BRITISH STANDARD

BS 5075-2:1982

(Reprinted, incorporating Amendments No. 1 and No. 2)

Concrete admixtures —

Part 2: Specification for air-entraining admixtures

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Cooperating organizations

The Cement, Gypsum, Aggregates and Quarry Products Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following:

Association of Consulting Engineers
Association of County Councils
Association of District Councils
Association of Metropolitan Authorities
Autoclaved Aerated Concrete Products Association
British Precast Concrete Federation Ltd.*
British Quarrying and Slag Federation
British Railways Board
British Ready Mixed Concrete Association*
British Steel Industry
Cement Admixtures Association*
Cement and Concrete Association*
Cement Makers' Federation*
Chemical Industries Association
Concrete Society Limited*
County Surveyors Society*
Department of the Environment (Building Research Establishment)*
Department of the Environment (Housing and Construction)
Department of the Environment (PSA)*
Department of the Environment (Transport and Road Research Laboratory)
Department of Transport*
Federation of Civil Engineering Contractors*
Gypsum Products Development Association
Institute of Quarrying
Institution of Civil Engineers*
Institution of Highway Engineers
Institution of Municipal Engineers
Institution of Public Health Engineers
Institution of Structural Engineers*
Institution of Water Engineers and Scientists
National Federation of Building Trades Employers*
Natural Environment Research Council (Institute of Geological Sciences)
Royal Institute of British Architects
Royal Institution of Chartered Surveyors
Sand and Ballast Hauliers and Allied Trades Alliance
Sand and Gravel Association Limited
Society of Chemical Industry*
Stone Federation

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the Technical Committee entrusted with the preparation of this British Standard:

Brick Development Association
British Ceramic Research Association
Electricity Supply Industry in England and Wales
Mortar Producers' Association Ltd.
Plasterers' Craft Guild

This British Standard, having been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee, was published under the authority of the Board of BSI and comes into effect on 26 February 1982

The following BSI references relate to the work on this standard:
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Contents

Foreword

This Part of this British Standard has been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee and is based on an initial draft provided by the Cement Admixtures Association. This Part of this standard incorporates such recommendations of other organizations as the Technical Committee felt were appropriate, and is based on the results of cooperative tests carried out in accordance with drafts of this Part.

This Part of this standard is concerned only with admixtures whose sole function is to entrain air in concrete. Air-entraining admixtures with additional properties, such as accelerating or retarding effects, have not been included because of the wide variation in the quantity of air-entraining admixture required to entrain a given quantity of air according to the actual circumstances prevailing, and consequent varying magnitude of such supplementary effects in practice. Accelerating admixtures, retarding admixtures and water-reducing admixtures are covered by Part 1 of this standard and mortar plasticizers are covered by BS 4887.

This Part of this standard specifies acceptance tests which demonstrate the ability of a particular admixture formulation to meet stipulated performance requirements in a specified concrete, and admixture uniformity tests which demonstrate that a particular consignment is similar to material that has previously been submitted to the acceptance tests. These acceptance tests include a selection of tests at one workability on a single control concrete without any admixture and on a similar test concrete of the same cement content and workability containing sufficient admixture to produce a stipulated air content of 5.0 ± 0.5 %. The effects of air-entraining admixtures on properties other than those covered, or on special concretes, are not specified and these should be the subject of advice from the admixture manufacturer.

In the acceptance tests, particular attention has been given to the use of test methods already covered in BS 1881 and BS 4551. Furthermore, the principle has been followed of having test and control mix concretes with the same cement content at nominally equal workabilities, as determined by compacting factor tests. However, workability can vary rapidly during the early stages after completion of mixing of concretes, and consequently a delay of 10 min to 15 min has been introduced into the procedure for compacting factor determination, so as to avoid this period of high variability. Control and consistency of the air-entraining performance of the admixture is covered by the requirement specified for repeatability of air content. The stability of the entrained air during the transition from fresh to hardened concrete is ensured by the saturated density requirement which also checks that the test mix concrete cubes and prisms have similar air contents. A stiffening-time test, which is carried out on mortar sieved from concrete, is included to establish that the air-entraining admixture does not significantly affect the setting of concrete. The resistances to penetration of 0.5 N/mm^2 and 3.5 N/mm^2 correspond approximately to the extreme limit for placing and compacting concrete and the time available for the avoidance of cold joints. This Part of this standard also deals with the effects of entrained air on compressive strength and resistance to the action of repeated freezing and thawing under wet conditions. The Technical Committee gave consideration to other possible tests for characterizing the quality of the air entrained in concrete by use of the admixture, such as change in air content on prolonged mixing, loss of entrained air on standing or on vibration, and estimation of the size and distribution of air voids by microscopical examination of polished concrete sections, but these have not been included because of difficulties of standardization and/or of interpreting the results. The direct freezing and thawing test adopted in this Part has been kept as simple as possible to avoid difficulties in its implementation, but it is believed that the test will provide adequate information on admixture performance with respect to the potential frost resistance of the air-entrained concrete. Of the various methods available for assessing the effects of repeated freezing and thawing on concrete, the change in length method was found in cooperative testing to be the most sensitive and convenient method to use and accordingly this method has been specified in this Part.

The admixture uniformity tests include determination of dry material content, ash content and chloride ion content for all admixtures, and relative density for liquid admixtures.

Although air-entraining admixtures are not normally expected to contain significant quantities of chloride, this Part of this standard requires, as a general safeguard, that the chloride content of all admixtures be declared. This declaration enables the purchaser or user to be fully aware of the amount of chloride that will be introduced into concrete by the use of any particular admixture and, if necessary, to take appropriate precautions.

The admixture dosage is dependent on many factors which govern the performance of an air-entraining admixture in achieving a specified air content. This leads to considerable variation in dosage, comparing one site with another, and it is unlikely that the dosage used in the admixture acceptance tests complying with this Part of this standard will be the optimum amount for use in a particular situation. Site trials are required, and some guidance on this topic as well as on the general use of air-entraining admixtures is given in appendix D.

Certification. Attention is drawn to the certification facilities described on the inside back cover of this standard.

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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 10, 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.

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1 Scope

This Part of this British Standard specifies the requirements and methods of test for determining the suitability of materials used to entrain a controlled amount of air in concrete, for the purpose of improving its resistance to freezing and thawing and/or modifying its workability.

2 References

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

3 Definitions

For the purposes of this Part of this British Standard the definitions given in BS 2787, together with the following, apply.

air-entraining admixture

an admixture that causes a controlled and stable quantity of air to be incorporated during the mixing of concrete, without significantly affecting the setting of the concrete

NOTE This entrained air reduces the water requirement of concrete (or alternatively increases the workability of fresh concrete at constant water/cement ratio) and provides hardened concrete of increased resistance to freezing and thawing, without lowering the strength beyond certain limits.

4 Sampling

An admixture to be tested in accordance with the requirements of this Part of this standard shall be sampled by the appropriate method described in appendix A of BS 5075-1:1982.

5 Performance requirements

Admixtures shall comply with the performance requirements detailed in Table 1. For the purposes of acceptance testing, a representative sample of admixture, as defined in the appropriate subclause in appendix A of BS 5075-1:1982, shall be subjected to the tests listed in Table 1 and shall comply with the relevant requirements specified therein.

Each test mix containing the admixture shall be compared with a control mix made on the same day under the same conditions and the average result obtained from two such comparisons shall be taken to assess compliance with the requirements for stiffening time, saturated density and compressive strength given in Table 1.

Consignments of this admixture which have the same description, given as in **7.3** a) and b), need not be tested individually for acceptance. If any characteristic of the admixture given in **7.3** a) and b) is changed, new acceptance tests shall be carried out and the designation as given in clause**10** b) shall be changed.

NOTE 1 Although the purpose of the tests is to verify compliance with the specified requirements, the results will also serve to demonstrate the effect of the admixture on certain properties of the concrete.

NOTE 2 For the purposes of acceptance testing, the manufacturer[1] or his agent may be required by the purchaser to demonstrate compliance with the test requirements. The manufacturer is responsible thereafter for ensuring, by his control of production, that consignments of admixture maintain, on delivery, the performance of the sample originally tested for acceptance.

6 Admixture uniformity tests and requirements

Any batch of admixture shall have the same composition, given as in **7.3** b), as that of the admixture tested for acceptance. To check this uniformity of composition, a sample of the batch taken in accordance with appendix A of BS 5075-1:1982 shall be tested in accordance with appendices D and E of BS 5075-1:1982 and it shall satisfy the requirements given in Table 2.

7 Information to be provided by the manufacturer

7.1 Information concerning the admixture. The following information shall be provided by the manufacturer in a printed form.

a) The name, trade mark or other means of identification of the manufacturer.

b) The trade designation of the product, i.e. brand name, reference number and/or letter.

c) The description of the material, i.e. air-entraining admixture.

7.2 Information concerning the admixture acceptance tests. The following information shall be provided by the manufacturer in a printed form if requested.

a) The name and location of the test laboratory where admixture acceptance and uniformity tests were made and the date of testing.

b) The sources of the cement (works of manufacture) and aggregates (quarry or pit, or, for material dredged from seas, estuaries or rivers, the locality).

c) The quantity of admixture used in the test mix concretes.

[1] The term "manufacturer" throughout this standard includes the supplier where appropriate.

d) The values of compacting factor, water/cement ratio and cement content for each batch of the control and test mix concretes.

e) The stiffening times to reach resistances to penetration of 0.5 N/mm^2 and 3.5 N/mm^2 for mortars sieved from each control and test mix concrete.

Table 1 — Performance requirements and tests

Characteristic	Test reference	Requirements
Repeatability of air content	**B.2**	Air contents of three identical and consecutive test mix concrete batches all to be in the range 4.0 % to 6.0 %, when determined by one operator using one set of apparatus.
Stiffening time	**B.3**	Average times from completion of mixing to reach resistances to penetration of 0.5 N/mm^2 and 3.5 N/mm^2 for the two batches of the test mix concrete to be within 1 h of the corresponding times for the two batches of the control mix concrete.
Saturated density	**B.5**	a) The 3 day average saturated densities of the six cubes and of the four prisms from the two batches of the test mix concrete to be within 20 kg/m^3 of each other. b) The 28 day average saturated density of the six cubes from the two batches of the test mix concrete to be at least 50 kg/m^3 lower than that of the six cubes from the two batches of the control mix concrete.
Compressive strength	**B.6**	Average compressive strength of the six cubes from the two batches of the test mix concrete to be at least 70 % of that of the six cubes from the two batches of the control mix concrete when tested at age 28 days.
Resistance to freezing and thawing	Appendix C	The relative length change of at least three of the four prisms of the test mix concrete not to exceed + 0.050 % after 50 cycles of freezing and thawing.

Table 2 — Admixture uniformity test requirements

Characteristic	Test reference	Requirement
Dry material content	D.1 of BS 5075-1:1982	a) For liquid admixtures: to be within 3 % (*m*/*m*) of the value stated by the manufacturer. b) For solid admixtures: to be within 5 % (*m*/*m*) of the value stated by the manufacturer.
Ash content	D.2 of BS 5075-1:1982	To be within 1.0 % (*m*/*m*) of the value stated by the manufacturer.
Relative density	D.3 of BS 5075-1:1982	For liquid admixtures: to be within 0.02 of the value stated by the manufacturer.
Chloride ion content	Appendix E of BS 5075-1:1982	To be within 5 % of the value stated by the manufacturer or within 0.2 % (*m*/*m*), whichever is the greater.

f) The air content of each batch of the control and test mix concretes.

g) The ratio of the average compressive strength of the test mix concrete cubes to that of the control mix concrete cubes, expressed as a percentage, for both pairs of control and test mix concretes at age 28 days.

h) The 3 day average saturated density of each set of prisms and cubes prepared from the test mix concrete and the 28 day average saturated density of each set of cubes prepared from the two batches of the test and control mix concretes.

i) The values of original length and percentage relative length change after 50 cycles of freezing and thawing for each test prism subjected to the freezing and thawing test.

7.3 Additional information. The following information shall be provided by the manufacturer in a printed form.

a) Physical state (i.e. liquid or solid) and colour.

b) Composition.

1) Generic type of main active constituent(s), e.g. alkali salt of wood resin, alkali salt of sulphated or sulphonated hydrocarbon.

2) Dry material content.

3) Ash content.

4) Relative density of liquid admixtures.

5) Chloride ion content, expressed as a percentage by mass of total admixture.

c) Packaging, recommended storage conditions, maximum storage time before use and special precautions at extremes of temperature, including instructions regarding liquids which have become frozen. Where any special requirements on storage life apply, they shall be stated in the words:

"This admixture shall not be taken to comply with the requirements of BS 5075-2:1982 after (date)."

d) Instructions for use and any necessary safety precautions, e.g. if caustic, toxic or corrosive.

e) Any known incompatibility with other admixtures or with certain types of cement etc.

f) The manufacturer's recommended dosage or dosages.

g) Effects of underdosage and overdosage.

h) The number and year of this Part of this British Standard, i.e. BS 5075-2:1982[2)].

8 Manufacturer's compliance certificate

The manufacturer shall provide a certificate stating that the admixture, at the time of delivery, complied with the requirements of this Part of this standard. The manufacturer shall also provide the results of any uniformity tests which relate to current supplies of the admixture.

9 Manufacturer's storage certificate

The manufacturer shall provide a certificate confirming that the storage recommendations have been followed for the admixture.

10 Marking

When admixtures are supplied in containers they shall be clearly marked with the following information. When the material is supplied into a bulk container at the point of delivery, the same information shall be provided on a clearly printed label handed over at the time of delivery.

a) The name, trade mark or other means of identification of the manufacturer.

b) The trade designation of the product, i.e. brand name, reference number and/or letter (see clause **5**).

c) The description of the material, i.e. air-entraining admixture.

d) The chloride ion content, expressed as a percentage by mass of total admixture.

e) A summary of storage requirements including any special requirement on storage life as indicated in **7.3** c) clearly marked in the words:

"This admixture shall not be taken to comply with the requirements of BS 5075-2:1982 after (date)."

f) Instructions for use and any necessary safety precautions, e.g. if caustic, toxic or corrosive.

g) The manufacturer's recommended dosage or dosages.

h) The number and year of this Part of this British Standard, i.e. BS 5075-2:1982[2)].

[2)] Marking BS 5075-2:1982 on or in relation to a product is a claim by the manufacturer that the product has been manufactured in accordance with the requirements of the standard. The accuracy of such a claim is therefore solely the manufacturer's responsibility. Enquiries as to the availability of third party certification to support such claims should be addressed to the Director, British Standards Institution, Maylands Avenue, Hemel Hempstead, Herts HP2 4SQ in the case of certification marks administered by BSI or to the appropriate authority for other certification marks.

Appendix A Preparation of concrete for admixture acceptance tests

A.1 General. Prepare the concrete for the admixture acceptance tests using the constituents, mix proportions and procedure given in **A.2** to **A.5**. Use identical cement and aggregates for all mixes in a series being compared.

To compare the properties of concrete with and without the addition of the admixture, make duplicate batches of test mix concrete with air contents of 5.0 ± 0.5 % and duplicate batches of control mix concrete with air contents of not more than 2.0 %.

A.2 Constituents

A.2.1 *Cement.* The cement shall be an ordinary Portland cement complying with the requirements of BS 12.

A.2.2 *Aggregates.* The aggregates shall be in an oven-dry condition. The coarse aggregate shall be an uncrushed gravel complying with BS 882. It shall consist of 20 mm and 10 mm single-sized materials. Neither of the sizes shall have a flakiness index higher than 35 % when tested in accordance with BS 812-105.1 nor a 10 % fines value less than 50 kN when tested in accordance with clause **8** of BS 812-3:1975.

The fine aggregate shall be an uncrushed sand complying with BS 882, except that the grading of the sand as used shall comply with Table 3. The sand shall be obtained from a source that is known to be free from organic matter and it shall have a content of acid-soluble matter of less than 5 % when tested in accordance with clause **7** of BS 4550-6:1978.

Table 3 — Fine aggregate grading limits

BS 410 sieve size		Mass passing BS sieve
mm	µm	%
10		100
5		90 to 100
2.36		85 to 100
1.18		75 to 100
	600	60 to 79
	300	12 to 40
	150	0 to 10

A.2.3 *Admixture.* The admixture shall be in the appropriate condition recommended by the manufacturer for general use in practice.

A.3 Mix proportions

NOTE It is advisable to prepare trial mixes to ensure that both the control and test mix concretes comply with the requirements given in **A.3.1** and **A.3.2** for compacting factor, cement content and air content.

A.3.1 *Control mix concrete.* The proportions, by mass, of the oven-dry aggregate shall be: 45 parts of 20 mm to 10 mm coarse aggregate: 20 parts of 10 mm to 5 mm coarse aggregate: 35 parts of fine aggregate. The cement content of the fully compacted concrete shall be 300 ± 5 kg/m^3. The water content of each batch shall be such as to produce a concrete having a compacting factor in the range 0.88 to 0.90 when determined in accordance with **B.4**.

The air content shall be not more than 2.0 % when tested in accordance with **B.2**.

A.3.2 *Test mix concrete.* The quantity of admixture added to the test mix shall be such as to entrain 5.0 ± 0.5 % of air when determined in accordance with **B.2**. Each batch of test mix concrete shall contain the same quantities of cement and coarse aggregate as used in the control mix concrete, but the amount of fine aggregate (sand) shall be reduced to give a total aggregate/cement ratio value which is 0.20 below that of the control mix concrete. The water content of each batch shall also be reduced to give a total water/cement ratio value (including water contributed by the admixture) which is 0.05 below that of the control mix concrete. By these adjustments, the increases in volume yield and workability due to entrained air are allowed for, so that the compacting factor and cement content of the test mix concrete (determined as in **B.4**) shall be within 0.02 and 5 kg/m^3, respectively, of those of the control mix concrete.

A.4 Type of mixer. The concrete shall be mixed in a pan mixer. In operation the mixer shall be filled to between 50 % and 90 % of its nominal batch capacity.

NOTE Each batch of control or test mix concrete will require approximately 100 kg or 40 litres of concrete for the full range of tests. A pan mixer with a nominal batch capacity of 50 litres will generally be most suitable. Guidance on the quantities required for each test on a batch of concrete is given in Table 4.

Table 4 — Approximate quantities of concrete required for each admixture acceptance test on a batch

Test	Quantity of concrete	
	kg	litres
Air content	15	6
Stiffening time	3 to 12	1.25 to 5
Compacting factor	50	20
Saturated density and compressive strength (3 cubes)	8	3
Resistance to freezing and thawing (2 prisms)	10	4

A.5 Mixing procedure

A.5.1 *General.* Prepare two identical batches of control mix concrete and two identical batches of test mix concrete in the same mixer using the same procedure and arrange the mixing so that the pair of control mix and test mix concrete batches is produced on the same day. Prepare an additional batch of test mix concrete in the same way to test for the repeatability of air content. Weigh the cement, aggregates and water.

A.5.2 *Mixing control mix concrete.* Place the aggregates in the mixer, add approximately half the mixing water and mix the material for 2 min. After standing for 8 min, with the pan covered to minimize evaporation, restart the mixer and add the cement gradually during the next 30 s. Add the remainder of the mixing water during the next 30 s and mix the concrete for a further 3 min.

A.5.3 *Mixing test mix concrete.* Adopt the mixing procedure described above but disperse the admixture in the second addition of water.

Appendix B Admixture acceptance tests on the control mix and test mix concretes

B.1 General. Use the same test procedure, in detail, for the control and test mix concretes. Carry out the tests required by the standard in accordance with the instructions given in **B.2** to **B.6**.

B.2 Air content. Determine the air content of each batch of the test and control mix concretes to the nearest 0.1 % according to the procedure described in BS 1881-106 with the following modification. Compact each layer of concrete in the air meter by mechanical vibration of minimum duration to give a relatively smooth concrete surface with a glazed appearance (e.g. 5 s per layer on a “V-B” table). Carry out the test immediately after completion of mixing of the concrete. Discard the concrete sample after the test. Where the air content of the control mix concrete exceeds 2.0 % change the batch or source of one or more constituents and repeat the test procedure.

B.3 Stiffening times. Determine the stiffening times of the mortar sieved from each batch of the test and control mix concretes by the method described in appendix C of BS 5075-1:1982. Report the times from completion of mixing of the concrete for the mortar to reach resistances to penetration of 0.5 N/mm^2 and 3.5 N/mm^2 to the nearest 15 min.

B.4 Compacting factor, plastic density and cement content. Determine the compacting factor in accordance with BS 1881-103 with the following modifications. Determine the compacting factor of each batch of the control and test mix concretes in duplicate on separate samples of the concrete. Determine the partially-compacted mass between 10 min and 15 min after the completion of the mixing, filling the hopper immediately prior to opening the trap door, and determine the fully compacted mass immediately thereafter. Compact the layers of concrete by mechanical vibration of minimum duration to give a relatively smooth concrete surface with a glazed appearance (e.g. 5 s per layer on a “V-B” table). The compacting factor is the ratio of the mean partially-compacted mass to the mean fully-compacted mass. Calculate the plastic density and cement content of the fresh concrete in accordance with BS 1881-103 from the mean fully-compacted mass.

B.5 Saturated density. Determine the saturated density of each cube prepared for compressive strength testing, and of each prism prepared for freeze-thaw testing, in accordance with BS 1881-114. For each batch of concrete, test three cubes at age 72 ± 2 h and at 28 days ± 8 h. In addition, test the two prisms from each batch of test mix concrete at age 72 ± 2 h. Calculate the average saturated density of each set of three cubes, or two prisms, to the nearest 5 kg/m^3.

B.6 Compressive strength. For each batch of the control and test mix concretes prepare three 100 mm test cubes between 30 min and 60 min after the completion of mixing. Make the cubes in accordance with BS 1881-108 with the following modifications. Compact the concrete by mechanical vibration of minimum duration to give a relatively smooth concrete surface with a glazed appearance (e.g. 5 s per layer on a "V-B" table). In addition, immediately after making the cubes, place the moulds in a single layer on a level surface in an atmosphere of at least 90 % relative humidity at a temperature of 20 ± 1 °C.

In order to reduce evaporation from the exposed top of the cubes, cover them with a flat impervious sheet (e.g. clean thin rubber or plastics, or lightly oiled steel) making contact with the upper edge of the mould. After marking for later identification, remove the cubes from the moulds at age 24 ± 0.5 h, immediately submerge them in water at a temperature of 20 ± 1 °C, and keep them there until required for testing. Test each cube for compressive strength at age 28 days ± 8 h in accordance with BS 1881-116. If one result within the set of three obtained on specimens tested at the same age varies by more than ± 5 % from the average of the set, discard the result and recalculate the average of the remaining results. If more than one result varies by more than ± 5 % from the average, discard the set of results and repeat the tests on the concrete. Calculate the ratio of the average strength of the test mix concrete cubes to the average strength of the control mix concrete cubes, as a percentage, to the nearest 1 % for both pairs of control and test mix concretes at age 28 days.

Appendix C Test for resistance to freezing and thawing

C.1 General. Determine the resistance of the air-entrained test mix concrete to repeated freezing and thawing using the specimens, apparatus and procedure given in **C.2** to **C.5**.

C.2 Test specimens. Prepare four test prisms, two from each batch of test mix concrete, of approximate dimensions 75 mm × 75 mm × 225 mm to 305 mm between 30 min and 60 min after completion of mixing of the concrete. Each prism shall have reference pieces of stainless steel cast in at the mid points of its end faces. The reference pieces shall be in accordance with **5.7.1 1)** of BS 1881-5:1970, and shall be free from oil or grease when mounted in the mould before casting the prism. Fill the mould in two layers approximately 40 mm deep and compact, cure and store the prisms as described for the test cubes in **B.6**. Do not allow the prisms to become dry at any time before or during subsequent testing or remain out of water for more than 15 min at any one time.

C.3 Apparatus. The following apparatus is required.

C.3.1 *Invar steel rod,* of approximately the same length as the test prisms, and with ends of the same shape as that of the reference pieces in the prisms.

C.3.2 *Measuring apparatus,* for determining differences in length, incorporating a micrometer gauge or a suitable dial gauge reading accurately to 0.0025 mm, and of the form illustrated in BS 1881-5.

C.3.3 *Rigid metal containers,* (e.g. made from 16 gauge (1.63 mm) mild steel and galvanized) of depth 90 mm to 100 mm and of such dimensions on plan that, when placed in the container, the prism, except for necessary supports, is completely surrounded by 3 mm to 5 mm of water at all times while it is being subjected to cycles of freezing and thawing. Identical containers shall be used for all specimens in a set.

NOTE The prism may be conveniently supported and spaced away from the sides of the container by cradles made from plastics-covered wire and these may also help in placing and removing the prism.

C.3.4 *Refrigerating cabinet,* which is capable of lowering the temperature of at least four prisms from + 16 ± 6 °C to – 15 ± 3 °C within 14 ± 2 h.

NOTE A domestic or commercial deep-freezer unit complying with the requirements of BS 922 & 1691 or BS 2501 may fulfill this requirement, but there is at present insufficient experience for recommendations to be made regarding the optimum size of the unit and the maximum loading of prisms which may be tested. Control of temperature conditions will probably be best achieved by maintaining a constant load within the refrigerating cabinet and by placing the specimen containers on suitable supports so that they are suspended in the cold air some distance away from the evaporator element of the refrigerator. In addition, excessive build-up of ice on the interior walls of the cabinet should be avoided by periodic defrosting during the thawing part of the cycle. In the cooperative testing work, a chest-type deep-freezer of 680 litres (24 ft^3) capacity and complying with the requirements of BS 2501 was used to freeze 13 prisms, the containers being supported in several plastics-covered wire baskets suspended from the top edges of the cabinet. The freezing requirements, and the further requirements for the thawing of the prisms, may also be met by a cabinet fitted with suitable refrigerating and heating equipment and controls.

C.3.5 *Temperature-measuring equipment,* consisting of mercury-in-glass thermometers, electrical resistance thermometers or thermocouples, capable of measuring the temperature at the mid-point of one of the side faces of one or more of the prisms under test to within ± 1 °C over the range – 18 °C to + 21 °C.

C.3.6 *One or more tanks,* containing clean water maintained at a temperature of 20 ± 1 °C.

C.4 Procedure

C.4.1 *Freezing and thawing cycle.* The normal freezing and thawing cycle of 24 h comprises a 16 h to 17 h period of freezing followed by a 7 h to 8 h period of thawing. Take the prisms from the water tank at 20 ± 1 °C at age 72 ± 2 h and, after the original length measurement, immerse them in water at 20 ± 2 °C in their individual containers. Transfer the containers to the cold refrigerating cabinet when the prisms are at age 72 h to 80 h and cool the prisms to – 15 ± 3 °C within 14 ± 2 h. After 16 h to 17 h in the cabinet, remove the prisms in their containers to the air at an ambient temperature of 20 ± 2 °C and allow them to thaw for 7 h to 8 h. Separate the containers to allow air flow between them.

NOTE 1 Alternatively, when using suitably controlled apparatus fitted with both heating and refrigerating equipment, the freezing and thawing parts of the specified cycle may be successively effected inside the apparatus.

Repeat this nominal 24 h cycle of freezing and thawing during succeeding 24 h periods in so far as this is practicable.

NOTE 2 When necessary for convenience of working, it is permissible to extend the freezing part of the cycle during week-ends or any other unavoidable interruptions by keeping the prisms in the frozen condition in the refrigerating cabinet. Such an extended freezing period is not to exceed 5 days.

Compliance with the temperature requirements of the freeze-thaw cycle shall be based on temperature measurements made by placing a suitable temperature measuring device in the water near the surface of one or more test prisms at the mid-point of one of the side faces. Frequently change the position at which temperature measurements are made in the refrigerating cabinet so that the extremes of temperature variation for test prisms in the cabinet are indicated.

C.4.2 *Measurement of the length changes.* For the determination of the effect on the test concrete of repeated freezing and thawing under wet conditions, make measurements of length change for each test prism, using the invar rod as a standard of length for checking the length of the measuring apparatus.

Immediately after removal of the prism, at age 72 ± 2 h, from water at 20 ± 1 °C, wipe the reference pieces, place the prism in the frame of the measuring apparatus and note the minimum reading. When using a dial gauge this is effected by slowly rotating the prism or the frame and observing the minimum reading. Reverse the prism end to end, remeasure in the same way, and calculate the average of the two readings.

Before and after each set of measurements, obtain length readings, in the same way, for the invar rod and determine an average value. Calculate the difference in length between the prism and the invar rod from the respective average readings and take this as the original wet measurement, l_0 mm. In addition, measure the length of the prism, adjacent to the reference pieces, to the nearest 1 mm and take this as the original wet length, L_0 mm.

After the original length measurements have been taken, subject the prisms to repeated cycles of freezing and thawing as described in **C.4.1**. On completion of 50 such cycles, place the prisms in the tank containing water at 20 ± 1 °C, for sufficient time for the temperature of the prisms to reach 20 ± 1 °C and make further length measurements, as described above, on each prism. Calculate the difference in length between the prism subjected to 50 cycles of freezing and thawing and the invar rod from the respective average readings and take this as the wet measurement after 50 cycles of freezing and thawing, l_{50} mm.

C.5 Expression of results. Calculate the relative length change for each prism after 50 cycles of freezing and thawing as the difference between the wet measurement after 50 cycles of freezing and thawing, l_{50} mm, and the original wet measurement, l_0 mm, expressed as a percentage of the original length, L_0 mm. Report the result for each prism to the nearest 0.001 %.

Relative length change (after 50 cycles of freezing and thawing)

$$= \frac{(l_{50} - l_0)}{L_0} \times 100\ \%$$

Appendix D Notes on the use of air-entraining admixtures

NOTE Reference should be made to codes of practice or other documents on the use of concrete for guidance on specific applications.

D.1 Nature of entrained air. Air-entraining admixtures are surface-active substances which dissolve in the mixing water and reduce its surface tension, thereby giving it a capacity for foaming or bubble formation on vigorous stirring or mixing. Hence, the formation and entrapping of air bubbles is promoted during the initial mixing of the fresh concrete, and these remain as air voids in the hardened concrete. Not only is the total volume of such entrained air of importance, but also its nature with respect to size and distribution of air voids. In general, entrained air should be in the form of a very large number of discrete bubbles or voids of diameter about 1 mm or smaller and these should be uniformly distributed throughout the cement paste fraction of the concrete. For providing concrete with protection against frost, the most important air voids appear to be those with diameters in the range 0.05 mm to 0.5 mm, and the void-spacing factor (i.e. the average maximum distance from a point in the cement paste to the nearest air void) should generally not exceed 0.2 mm.

D.2 Effects of entrained air. There are two main reasons for using air-entraining admixtures in concrete:

a) to increase the resistance of hardened concrete to the disruptive actions of repeated freezing and thawing under wet conditions, particularly in the presence of de-icing chemicals;

b) to improve the cohesion and workability of fresh concrete, especially for mixes with low cement content, or with lightweight or other aggregates, which may be harsh and difficult to handle.

The entrained air can bring about some reduction in the strength of the concrete, the compressive strength being more affected than the flexural or tensile strength. This reduction is usually compensated for by changes in the mix design.

To prevent excessive strength reduction and at the same time ensure the maximum benefit for durability, particular air contents are usually stipulated according to the maximum size of the aggregate used. It is generally recommended that the respective average air contents of fresh concrete at the time of placing should be 7 %, 6 %, 5 % and 4 % for nominal maximum aggregate sizes of 10 mm, 14 mm, 20 mm and 40 mm, based on the indicated optimum air content for freeze-thaw durability of approximately 10 % by volume of the mortar fraction in the concrete.

D.3 Factors influencing dosage. The amount of air-entraining admixture required to produce concrete with a specified air content depends on many factors and is thus subject to considerable variation in practice according to the actual circumstances prevailing. Generally, for a given dosage of air-entraining admixture relative to cement mass, the content of entrained air will increase as the water/cement ratio or workability increases, or the higher the alkali content of the mix, or the greater the sand content of the mix.

In general, for a given admixture dosage, the amount of entrained air decreases the greater the cement fineness, the higher the proportion of fine material in the mix, the greater the hardness of the mixing water, or the higher the temperature of the concrete.

The amount of entrained air may also vary with the type and condition of the mixer, the rate of mixing and the size of the concrete batch. Air content may increase with mixing time up to a point, beyond which it usually tends to decrease. The type and degree of vibration or other means of compaction can also affect the air content. The presence of organic impurities in the aggregate, mixing water or cement and the use in combination with other types of admixture, can bring about an increase or a decrease in the amount of air entrainment at a given dosage of air-entraining admixture. Water-reducing admixtures and other chemical admixtures such as calcium chloride can increase the air-entraining efficiency of an air-entraining admixture, while the use of finely-divided mineral admixtures such as pulverized-fuel ash or pigments may necessitate a marked increase in the dosage of air-entraining admixture to produce a given content of entrained air. The carbon content of pulverized-fuel ash and pigments may have a marked influence on the efficiency of air-entraining agents. In general, these different types of admixture should be added separately to the concrete mix and such combinations of admixture should not be used unless testing has shown them to be effective and not detrimental to the concrete.

In view of all these many factors affecting the process of entraining air in concrete, it is clear that extra care is required to maintain these factors as constant as possible, in order to achieve uniformity of air entrainment and air content.

D.4 Site trials and control. Air-entraining admixtures complying with the requirements of this Part of this standard will, in the majority of circumstances, give satisfactory performance on site, provided that good concrete mix design and high standards of quality control are employed. Concretes for road construction generally have a cement content of not less than 280 kg/m^3 and should have a workability which would be described as plastic, because dry mixes have insufficient water in which entrained air bubbles can be formed. Constituent materials should comply with the requirements of the appropriate British Standard. The materials and proportions used in the acceptance tests in this Part of this standard do not imply that other materials in other proportions will not perform equally satisfactorily subject to good mix design. Since the air-entraining efficiency of the admixture is influenced by many factors, a suitable admixture dosage should always be determined on the basis of results from site trial mixes using the specific materials and conditions of the given concrete work. Where necessary, the admixture dosage used should also be adjusted from time to time during the course of the concrete construction to the appropriate quantity for the specified air content. If it is difficult to obtain the required air content with the trial mixes, this probably indicates that the intended proportions of the concrete are inappropriate or that the constituents are contaminated.

During site working, close control has to be exercised over the production of the concrete and in particular the accurate dispensing of the admixture and the air content of the concrete. Dispensing equipment has to be sufficiently accurate to deliver within 5 % of the specified dosage rate in successive batches of concrete, and it should be cleaned and checked at regular intervals to ensure correct functioning. Since the significant air content with respect to enhanced durability is that present in concrete after compaction, the air content should preferably be determined at the time of placing of the concrete and by the use of a similar technique for compaction in the air meter as employed for the actual concrete. A pressure type air meter should be on site throughout the work and during continuous working the air content should be checked at least three times and quite possibly six or more times per day, the higher figure being appropriate where variations in the constituents of the mix are suspected. Whilst specifications may permit a slightly wider tolerance, it should be possible to maintain the air content generally within 1.5 % of the intended value. The higher the workability of the concrete the greater the tendency to air loss and therefore the loss of air should be checked for the more plastic mixes.

Standards publications referred to

BS 12, *Specification for ordinary and rapid-hardening Portland cement.*

BS 812, *Test aggregates.*

BS 812-1, *Methods for determination of particle size and shape.*

BS 812-2, *Methods for determination of physical properties.*

BS 812-3, *Methods for determination of mechanical properties.*

BS 812-105, *Methods for determination of particle shape.*

BS 812-105.1, *Flakiness index.*

BS 882, *Aggregates from natural sources for concrete.*

BS 922 & 1691, *Electrical refrigerators and food freezers for household use.*

BS 1881, *Methods of testing concrete.*

BS 1881-5, *Methods of testing hardened concretes for other than strength.*

BS 1881-103, *Method for determination of compacting factor.*

BS 1881-106, *Methods for determination of air content of fresh concrete.*

BS 1881-108, *Method for determination of density of compacted fresh concrete.*

BS 1881-111, *Method of normal curing of test specimens (20 °C method).*

BS 1881-114, *Methods for determination of density of hardened concrete.*

BS 1881-116, *Method for determination of compressive strength of concrete cubes.*

BS 2501, *Commercial refrigeration storage cabinets of the closed reach-in type.*

BS 2787, *Glossary of terms for concrete and reinforced concrete.*

BS 4550, *Methods of testing cement.*

BS 4550-6, *Standard sand for mortar cubes.*

BS 4551, *Methods of testing mortars and specification for mortar testing sand*[3].

BS 4887, *Mortar plasticizers*[3].

BS 5075, *Concrete admixtures.*

BS 5075-1, *Specification for accelerating admixtures, retarding admixtures and water-reducing admixtures.*

[3] Referred to in the foreword only.

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