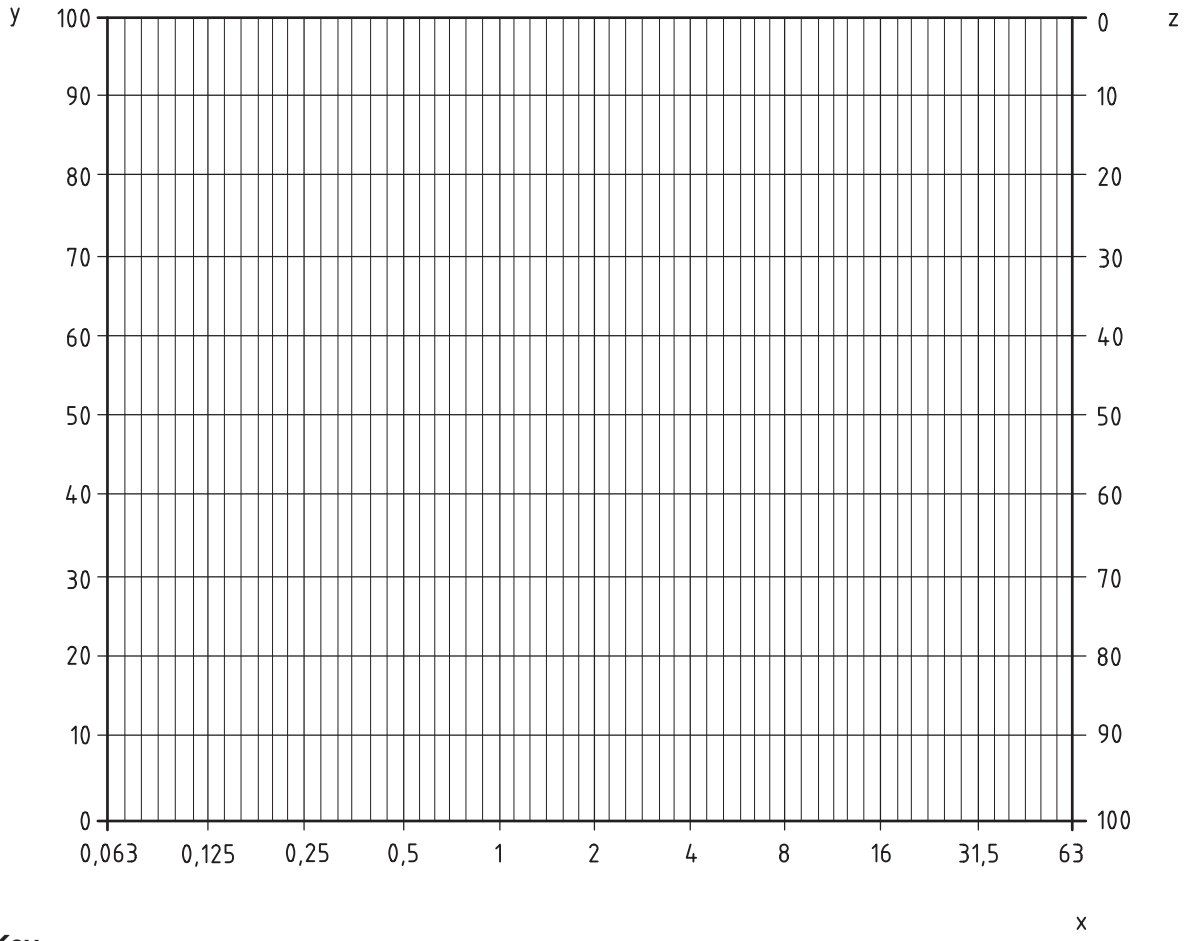
For dry sieving, $f = \dfrac{100\ P}{M_1}$ (to the nearest single decimal)

$\Sigma R_i + P =$	Remarks :
$\dfrac{M_2 - (\sum R_i + P)}{M_2} \times 100 =$ < 1 %	

The dry mass of the test portion should be recorded as M_1 when determined directly or as M_1' when calculated from a duplicate test portion.

Annex D
(informative)

Graphical presentation of results



Key

y Cumulative % passing
x Sieves of square aperture (mm)
z Cumulative % retained

Figure D.1 — Graphical presentation of results

Bibliography

EN 1097-6, *Tests for mechanical and physical properties of aggregates — Part 6: Determination of particle density and water absorption*

EN 13055, *Lightweight aggregates*

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