BRITISH STANDARD

BS 812-121: 1989

Testing aggregates —

Part 121: Method for determination of soundness

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee (CAB/-) to Technical Committee CAB/2, upon which the following bodies were represented:

Aggregate Concrete Block Association
Association of Consulting Engineers
Association of Consulting Scientists
Association of Lightweight Aggregate Manufacturers
Brick Development Association
British Aggregate Construction Materials Industries
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British Ceramic Research Ltd
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Mortar Producers' Association Limited
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Society of Chemical Industry

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Contents

Foreword

This Part of BS 812 has been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee. It forms part of a general revision of the 1975 edition of BS 812. As each test, or collection of tests, is prepared it is intended to issue it as a separate Part or Section of this standard.

This Part of BS 812 contains the test procedures for the determination of the "soundness" of aggregates. Soundness tests were not included in previous editions of BS 812 but have now been included because there is a need, in some circumstances, for a test to identify certain aggregates which are apparently suitable for use, when tested by the test procedures described in other Parts of this standard (e.g. the mechanical strength tests described in BS 812-110[1)], BS 812-111[1)], BS 812-112[1)] and BS 812-113[1)], but which fail in service.

The definitive method is based on finding the degree of degradation that occurs when test portions of an aggregate in the size range 10.0 mm to 14.0 mm are subjected to cycles of immersion in saturated magnesium sulphate solution followed by oven-drying. The degree of degradation is expressed as the magnesium sulphate soundness value. Appendix A recommends procedures for carrying out the test on test portions of aggregate in size ranges other than the one used in the definitive method.

The sulphate soundness test has a long history. It is reported that it first appeared in France around 1818 as a test for classifying the resistance of building stone to deterioration under freeze-thaw conditions. In North America it has been incorporated in the ASTM book of standards, designation C88, since 1931. It did not come into widespread use in the United Kingdom until the late 1970s.

Current experience of the use of the test in the UK relates mainly to aggregates in materials forming the surfacing of airfields/airports and of highway pavements.

It is intended that advice on the applicability of this test for given situations and on the selection of limits will be included in future Parts of this standard. Similarly it is intended that advice on calibration will be included in Part 100[1)].

It is intended that other British Standards should call up BS 812 test methods as the basis for compliance. Nevertheless it is *not* intended that all aggregates should be subjected regularly to all the listed tests. Specifications in other standards should call up only relevant test methods.

Reference should be made to BS 812-101 for general guidance on testing aggregates, precision of test methods and variance arising from sampling errors.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

[1)] In preparation.

1 Scope

This Part of BS 812 describes the method for determining the soundness of aggregates by subjecting the aggregate to cycles of immersion in a saturated solution of magnesium sulphate followed by oven-drying. The method is applicable to aggregate passing a 14.0 mm test sieve but is retained on a 10.0 mm test sieve.

NOTE 1 The majority of aggregates can be tested for soundness using this method. Precision has been established for the rock types listed in Table 1. The test may not be suitable for all rock types and reservations have been expressed elsewhere in respect of some carbonate aggregates and some aggregates having a high proportion of magnesium bearing minerals or of cryptocrystalline quartz.

For other size fractions, a recommended method is described in appendix A.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 812 the definitions given in BS 812-101 and BS 812-102 apply.

3 Principle

A sample of aggregate in the size range 10.0 mm to 14.0 mm is subjected to five cycles of: immersion in a saturated solution of magnesium sulphate; followed by oven-drying at 105 °C to 110 °C. This subjects the sample of aggregate to the disruptive effects of the repeated crystallization and rehydration of magnesium sulphate within the pores of the aggregate. The extent of the disruption is dependent upon the soundness of the aggregate. The degree of degradation arising from the disruptive effects is measured by the extent to which material finer than 10.0 mm in particle size is produced.

4 Sampling

The sample to be used for the test (the laboratory sample) shall be taken in accordance with the procedure described in clause **5** of BS 812-102:1984.

5 Apparatus

5.1 *Test sieves*, with square hole perforated plate of sizes 14.0 mm, 10.0 mm and 6.3 mm, and a woven wire 3.35 mm test sieve. The test sieves shall comply with BS 410.

5.2 *A balance*, of at least 10 kg capacity, accurate to 5 g.

5.3 *A balance*, of at least 500 g capacity, accurate to 0.05 g.

5.4 *At least two brass or stainless steel mesh baskets* for immersing aggregate specimens in the solution (see **6.3**), which permit free access to the solution and drainage the solution from the aggregate under test. A suitable design is shown in Figure 1.

5.5 *Containers*, of diameter such that the baskets listed in **5.5** can be readily placed in and out, and with a volume at least five times the volume of the immersed aggregate (see note).

NOTE Polypropylene beakers of 2 L capacity make suitable containers.

5.6 *A means of maintaining the temperature of the solution*, inside the containers, at 20 ± 2 °C (see note).

NOTE A tank of the type used for curing concrete cubes has been found to be suitable.

5.7 *An oven*, capable of maintaining a temperature within the range 105 °C to 110 °C, with fan-assisted air circulation, and ventilation by convection. The oven shall be capable of being heated continuously at 105 °C to 110 °C, and the rate of evaporation at this range of temperature shall be at least 100 g over 4 h, during which time the doors of the oven shall be kept closed. This rate shall be determined by the loss of water from 1 L squat beakers (Griffin low-form type), each initially containing 500 g of distilled water, at a temperature of 20 ± 2 °C, placed at each corner and at the centre of each shelf of the oven. The evaporation requirement is to apply to each test location with the oven empty except for beakers of water (see note).

NOTE The oven should not be used for any other purposes while in use for the test unless it has been shown previously that the above performance requirement has also been achieved with the oven loaded in a similar manner to that proposed.

5.8 *A density hydrometer*, complying with BS 718:1979 type M50, graduated at 20 °C for medium surface tension 55 mN/m, to measure densities in the range 1.284 g/mL to 1.300 g/m L to an accuracy of 0.001 g/m L (see note).

NOTE A satisfactory method of using the hydrometer is to decant the solution under test into a gas jar, measure the density, and then to return the solution to its original container.

5.9 *A desiccator*, large enough to contain at least two of the baskets listed in **5.4**.

6 Reagents

6.1 *A supply of distilled water or deionized water*.

6.2 *Barium chloride*, 5 % solution. Dissolve 5 g of barium chloride in 100 mL of distilled or deionized water.

6.3 *A saturated solution of magnesium sulphate*.

NOTE A minimum quantity of 3 L is required for each test.

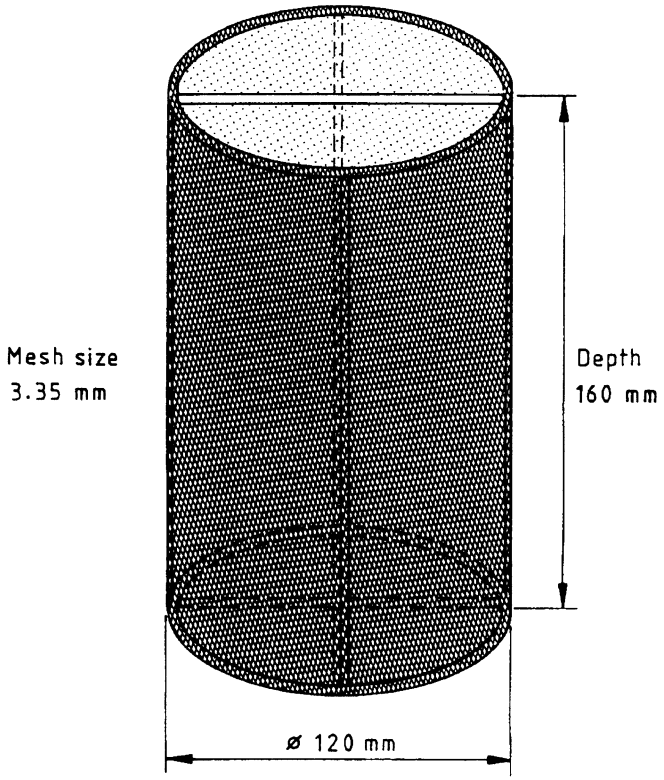
6.3.1 For the preparation of this solution use crystalline magnesium sulphate heptahydrate ($MgSO_4.7H_2O$) general purpose reagent (GPR) grade (see note).

NOTE Magnesium sulphate B.P. (Epsom salts), obtainable from pharmaceutical chemists, is suitable.

6.3.2 Prepare the solution by slowly adding 1 500 g of the crystalline salt to each litre of water. During preparation maintain the temperature at between 25 °C and 30 °C and stir thoroughly during the addition of crystals. After preparation lower the temperature to 20 ± 2 °C maintain at this temperature for at least 48 h before use (see note).

NOTE According to published data on the solubility of magnesium sulphate a saturated solution at 20 °C contains a 25.2 % concentration of $MgSO_4$(*m*/*m*)which has a relative density (20/4) of 1.290. The theoretical minimum mass of crystalline $MgSO_4.7H_2O$ required to produce this degree of saturation, in 1 L of ion-free water at 20 °C, is 1 092 g. The mass of 1 500 g is intended to ensure that excess crystals are present in the solution during preparation and all subsequent stages of the tests, but further quantities should be added if necessary.

6.3.3 Prior to use check that the solution has achieved a density of 1.292 ± 0.008 g/mL, using the density hydrometer, (see note to **5.8**). If not, reject the solution and repeat stages **6.3.2** and **6.3.3** using fresh crystals.



NOTE. The dimensions given are not critical and are intended only as a guide. The main requirements are that the baskets should be large enough to allow the specimens to be totally immersed and to permit free circulation of the magnesium sulphate solution. The mesh should be strong enough to hold the aggregate but not so coarse that particles can pass through at the start of the test.

Figure 1 — Basket for magnesium sulphate soundness testing

7 Preparation of test portions and specimens

7.1 Reduce the laboratory sample by the procedures described in clause **6** of BS 812-102:1984 to produce two test portions of sufficient mass such that each will produce a minimum mass of 500 g of the 10.0 mm to 14.0 mm size range when processed as described in **7.3**.

7.2 Dry each test portion in the oven at 105 °C to 110 °C to constant mass and allow to cool in the desiccator to laboratory temperature.

7.3 Sieve each dried test portion using the 14.0 mm and 10.0 mm test sieves to obtain two test specimens of material, of 500 g approximate mass, in the size range 10.0 mm to 14.0 mm.

7.4 Wash the test specimens with distilled water until they are seen to be free from dust, allow to drain and dry in the oven at 105 °C to 110 °C for at least 24 h. Remove from the oven and allow to cool in the desiccator.

7.5 Repeat the sieving of each specimen using the 14.0 mm and 10.0 mm sieves to ensure that only material in this size range is used.

7.6 Weigh out between 420 g and 430 g of each test Specimen and record the masses (M_1) to the nearest 0.1 g. Transfer the specimens to two labelled mesh baskets.

NOTE In order to reduce to a minimum any loss by abrasion, take care to avoid shaking the specimens in their baskets at all subsequent stages.

7.7 Follow the procedure described in clause **8** for each specimen.

8 Procedure

8.1 Immerse the basket, containing the specimen under test, in a container holding the saturated solution of magnesium sulphate, so that the aggregate is completely immersed, for a period of 17 h ± 30 min. Suspend each basket so that there is a minimum of 20 mm of solution above the specimen and 20 mm separation from any salt cake accumulation or from any other basket. Take particular care during the process of immersion to ensure that no whole piece of aggregate is lost from the basket. Cover the container holding the solution and the test specimen to reduce evaporation and to prevent ingress of foreign matter.

NOTE Clock glasses are suitable covers.

8.2 At the end of the immersion period remove the basket from the solution, cover the container and leave the basket to drain for a period of 2 h ± 15 min. Place the basket in the oven maintained at a temperature of 105 °C to 110 °C for at least 24 h. Remove the basket from the oven and leave to cool to laboratory temperature for 5 h ± 15 min.

8.3 Prior to the next immersion break up any salt cake which may have accumulated at the bottom of the container, stir the solution thoroughly with a glass rod and allow to settle for 30 min. Check that the density of the solution in the container is still in the required range and if it is not replace it with unused saturated solution of magnesium sulphate.

NOTE In cases where severe disintegration of the aggregate occurs during the course of the test the relative density recorded may not accurately reflect the degree of saturation of the solution, because of the suspended fines or ion-exchange effects. Where the density falls outside the range given in **6.3.3** the test procedure calls for replacement with a fresh solution of magnesium sulphate.

8.4 Immerse the basket in the saturated solution of magnesium sulphate and repeat the process of immersion, drainage, oven-drying, cooling and agitation described in **8.1** to **8.3** until five cycles have been completed, each cycle taking 48 ± 2 h. When scheduling the tests, a nominal value of 24 h is used for the oven-drying period.

8.5 When the specimen has cooled after the last cycle of the test, wash the aggregate in the basket with water until it is free of magnesium sulphate. Check that no magnesium sulphate remains by adding a few drops of the barium chloride solution to a 10 mL aliquot of the washings and comparing the turbidity of this with the turbidity of an equal volume of fresh tap water.

8.6 Dry the specimen in an oven at 105 °C to 110 °C to constant mass and allow to cool in the desiccator to laboratory temperature. Hand sieve the specimen on a 10.0 mm sieve and record the mass (M_2) of material retained on the sieve to the nearest 0.1 g.

9 Calculation and expression of test results

9.1 Calculate the soundness value S (in %) of each specimen from the following equation, recording each value to the first decimal place.

$$S = 100\ M_2/M_1$$

where

M_1 is the initial mass of the test specimen (in g);

M_2 is the mass of material retained on the 10.0 mm sieve at the end of the test (in g).

9.2 Calculate the mean of the two results obtained to give the magnesium sulphate soundness value (MSSV) to the nearest whole number.

10 Precision

10.1 A precision experiment was carried out involving ten laboratories. Details of the experiment and the precision data are given in appendix B.

10.2 Uses of precision data are described in clause **5** of BS 812-101:1984.

11 Test report

The test report shall affirm that the soundness, as measured by the magnesium sulphate soundness value, was determined in accordance with this Part of BS 812, and the following information shall be given.

a) Sample identification and sample description including rock type and aggregate size.

b) Aggregate size fractions.

c) The magnesium sulphate soundness value and the individual soundness values of the two specimens.

If a certificate of sampling is available a copy shall be included with the report.

Appendix A Recommended procedure for determining the magnesium sulphate soundness value for other size fractions of aggregate

A.1 General

When required, or if the definitive size fraction passing the 14 mm test sieve and retained on a 10 mm sieve is not available, tests may be made on aggregates of other sizes which pass a 28.0 mm test sieve and are retained on a 300 μm test sieve.

Because of lack of experience of testing sizes other than the definitive size fraction, it has not been possible to give any positive indication as to how the results obtained on other sizes would compare with those obtained by the standard test procedures.

A.2 Apparatus and reagents

A.2.1 *General.* The apparatus and reagents are as described in clauses **5** and **6** with the additional apparatus given in **A.2.2** and **A.2.3**.

A.2.2 *Test sieves,* of appropriate sizes, as given in Table 1. The test sieves shall comply with BS 410.

A.2.3 *Wire mesh baskets,* of appropriate size, as shown in Table 1.

A.3 Preparation of test portions and specimens

Follow the procedure described in clause **7**, using the appropriate mass of test specimen, sieves and mesh baskets as described in Table 1, according to the size of aggregate under test.

A.4 Procedure

Follow the procedure described in clause **8**. At the end of the procedure hand sieve the specimen on the appropriate sieve.

A.5 Calculation and expression of results

Follow the general procedure given in clause **9**.

A.6 Test report

The test report shall contain the information specified in clause **11**.

Appendix B Details of the evaluation of precision data

B.1 The precision data given in Table 2 were determined from an experiment conducted in 1985/86 involving ten laboratories. The experiment was designed, and the data analysed, following the principles set out in BS 5497-1.

B.2 The materials consisted of 10 t lots, from which 100 kg laboratory samples were taken according to BS 812-102. Two laboratory samples were then selected at random and sent to each laboratory. The laboratories produced two test portions from each laboratory sample by following the procedure given in **6.4** of BS 812-102:1984. (The same materials were used to obtain precision data on several other tests.)

B.3 The tests for outliers given in BS 5497-1 were applied to the test results. Two laboratory averages were deleted as outliers.

Table 1 — Recommended test sieves, mesh baskets and mass of specimens for testing aggregates outside the size range 10.0 mm to 14.0 mm

Size fraction	Mass of test specimen	Test sieve		Mesh baskets		
		Passing	Retained	Mesh size	Height	Diameter
	g	mm	mm	mm	mm	mm
Larger than 14.0 mm	800–830	28.0	20.0	3.35	160	120
	600 – 630	20.0	14.0	3.35	160	120
10.0 mm to 14.0 mm	400 – 420	14.0	10.0	3.35	160	120
Smaller than 10.0 mm	300 – 310	10.0	6.30	1.18	120	95
	200 – 210	6.30	5.00	1.18	120	95
	200 – 210	5.00	3.35	0.60	120	95
	200 – 210	3.35	2.36	0.60	120	95
	100 – 110	2.36	1.18	0.15	80	65
	100 – 110	1.18	0.60	0.15	80	65
	100 – 110	0.60	0.30	0.15	80	65

Table 2 — Precision data for the magnesium sulphate soundness value $\bar{x}$ = average MSSV at given statistical levels

$\bar{x}$	r_1	R_1	R_2	$\sqrt{V_r}$	$\sqrt{V_L}$	$\sqrt{V_s}$	Rock type used in precision exercise
%	%	%	%	%	%	%	
29.1	7.3	19.6	19.8	2.61	6.47	1.06	Oolitic limestone
61.8	10.7	17.8	19.4	3.80	5.07	2.75	Lithic sandstone
80.9	9.1	16.4	16.5	3.25	4.86	0.59	Quartz dolerite
91.0	5.2	8.2	8.2	1.86	2.27	0.00	Olivine basalt
94.5	3.7	5.7	5.9	1.33	1.55	0.53	Shelly limestone
95.6	4.7	6.8	9.7	1.69	1.75	2.48	Olivine basalt
96.4	3.0	4.1	4.8	1.01	0.99	0.92	Lithic sandstone
96.8	1.5	2.6	2.8	0.53	0.75	0.36	Quartz dolerite

B.4 Definitions of $\bar{x}$, r_1, R_1, R_2, V_r, V_L and V_S are given in clauses **2** and **5** of BS 812-101:1984. The variabilities which result from the sampling and sample reduction operations are apportional to V_r and V_s according to definitions of sampling error and sample reduction error given in clause **2** of BS 812-101:1984.

B.5 The precision data from Table 1 are approximately represented by the following simplified equations, where x = MSSV (see **9.2**).

$$r_1 = \sqrt{\{0.18\ \bar{x}\ (100 - x)\}}$$

$$R_1 = \sqrt{\{0.31\ \bar{x}\ (100 - x)\}}$$

$$R_2 = \sqrt{\{0.34\ \bar{x}\ (100 - x)\}}$$

These may be used to interpolate values of r_1, R_1 and R_2 for levels of percentage retained between those which appear in Table 1.

B.6 Confidence limits of 95 % for a test result may be calculated as:

$$\pm \sqrt{\{R_2^2/2 - r_1^2/4\}}$$

when the test result is calculated as the average of two specimens.

Publications referred to

BS 410, *Specification for test sieves.*

BS 718, *Specification for density hydrometers.*

BS 812, *Testing aggregates.*

BS 812-100, *Definitions, symbols, common equipment and calibration*[2)].

BS 812-101, *Guide to sampling and testing aggregates.*

BS 812-102, *Methods of sampling.*

BS 812-110, *Methods for determination of the aggregate crushing value*[2)].

BS 812-111, *Methods for determination of the ten percent fines value*[2)].

BS 812-112, *Methods for determination of the aggregate impact value*[2)].

BS 812-113, *Method for determination of aggregate abrasion value*[2)].

BS 5497, *Precision of test methods.*

BS 5497-1, *Guide for the determination of repeatability and reproducibility for a standard test method by inter-laboratory tests.*

[2)] Referred to only in foreword and in preparation.

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