Concrete

Part 4. Specification for the procedures to be used in sampling, testing and assessing compliance of concrete

BSI STANDARDS

STANDARDS

Amendment No. 1
published and effective from 29 November 1991
to BS 5328 : Part 4 : 1990

Concrete

Part 4. Specification for the procedures to be used in sampling, testing and assessing compliance of concrete

AMD 6928

Revised text

AMD 6928
November 1991

Foreword

At the end of paragraph 7 insert the following.
'The specification of designated mixes is unlikely to be appropriate for factory produced precast concrete products.'

AMD 6928
November 1991

Clause 3.7.1 Methods of calculation and test

At the end of item (c) in paragraph 1 delete '1990' and substitute '1991'.

AMD 6928
November 1991

Clause 3.8.4 Compliance

In paragraph 2, last line delete '1990' and substitute '1991'.

AMD 6928
November 1991

Clause 3.13.1

In line 2 delete '1990' and substitute '1991'.
In line 7 delete '**3.16.1**' and substitute '**3.16.2**'.

AMD 6928
November 1991

Clause 3.14.1

In line 2 delete '1990' and substitute '1991'.

Contents

Foreword

This Part of BS 5328 has been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Policy Committee. This Part, together with BS 5328 : Parts 1, 2 and 3, is a revision of BS 5328 : 1981, which is withdrawn, and forms a comprehensive standard for the specification of concrete to which codes of practice and contractual documents can refer. It includes recommendations originating from, and complementing clauses in, BS 8110 : Part 1.

As this standard involves selection by the specifier from a number of options and, in certain instances, agreement on requirements between the purchaser and producer, any requirement for compliance with BS 5328 or any claim of compliance with it has to be qualified by reference to the selection and to any such agreements.

This standard covers the methods for specifying and producing concrete as a construction material up to the point of delivery into the construction. The standard is now in four Parts:

Part 1. Guide to specifying concrete
Part 2. Methods for specifying concrete mixes
Part 3. Specification for the procedures to be used in producing and transporting concrete
Part 4. Specification for the procedures to be used in sampling, testing and assessing compliance of concrete

Part 1 provides guidance to the specifier and purchaser of concrete on the selection of requirements for materials and concrete mixes. Part 2 provides a choice of methods by which the purchaser can convey the selected requirements to the producer. Part 3 specifies for the producer the procedures to be used in producing and transporting the concrete. Part 4 specifies the procedures to be used by the purchaser in sampling, testing and assessing concrete for compliance.

This standard provides methods for specifying concrete mixed on site or in a precast concrete factory and for the purchase and supply of ready-mixed concrete. It takes account of the distinct and different responsibilities of the purchaser and the producer. There are a number of instances in which the purchaser has to select from the various options given in this standard in order to specify the concrete required. The purchaser is responsible for passing on to the producer the requirements of the specifying body, e.g. the engineer's or architect's specification, together with any additional requirements. Throughout this standard the terms 'specify' and 'specification' are used in relation to both sets of requirements. There may be occasions where it is advantageous for economic or technical reasons to propose changes to the specification. In such cases the producer and purchaser should agree the proposed amendments for approval and sanction by the specifying body.

Precautions need to be taken when working with cement and wet concrete and attention is drawn to these in BS 5328 : Parts 3 and 4.

This standard covers concrete produced by normal methods, but it does not apply to precast concrete products where British Standard specifications contain the specification of the concrete. Many of the requirements of the standard, e.g. the use of materials and the control of production, apply equally to precast concrete and to in situ concrete. However, some of its requirements concerning the responsibilities of the purchaser and producer may not apply in the case of precast concrete.

It is necessary for the purchaser to take into account the requirements of specialized codes of practice and any influences of the construction process. Provisions are made in this standard for the inclusion of any special requirements.

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

Specification

0 Introduction

This Part of BS 5328 describes methods of sampling and testing of concrete, which have been specified in accordance with BS 5328 : Part 2, and defines, for both purchaser and producer, the compliance limits for the various tests that may be specified.

As an alternative to assessing compliance with cement content or water/cement ratio requirements by analysis, or observation of the batching, 'equivalent strength' grades are now given for which the strength compliance is deemed to satisfy a given minimum cement content and/or maximum free water/cement ratio.

Modifications have been made to the strength compliance requirements. The validity of the testing is now checked by applying a limit to the range of the two strength determinations, the mean of which constitutes the test result. For compressive strengths, requirements are given for the first two results and the first three results.

The use of superplasticizers to produce flowing concrete is accommodated by the inclusion of flow table compliance values. Sampling and testing of concrete for compliance should be specified to be carried out by organizations accredited by the National Measurement Accreditation Service (NAMAS) for the relevant test.

1 Scope

This Part of BS 5328 specifies the procedures to be followed when assessing the quality of concrete for compliance with a specification prepared in accordance with BS 5328 : Part 2.

NOTE. 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 5328 the definitions given in BS 5328 : Part 1 and BS 6100 apply.

3 Sampling and testing

3.1 General

All sampling and testing of the constituent materials shall be carried out in accordance with the appropriate British Standard.

All sampling, curing and testing of the concrete, fresh or hardened, shall be carried out in accordance with the relevant Parts of BS 1881 unless stated otherwise in this Part of BS 5328.

Caution. When cement is mixed with water, alkali is released. Take precautions to avoid dry cement entering the eyes, mouth and nose when mixing cement or concrete by wearing suitable protective clothing. If cement or concrete enters the eye, immediately wash it out thoroughly with clean water and seek medical treatment without delay.

When sampling and testing for compliance are required to be quality assured, evidence of certification and any change in certification shall be provided on request.

The producer shall be afforded all reasonable opportunity and facility to inspect the sampling and testing regime employed by the purchaser.

3.2 Point and time of sampling

For the assessment of compliance of ready-mixed concrete, the point and time of sampling shall be at discharge from the producer's delivery vehicle or from the mixer when delivered into the purchaser's vehicle.

For the assessment of compliance of concrete supplied to the construction, the point and time of sampling shall be at delivery into the construction, unless agreed otherwise.

NOTE. Samples taken for assessing ready-mixed concrete may be used also for assessing compliance of concrete as supplied to the construction when either:

(a) concrete is discharged from the producer's vehicle directly into the construction; or

(b) effects due to time delays, ambient conditions, transport and handling between discharge from the producer's vehicle and delivery into the construction are agreed to be minimal; or

(c) adjustments to specified values have been agreed to take account of significant effects as under item (b). Such adjustments may be nominal or based on trials.

Similarly, samples taken at the point of production of concrete, whether ready-mixed, site mixed or factory precast, may be used to assess concrete supplied to the construction.

When concrete is sampled for compliance tests at the point of delivery into the construction, the purchaser shall ensure that the sampling is spread representatively within a single identified batch as produced, in accordance with BS 1881 : Part 101.

3.3 Compliance with concrete properties and mix proportions

When properties other than those mentioned in BS 5328 : Part 2 are specified (for example thermal conductivity or modulus of elasticity of concrete), the method of test, the compliance requirements and tolerances shall be specified or agreed in advance between the purchaser and producer.

3.4 Temperature of fresh concrete

When required, the temperature of the fresh concrete shall be measured in one of the following ways.

(a) Within 2 min of taking the sample at delivery insert a type A 100 mm immersion thermometer having a range of − 5 °C to + 110 °C, graduated at each 1 °C and complying with BS 1704, in the sample to a depth of at least 100 mm. When steady conditions have been maintained for 1 min record the temperature to the nearest 1 °C.

(b) Use an alternative form of temperature measurement which provides the same accuracy as given in item (a).

The measured concrete temperature shall not

3.5 Workability

The workability shall be within the following limits on the specified value as appropriate.

Slump		
(i) When sampled in accordance with BS 1881 : Part 101	±25 mm or ±⅓ of the specified value, whichever is the greater.	
(ii) When sampled in accordance with BS 1881 : Part 102	Specified value	Tolerance
	10 mm	+35 mm − 10 mm
	25 mm	+35 mm − 25 mm
	50 mm	±35
	75 mm and over	± [(⅓ specified slump) + 10 mm]
Limits for intermediate slumps shall be derived by interpolation.		
Vebe time	±3 s or $\pm\frac{1}{5}$ of the specified value, whichever is the greater	
Compacting factor	±0.03, where specified value is 0.90 or greater.	
	±0.04, where specified value is less than 0.90 but more than 0.80.	
	±0.05, where specified value is 0.80 or less.	
Flow	Specified value ± 50 mm	

3.6 Air content of fresh concrete

The total air content determined from individual samples of concrete taken at the point of delivery into the construction and representative of any given batch of concrete shall be the specified total value ±2.0 %. The mean total air content from any four consecutive determinations from separate batches shall be the specified value ±1.5 %.

NOTE 1. Total air content comprises entrained air plus entrapped air remaining after compaction.

NOTE 2. In certain forms of construction, e.g. airfield pavements, tolerances on the air content may need to be agreed between the purchaser and the producer.

NOTE 3. The method of measuring air content described in BS 1881 : Part 106 is not necessarily applicable to concrete made with lightweight aggregates, air-cooled blastfurnace slag, aggregates of high porosity, very stiff concrete which cannot be compacted by vibration alone or aerated concrete. Specialist advice should be sought from materials suppliers or other sources on the method of test when these are required.

3.7 Chloride content of fresh concrete

3.7.1 *Methods of calculation and test*

Unless otherwise specified and agreed between purchaser and producer, the method of calculation and test shall be based upon the chloride contents of the constituents and the composition of the concrete. The chloride content of each constituent used in the calculation shall be one of the following:

(a) the measured value;

(b) the value declared by the manufacturer;

(c) the maximum value where specified in the British Standard for the constituent as appropriate (see **4.2.2** of BS 5328 : Part 1 : 1990).

The method of measuring chloride content under item (a) or (b) shall be as follows:

cement, ground granulated blastfurnace slag (ggbs) and pulverized-fuel ash (pfa)	BS 4550 : Part 2
aggregate	BS 812 : Part 117
admixture	BS 5075 : Part 1
water	**9.2** of BS 812 : Part 117 : 1988

The composition of the fresh concrete used in the calculation shall be either that declared as required under **3.1** of BS 5328 : Part 3 : 1990 or that obtained from observation of the batching or from examination of autographic records of the batching plant.

3.7.2 *Compliance*

When assessment of compliance is based on specified or declared values for chloride content of constituents and the declared or observed composition of the concrete, the calculated chloride content of the concrete expressed as the percentage of chloride ion by mass of cement shall not exceed the specified maximum value.

When assessment is based on measured values of chloride content of the fresh concrete or on analysis of fresh concrete for determination of composition, compliance rules shall be specified or agreed in advance by the purchaser and producer.

3.8 Reactive alkali content of concrete

3.8.1 *General*

The concentration of alkalis shall be expressed as the percentage of sodium oxide equivalent, $\%(Na_2O)_e$, using the equation:

$$\%(Na_2O)_e = \%(Na_2O) + 0.658\ \{\%(K_2O)\}$$

The estimation of the reactive alkali content of concrete shall be based on the summation of the reactive alkalis in kilograms in each of the constituents. The calculation shall be based on either:

(a) certified average alkali contents;

(b) declared values;

(c) maximum values when specified in the British Standard for the constituent; or

(d) a combination of the above.

If the reactive alkalis, summed from all the constituents other than the cement components, are 0.2 kg/m^3 or less they can be ignored in the calculation of the reactive alkali content.

3.8.2 ***Methods of test for alkali***

3.8.2.1 *Method of test for Portland cement*

When testing cement complying with BS 12, BS 1370 or BS 4027 or the Portland cement component of composite cements, either the method given in **16.2.4.1** of BS 4550 : Part 2 : 1970, or a secondary X-ray method calibrated against this method, shall be adopted.

When testing composite cements the components shall be tested separately.

3.8.2.2 *Method A for testing ggbs and pfa*

When testing ggbs complying with BS 6699, pfa complying with BS 3892 : Part 1 or Part 2 or the ggbs or pfa component of composite cements, either the method given in **16.2.4.1** (for ggbs) or **16.2.4.2** (for pfa) of BS 4550 : Part 2 : 1970, or a secondary X-ray method calibrated against these methods, shall be adopted. The reactive alkali shall be taken as 50 % of the measured value when testing ggbs or 17 % of the measured value when testing pfa.

3.8.2.3 *Method B for testing ggbs and pfa*

When testing ggbs complying with BS 6699, pfa complying with BS 3892 : Part 1 or Part 2 or the ggbs or pfa component of composite cements, the method given in 16.11 of Concrete Society Report No. 30 shall be adopted.

3.8.2.4 *Calculation of reactive alkali in composite cements and combinations*

The reactive alkali content (A_r) of the cement shall be calculated from the following equation:

$$A_r = (PA_c + (100 - P)A_b)/100$$

where

P is the content of Portland cement in the cement or combination (in % *m/m*);

A_c is the content of alkalis in the Portland cement component (in % *m/m*);

A_b is the content of reactive alkalis in the ggbs

3.8.2.5 *Method of test for aggregates*

The chloride content of aggregates shall be determined using the method given in BS 812 : Part 117. The sodium oxide equivalent shall be calculated by multiplying the percentage of chloride ion by 0.76.

The chloride ion content of aggregates containing 0.01 % chloride ions by mass or more shall be determined at least weekly in accordance with BS 812 : Part 117. When the chloride ion content is less than 0.01 % it shall be regarded as nil, and routine testing is not required for the purposes of this compliance procedure.

3.8.3 ***Use of test results***

3.8.3.1 *Certified average alkali contents*

Cement, ggbs and pfa suppliers will, on request, provide a certified average alkali content determined by the methods given in **3.8.1**. The latest available data relevant to the period of supply shall be used in the calculations.

3.8.3.2 *Mix proportions*

The reactive alkali content per cubic metre of concrete shall be calculated from the declared mix proportions or from those obtained from observation of the batching or from examination of the autographic records of the batching.

3.8.4 ***Compliance***

When compliance is assessed by a calculation based on certified average values for reactive alkali content of constituents and the declared or observed composition of the concrete, the calculated reactive alkali content of the concrete, expressed as equivalent sodium oxide by mass of concrete, shall not exceed the permitted reactive alkali content.

When compliance is assessed by a single analysis of reactive alkali content of one or more of the constituents, the concrete shall be deemed to comply with the permitted reactive alkali content if the calculated reactive alkali content of the concrete is not greater than the permitted alkali content plus 0.50 kg/m^3 (see **4.2.4** of BS 5328 : Part 1 : 1990).

When assessment is based on more than one set of measured values or on analysis of fresh concrete for determination of composition, compliance rules shall be specified or agreed in advance by the purchaser and producer.

3.9 Minimizing the risk of cracking due to alkali-silica reaction by methods other than the control of alkali

Compliance requirements shall be agreed between the purchaser and producer where precautions are taken to minimize the risk of damage due to alkali-silica reaction by either:

(b) the use of a well established service record for the particular cement and aggregate combination showing no history of cracking due to alkali-silica reaction.

3.10 Density of fresh concrete

Where minimum density of fresh concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 107 shall be not less than the specified value and any individual result shall be not less than 97.5 % of the specified value.

Where maximum density of fresh concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 107 shall be not more than the specified value and any individual result shall be not more than 102.5 % of the specified value.

3.11 Density of hardened concrete

Where minimum density of hardened concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 114 shall be not less than the specified value and any individual result shall be not less than 95 % of the specified value.

Where maximum density of hardened concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 114 shall be not more than the specified value and any individual result shall be not more than 105 % of the specified value.

3.12 Cement content or mix proportions by the analysis of fresh concrete

Where fresh concrete is to be analysed to determine the mix proportions, cement content or free water/cement ratio, the sampling and testing shall be carried out by a method specified in DD 83 or as otherwise agreed.

3.13 Minimum or maximum cement content

3.13.1 Where an equivalent grade (see **7.5** of BS 5328 : Part 1 : 1990) is permitted to be used to provide assurance of minimum cement content, the concrete shall be deemed to comply with the specified minimum cement content if the compressive strength results for the equivalent grade comply with the requirements of **3.16.1**.

3.13.2 Where compliance is assessed by observation of the batching or from examination of the autographic records of the batching plant, the mean of any four consecutive observed cement contents shall be not less than the specified minimum value or not greater than the specified maximum value and any individual observed cement content shall be not less than 95 % of the specified minimum value or not greater than 105 % of the specified maximum value.

3.13.3 Where compliance is assessed from the results of one of the analysis tests on the fresh concrete described in DD 83, the compliance limits shall be specified or agreed by the purchaser and producer based on the information given in DD 83.

3.14 Maximum free water/cement ratio

3.14.1 Where an equivalent grade (see **7.5** of BS 5328 : Part 1 : 1990) is permitted to be used to provide assurance of maximum free water/cement ratio, the concrete shall be deemed to comply with the specified maximum free water/cement ratio if the compressive strength results for the equivalent grade comply with the requirements of **3.16.2**.

3.14.2 Where compliance with the specified maximum free water/cement ratio is assessed by observation of the batching or from examination of the autographic records of the batching plant, allowance shall be made for the water in the aggregates and admixtures. The mean free water/cement ratio of any four consecutive observations shall be not greater than the specified maximum value and any individual observed free water/cement ratio shall be not more than 5 % greater than the value specified.

3.14.3 Where compliance with the specified maximum free water/cement ratio is assessed using workability test results, satisfactory evidence of the relationship between free water/cement ratio and workability for the materials used shall be available (see **3.5** of BS 5328 : Part 3 : 1990). Compliance with the maximum free water/cement ratio shall be deemed to be satisfied when the workability complies with **3.5** provided the materials are in compliance and the cement content is as declared (see clause **3** of BS 5328 : Part 3 : 1990).

3.14.4 Where compliance is assessed from the results of one of the analysis tests on the fresh concrete described in DD 83, the compliance limits shall be specified or agreed by the purchaser and producer based on the information given in DD 83.

3.15 Specified mix proportions (prescribed and standard mixes only)

3.15.1 When compliance is assessed by either observation of the batching, or examination of the autographic records of the batch weights used, an individual assessment of the mix proportions shall be within ±5 % of the values specified and the mean of any four consecutive assessments of cement content shall be not less than the specified value. Account shall be taken of the adjustments permitted in **4.3.2** of BS 5328 : Part 3 : 1990.

3.15.2 Where compliance is assessed from the results of one of the analysis tests on the fresh concrete specified in DD 83, the compliance limits shall be specified or agreed by the purchaser and

3.16 Strength (for designed mixes or where equivalent grade is used to assess compliance for minimum cement content or maximum free water/cement ratio)

3.16.1 ***Sampling and testing***

Batches of concrete to be tested shall be selected at random and a sample obtained by taking a number of increments in accordance with BS 1881 : Part 101.

Two compressive strength test specimens for the selected age for compliance testing shall be prepared from the sample as described in BS 1881 : Part 108 and both the specimens shall be cured in one of the following ways:

(a) for 28 days as described in BS 1881 : Part 111; or

(b) by any other regime of curing specified or agreed between the producer and purchaser (e.g. 7 days, normal curing or accelerated curing at an elevated temperature (see BS 1881 : Part 112)) that will enable the strength at 28 days to be predicted.

On completion of the curing, the specimens shall be tested and the mean of the two results shall be taken as the test result.

When the difference between the two results divided by their mean exceeds 15 %, the test result shall be deemed invalid.

3.16.2 ***Compressive strength***

When both the following conditions are met, the concrete complies with the specified compressive strength.

(a) The mean strength determined from the first two, three or four consecutive test results, or from any group of four consecutive test results complies with the appropriate limits in column A of table 1.

(b) Any individual test result complies with the appropriate limits in column B of table 1.

3.16.3 ***Flexural strength***

When both the following conditions are met, the concrete complies with the specified flexural strength.

(a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

(b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2.

Table 1. Characteristic compressive strength compliance requirements

Specified grade	group of test results	A	B
		The mean of the group of test results exceeds the specified characteristic compressive strength by at least:	Any individual test result is not less than the characteristic compressive strength less:
		N/mm^2	N/mm^2
C20 and above	first 2	1	3
	first 3	2	3
	any consecutive 4	3	3
C7.5 to C15	first 2	0	2
	first 3	1	2
	any consecutive 4	2	2

3.17 Quantity of concrete represented by strength test results

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches. Similarly, the first two or three results shall be taken as representing all the intervening batches. For the individual test result requirements given in column B of table 1, or in item (b) of **3.16.3**, only the particular batch from which the sample was taken shall be at risk.

If the purchaser fails to specify the mean rate of sampling (see BS 5328 : Part 2), or fails to operate the specified rate, the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3.

STANDARDS

Amendment No. 2
published and effective from 15 September 1995
to BS 5328 : Part 4 : 1990

Concrete
Part 4. Specification for the procedures to be used in sampling, testing and assessing compliance of concrete

Revised text

Clause 3.16.2 Compressive strength

After item (b), insert the following.

NOTE. It should be recognized that even for well controlled continuous production, statistical analysis of strength data will give a small probability that a result indicates a non-compliance with criteria (a) or (b). Advice on the action to be taken in the event of such non-compliance is given in clause **9** of BS 5328 : Part 1 : 1991.

AMD 8760/September 1995

Clause 3.16.3 Flexural strength

After item (b) insert the following.

NOTE. It should be recognized that even for well controlled continuous production, statistical analysis of strength data will give a small probability that a result indicates a non-compliance with criteria (a) or (b). Advice on the action to be taken in the event of such non-compliance is given in clause **9** of BS 5328 : Part 1 : 1991.

AMD 8760/September 1995

Concrete

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Incorporating Amendments Nos. 1 and 2 and implementing Amendment No. 3, not published separately

ICS 91.100.30

BSI

Contents

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Caution. When cement is mixed with water, alkali is released. Take precautions to avoid dry cement entering the eyes, mouth and nose when mixing cement or concrete by wearing suitable protective clothing. If cement or concrete enters the eye, immediately wash it out thoroughly with clean water and seek medical treatment without delay. Wash wet concrete off the skin immediately.

When sampling and testing for compliance are required to be quality assured, evidence of certification and any change in certification shall be provided on request.

The producer shall be afforded all reasonable opportunity and facility to inspect the sampling and testing regime employed by the purchaser.

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For the assessment of compliance of ready-mixed concrete, the point and time of sampling shall be at discharge from the producer's delivery vehicle or from the mixer when delivered into the purchaser's vehicle.

For the assessment of compliance of concrete supplied to the construction, the point and time of sampling shall be at delivery into the construction, unless agreed otherwise.

NOTE. Samples taken for assessing ready-mixed concrete may be used also for assessing compliance of concrete as supplied to the construction when either:

(a) concrete is discharged from the producer's vehicle directly into the construction; or

(b) effects due to time delays, ambient conditions, transport and handling between discharge from the producer's vehicle and delivery into the construction are agreed to be minimal; or

(c) adjustments to specified values have been agreed to take account of significant effects as under item (b). Such adjustments may be nominal or based on trials.

Similarly, samples taken at the point of production of concrete, whether ready-mixed, site mixed or factory precast, may be used to assess concrete supplied to the construction.

When concrete is sampled for compliance tests at the point of delivery into the construction, the purchaser shall ensure that the sampling is spread representatively within a single identified batch as produced, in accordance with BS 1881 : Part 101.

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When properties other than those mentioned in BS 5328 : Part 2 are specified (for example thermal conductivity or modulus of elasticity of concrete), the method of test, the compliance requirements and tolerances shall be specified or agreed in advance between the purchaser and producer.

3.4 Temperature of fresh concrete

When required, the temperature of the fresh concrete shall be measured in one of the following ways.

(a) Within 2 min of taking the sample at delivery insert a type A 100 mm immersion thermometer having a range of − 5 °C to +110 °C, graduated at each 1 °C and complying with BS 1704, in the sample to a depth of at least 100 mm. When steady conditions have been maintained for 1 min record the temperature to the nearest 1 °C.

(b) Use an alternative form of temperature measurement which provides the same accuracy as given in item (a).

The measured concrete temperature shall not exceed any specified maximum value or fall below

3.5 Workability

The workability shall be within the following limits on the specified value as appropriate.

Slump		
(i) When sampled in accordance with BS 1881 : Part 101	±25 mm or ±⅓ of the specified value, whichever is the greater.	
(ii) When sampled in accordance with BS 1881 : Part 102	Specified value	Tolerance
	10 mm	+35 mm −10 mm
	25 mm	+35 mm −25 mm
	50 mm	±35
	75 mm and over	± [(⅓ specified slump) + 10 mm]
Limits for intermediate slumps shall be derived by interpolation.		
Vebe time	±3 s or ± $\frac{1}{5}$ of the specified value, whichever is the greater	
Compacting factor	±0.03, where specified value is 0.90 or greater.	
	±0.04, where specified value is less than 0.90 but more than 0.80.	
	±0.05, where specified value is 0.80 or less.	
Flow	Specified value ± 50 mm	

3.6 Air content of fresh concrete

The total air content determined from individual samples of concrete taken at the point of delivery into the construction and representative of any given batch of concrete shall be the specified total value ±2.0 %. The mean total air content from any four consecutive determinations from separate batches shall be the specified value ±1.5 %.

NOTE 1. Total air content comprises entrained air plus entrapped air remaining after compaction.

NOTE 2. In certain forms of construction, e.g. airfield pavements, tolerances on the air content may need to be agreed between the purchaser and the producer.

NOTE 3. The method of measuring air content described in BS 1881 : Part 106 is not necessarily applicable to concrete made with lightweight aggregates, air-cooled blastfurnace slag, aggregates of high porosity, very stiff concrete which cannot be compacted by vibration alone or aerated concrete. Specialist advice should be sought from materials suppliers or other sources on the method of test when these are required.

3.7 Chloride content of fresh concrete

3.7.1 *Methods of calculation and test*

Unless otherwise specified and agreed between purchaser and producer, the method of calculation and test shall be based upon the chloride contents of the constituents and the composition of the concrete. The chloride content of each constituent used in the calculation shall be one of the following:

(a) the measured value;

(b) the value declared by the manufacturer;

(c) the maximum value where specified in the British Standard for the constituent as appropriate (see **5.2.2** of BS 5328 : Part 1 : 1997).

The method of measuring chloride content under item (a) or (b) shall be as follows:

cement, ground granulated blastfurnace slag (ggbs) and pulverized-fuel ash (pfa)	BS 4550 : Part 2
aggregate	BS 812 : Part 117
admixture	BS 5075 : Part 1
water	**9.2** of BS 812 : Part 117 : 1988

The composition of the fresh concrete used in the calculation shall be either that declared as required under **3.1** of BS 5328 : Part 3 : 1990 or that obtained from observation of the batching or from examination of autographic records of the batching plant.

3.7.2 *Compliance*

When assessment of compliance is based on specified or declared values for chloride content of constituents and the declared or observed composition of the concrete, the calculated chloride content of the concrete expressed as the percentage of chloride ion by mass of cement shall not exceed the specified maximum value.

When assessment is based on measured values of chloride content of the fresh concrete or on analysis of fresh concrete for determination of composition, compliance rules shall be specified or agreed in advance by the purchaser and producer.

3.8 Reactive alkali content of concrete

3.8.1 *General*

The concentration of alkalis shall be expressed as the percentage of sodium oxide equivalent, $\%(Na_2O)_e$, using the equation:

$$\%(Na_2O)_e = \%(Na_2O) + 0.658\ \{\%(K_2O)\}$$

The estimation of the reactive alkali content of concrete shall be based on the summation of the reactive alkalis in kilograms in each of the constituents. The calculation shall be based on either:

(a) certified average alkali contents;

(b) declared values;

(c) maximum values when specified in the British Standard for the constituent; or

(d) a combination of the above.

If the reactive alkalis, summed from all the constituents other than the cement components, are 0.2 kg/m^3 or less they can be ignored in the calculation of the reactive alkali content.

3.8.2 ***Methods of test for alkali***

3.8.2.1 *Method of test for Portland cements*

When testing cement complying with BS 12, BS 1370, BS 4027, BS 7583 or the Portland cement component of composite cements containing ggbs or pfa, either the method given in **NA.5.1** of BS EN 196-21 : 1992, or a secondary X-ray method calibrated against this method, shall be adopted.

When testing composite cements containing ggbs or pfa the components shall be tested separately.

3.8.2.2 *Method A for testing ggbs and pfa*

When testing ggbs complying with BS 6699, pfa complying with BS 3892 : Part 1 or Part 2 or the ggbs or pfa component of composite cements, either the method given in **NA.5.1** (for ggbs) or **NA.5.2** (for pfa) of BS EN 196-21 : 1992, or a secondary X-ray method calibrated against these methods, shall be adopted. The reactive alkali shall be taken as 50 % of the measured value when testing ggbs or 17 % of the measured value when testing pfa.

3.8.2.3 *Method B for testing ggbs and pfa*

When testing ggbs complying with BS 6699, pfa complying with BS 3892 : Part 1 or Part 2 or the ggbs or pfa component of composite cements, the method given in **16.11** of Concrete Society Report No. 30 shall be adopted.

3.8.2.4 *Calculation of reactive alkali content of composite cements and combinations containing ggbs or pfa*

The reactive alkali content (A_r) of the cement or combination shall be calculated from the following equation:

$$A_r = (PA_c + (100-P)A_b)/100$$

where

P is the content of Portland cement in the cement or combination (in % *m/m*);

A_c is the content of alkalis in the Portland cement component (in % *m/m*);

A_b is the content of reactive alkalis in the ggbs or pfa (in % *m/m*).

3.8.2.5 *Method of test for aggregates*

The chloride content of aggregates shall be determined using the method given in BS 812 : Part 117. The sodium oxide equivalent shall be calculated by multiplying the percentage of chloride ion by 0.76.

The chloride ion content of aggregates containing 0.01 % chloride ions by mass or more shall be determined at least weekly in accordance with BS 812 : Part 117. When the chloride ion content is less than 0.01 % it shall be regarded as nil, and routine testing is not required for the purposes of this compliance procedure.

3.8.3 ***Use of test results***

3.8.3.1 *Certified average alkali contents*

Cement, ggbs and pfa suppliers will, on request, provide a certified average alkali content determined by the methods given in **3.8.1**. The latest available data relevant to the period of supply shall be used in the calculations.

3.8.3.2 *Mix proportions*

The reactive alkali content per cubic metre of concrete shall be calculated from the declared mix proportions or from those obtained from observation of the batching or from examination of the autographic records of the batching.

3.8.4 ***Compliance***

When compliance is assessed by a calculation based on certified average values for reactive alkali content of constituents and the declared or observed composition of the concrete, the calculated reactive alkali content of the concrete, expressed as equivalent sodium oxide by mass of concrete, shall not exceed the permitted reactive alkali content.

When compliance is assessed by a single analysis of reactive alkali content of one or more of the constituents, the concrete shall be deemed to comply with the permitted reactive alkali content if the calculated reactive alkali content of the concrete is not greater than the permitted alkali content plus 0.50 kg/m^3 (see **5.2.4** of BS 5328 : Part 1 : 1997).

When assessment is based on more than one set of measured values or on analysis of fresh concrete for determination of composition, compliance rules shall be specified or agreed in advance by the purchaser and producer.

3.9 Minimizing the risk of cracking due to alkali-silica reaction by methods other than the control of alkali

Compliance requirements shall be agreed between the purchaser and producer where precautions are taken to minimize the risk of damage due to alkali-silica reaction by either:

(a) the use of an aggregate combination likely to be non-reactive;

(b) the use of a well established service record for the particular cement and aggregate combination showing no history of cracking due to alkali-silica reaction.

3.10 Density of fresh concrete

Where minimum density of fresh concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 107 shall be not less than the specified value and any individual result shall be not less than 97.5 % of the specified value.

Where maximum density of fresh concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 107 shall be not more than the specified value and any individual result shall be not more than 102.5 % of the specified value.

3.11 Density of hardened concrete

Where minimum density of hardened concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 114 shall be not less than the specified value and any individual result shall be not less than 95 % of the specified value.

Where maximum density of hardened concrete is specified, the mean of any four consecutive determinations in accordance with BS 1881 : Part 114 shall be not more than the specified value and any individual result shall be not more than 105 % of the specified value.

3.12 Cement content or mix proportions by the analysis of fresh concrete

Where fresh concrete is to be analysed to determine the mix proportions, cement content or free water/cement ratio, the sampling and testing shall be carried out by a method specified in DD 83 or as otherwise agreed.

3.13 Minimum or maximum cement content

3.13.1 Where an equivalent grade (see **8.5** of BS 5328 : Part 1 : 1997) is permitted to be used to provide assurance of minimum cement content, the concrete shall be deemed to comply with the specified minimum cement content if the compressive strength results for the equivalent grade comply with the requirements of **3.16.2**.

3.13.2 Where compliance is assessed by observation of the batching or from examination of the autographic records of the batching plant, the mean of any four consecutive observed cement contents shall be not less than the specified minimum value or not greater than the specified maximum value and any individual observed cement content shall be not less than 95 % of the specified minimum value or not greater than 105 % of the specified maximum value.

3.13.3 Where compliance is assessed from the results of one of the analysis tests on the fresh concrete described in DD 83, the compliance limits shall be specified or agreed by the purchaser and producer based on the information given in DD 83.

3.14 Maximum free water/cement ratio

3.14.1 Where an equivalent grade (see **8.5** of BS 5328 : Part 1 : 1997) is permitted to be used to provide assurance of maximum free water/cement ratio, the concrete shall be deemed to comply with the specified maximum free water/cement ratio if the compressive strength results for the equivalent grade comply with the requirements of **3.16.2**.

3.14.2 Where compliance with the specified maximum free water/cement ratio is assessed by observation of the batching or from examination of the autographic records of the batching plant, allowance shall be made for the water in the aggregates and admixtures. The mean free water/cement ratio of any four consecutive observations shall be not greater than the specified maximum value and any individual observed free water/cement ratio shall be not more than 5 % greater than the value specified.

3.14.3 Where compliance with the specified maximum free water/cement ratio is assessed using workability test results, satisfactory evidence of the relationship between free water/cement ratio and workability for the materials used shall be available (see **3.5** of BS 5328 : Part 3 : 1990). Compliance with the maximum free water/cement ratio shall be deemed to be satisfied when the workability complies with **3.5** provided the materials are in compliance and the cement content is as declared (see clause **3** of BS 5328 : Part 3 : 1990).

3.14.4 Where compliance is assessed from the results of one of the analysis tests on the fresh concrete described in DD 83, the compliance limits shall be specified or agreed by the purchaser and producer based on the information given in DD 83.

3.15 Specified mix proportions (prescribed and standard mixes only)

3.15.1 When compliance is assessed by either observation of the batching, or examination of the autographic records of the batch weights used, an individual assessment of the mix proportions shall be within ±5 % of the values specified and the mean of any four consecutive assessments of cement content shall be not less than the specified value. Account shall be taken of the adjustments permitted in **4.3.2** of BS 5328 : Part 3 : 1990.

3.15.2 Where compliance is assessed from the results of one of the analysis tests on the fresh concrete specified in DD 83, the compliance limits shall be specified or agreed by the purchaser and producer based on the information given in DD 83.

3.16 Strength (for designed mixes or where equivalent grade is used to assess compliance for minimum cement content or maximum free water/cement ratio)

3.16.1 *Sampling and testing*

Batches of concrete to be tested shall be selected at random and a sample obtained by taking a number of increments in accordance with BS 1881 : Part 101.

Two compressive strength test specimens for the selected age for compliance testing shall be prepared from the sample as described in BS 1881 : Part 108 and both the specimens shall be cured in one of the following ways:

(a) for 28 days as described in BS 1881 : Part 111; or

(b) by any other regime of curing specified or agreed between the producer and purchaser (e.g. 7 days, normal curing or accelerated curing at an elevated temperature (see BS 1881 : Part 112)) that will enable the strength at 28 days to be predicted.

On completion of the curing, the specimens shall be tested and the mean of the two results shall be taken as the test result.

When the difference between the two results divided by their mean exceeds 15 %, the test result shall be deemed invalid.

3.16.2 *Compressive strength*

When both the following conditions are met, the concrete complies with the specified compressive strength.

(a) The mean strength determined from the first two, three or four consecutive test results, or from any group of four consecutive test results complies with the appropriate limits in column A of table 1.

(b) Any individual test result complies with the appropriate limits in column B of table 1.

NOTE. It should be recognized that even for well controlled continuous production, statistical analysis of strength data will give a small probability that a result indicates a non-compliance with criteria (a) or (b). Advice on the action to be taken in the event of such non-compliance is given in clause **10** of BS 5328 : Part 1 : 1997.

3.16.3 *Flexural strength*

When both the following conditions are met, the concrete complies with the specified flexural strength.

(a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

(b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2.

NOTE. It should be recognized that even for well controlled continuous production, statistical analysis of strength data will give a small probability that a result indicates a non-compliance with criteria (a) or (b). Advice on the action to be taken in the event of such non-compliance is given in clause **10** of BS 5328 : Part 1 : 1997.

Table 1. Characteristic compressive strength compliance requirements

Specified grade	group of test results	A	B
		The mean of the group of test results exceeds the specified characteristic compressive strength by at least:	Any individual test result is not less than the characteristic compressive strength less:
		N/mm^2	N/mm^2
C20 and above	first 2	1	3
	first 3	2	3
	any consecutive 4	3	3
C7.5 to C15	first 2	0	2
	first 3	1	2
	any consecutive 4	2	2

3.17 Quantity of concrete represented by strength test results

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches. Similarly, the first two or three results shall be taken as representing all the intervening batches. For the individual test result requirements given in column B of table 1, or in item (b) of **3.16.3**, only the particular batch from which the sample was taken shall be at risk.

If the purchaser fails to specify the mean rate of sampling (see BS 5328 : Part 2), or fails to operate the specified rate, the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3.