

## Concrete for normal uses

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The new standards for concrete, BS EN 206–1 and BS 8500 will co-exist and have equal status to the existing BS 5328 until its withdrawal in December 2003. However, BSI recommends that BS 5328 is used for specifications until the end of 2003 and BS EN 206-1/BS 8500 is used from 2004.

One of a series of publications produced in conjunction with the following organizations, and part-funded by DTI (formerly DETR):

Association of Concrete Industrial Flooring Contractors  
Association of Lightweight Aggregate Manufacturers  
British Cement Association  
British Standards Institution  
Building Research Establishment  
Cement Admixtures Association  
Cementitious Slag Makers Association  
Concrete Industry Alliance  
Concrete Society  
Glanville Consultants  
Institute of Concrete Technology  
Ove Arup & Partners  
Quarry Products Association  
Ready-mixed Concrete Bureau  
RMC Readymix  
L M Scofield Ltd.  
United Kingdom Quality Ash Association

A full list of the publications in this series is given on the back page.

### INTRODUCTION

This publication gives guidance on the specification of normal-weight concrete for normal uses. Guidance on concrete resistant to chemical attack, concrete for industrial floors, coloured concrete and lightweight concrete is given in other publications in this series.

BS EN 206–1, *Concrete. Part 1: Specification, performance, production and conformity* is a ‘framework standard’. This is a standard where some of the detailed requirements are given in national provisions, i.e. the details of what to specify and certain rules of application are given in a British Standard, BS 8500, *Complementary British Standard to BS EN 206–1*. To help specifiers, producers and users, a derived publication, *Standards for fresh concrete*, will be produced that contains the text of both standards woven together, plus guidance on their use.

Concrete may be specified as either designed concrete or prescribed concrete, each with its respective sub-set of designated and standardized prescribed concrete. Designed concrete contains a performance requirement for strength. Prescribed concrete requires the producer only to batch the specified quantities of constituent materials; the specifier assumes responsibility for concrete performance. The use of prescribed and standardized prescribed concrete for structural applications is the exception, and consequently this publication covers designed and designated concrete only.

BS 8500 has also introduced proprietary concrete that satisfies a defined performance under standard test conditions, e.g. self-compaction. Any claims made for proprietary concrete are the responsibility of the producer and BSI has not substantiated any such claims. Specification using proprietary concrete is not covered in this publication.

In the case of **designed** concrete, specify that the concrete shall be produced in accordance with the relevant clauses of BS EN 206–1/BS 8500–2 and also specify the following:

- compressive strength class;

- limiting values for concrete composition or the design chemical class;
- maximum aggregate size;
- chloride content class;
- consistence class.

A form to help with the specification of designed concrete is given in Annex A.

In the case of **designated** concrete, specify that the concrete shall be produced in accordance with the relevant clauses of BS EN 206–1/BS 8500–2 and also specify the following:

- appropriate designated concrete;
- maximum aggregate size when other than 20 mm;
- consistence class.

Where specifying concrete for normal uses, options for specifying additional requirements are available, but are not normally needed (see *Standards for fresh concrete* or clause 4 of BS 8500–1).

The requirements in BS 8500–2 for designated concrete and recommendations in BS 8500–1, Annex A for designed concrete should provide adequate durability provided the exposure is as expected, the minimum cover to reinforcement is achieved and the concrete is placed, compacted and cured in accordance with DD ENV 13670–1, *Execution of concrete structures. Part 1: Common rules*.

All designed concretes and designated concretes conforming to BS 8500–2 are required to be designed by the producer to minimise the risk of deleterious ASR, hence there is not normally a need to specify additional requirements in this respect.

## EXPOSURE CLASSIFICATION

The exposure classification used in BS EN 206–1 and BS 8500 is completely different from that used in BS 8110 and BS 5328.

BS EN 206–1 contains a set of exposure classes related to different mechanisms of deterioration. This system is described in clause 4 of BS EN 206–1, and practical examples of the exposure classes are given in BS 8500–1, A.2. The main classification is:

- X0 – No risk of corrosion or attack;
- XC – Corrosion induced by carbonation;
- XD – Corrosion induced by chlorides other than from seawater;
- XS – Corrosion induced by chlorides from seawater;
- XF – Freeze/thaw attack;
- XA – Chemical attack.

BS EN 206–1 does not contain abrasion classes. See *Concrete for industrial floors* in this series for guidance on abrasion classes for floors.

With the exception of X0, each class of exposure is split into a number of sub-classes. For each concrete element, the relevant exposure classes have to be identified. There will always be one and, in many cases, more than one relevant exposure class. Different exposure classes may apply to different faces of the same element.

Some examples of combined exposure classes are given in Table 1.

Exposure class X0 can only exist on its own.

The exposure classification in BS EN 206–1 for chemical attack (XA) is limited to natural ground and static water conditions. However BRE Special Digest 1, *Concrete in aggressive ground*, covers a much wider range of conditions e.g. acid attack, brownfield sites and the thaumasite form of sulfate attack, and consequently, BS 8500 adopts the Special Digest 1 approach to classification for chemical attack, see *Concrete resistant to chemical attack* in this series. These publications explain and use the terms ‘aggressive chemical environment for concrete (ACEC) class’ and ‘design chemical (DC–) class’.

## DETERMINATION OF THE CONCRETE QUALITY

The concrete quality will depend upon:

- structural considerations leading to a strength class;
- identified relevant exposure classes;

**Table 1:** Examples of combined exposure

Example	Relevant exposure classes
External reinforced concrete element not highly saturated but exposed to freezing and to rain or water	XC3 - 4 + XF1
Horizontal external reinforced concrete element where water accumulates and which are exposed to freezing	XC3 - 4 + XF3
External reinforced concrete element subject to frequent splashing with water and which is exposed to freezing	XC3 - 4 + XF3
Fully buried reinforced concrete foundation	XC2 + ACEC class <sup>[1]</sup>
Reinforced concrete foundation where part of the foundation may freeze	XC2 + ACEC class <sup>[1]</sup> + XF3
Reinforced concrete seawall <sup>[2]</sup>	XS3 + XC3-4 + ACEC class <sup>[1]</sup>
Bridge abutment	XD3 + XC3-4 + XF2 + ACEC class <sup>[1]</sup>
<b>Notes</b>	
[1] See <i>Concrete resistant to chemical attack</i> in this series.	
[2] Depending on location, a freeze/thaw exposure class, either XF2 or XF4, may have to be added.	

- intended working life;
- selected minimum cover to reinforcement;
- other considerations e.g. aesthetics, controlling thermal cracking, lightweight concrete.

The selection of some options will limit the available methods of specification, see BS 8500–1.

European design codes give recommendations for intended working lives for various types of structure. For resistance to corrosion of reinforcement, longer intended working lives require higher concrete qualities and/or larger minimum cover to reinforcement. The recommended intended working life for buildings and commercial structures is “at least 50 years”. BS 8500 uses the term “at least” to make it clear that most structures are expected to perform adequately for a period in excess of the intended working life.

In the European design codes, the nominal cover to reinforcement comprises a minimum cover plus a variable margin to allow for fixing tolerances. This margin for surfaces cast against formwork is typically in the range 5 to 15 mm. BS 8500 uses the nominal cover but expresses it as a minimum cover plus a margin. The minimum cover is the basis on which the

durability provisions are based. The designer selects the margin having taken into account consequences of low cover, the level of workmanship expected on site and the quality control procedures.

For most building and commercial structures, the **designated** concrete method of specification is appropriate. BS 8500–1, **A.4** gives guidance on the selection of designated concrete. The inputs are the exposure classes and intended working life. From these, the appropriate designated concrete and nominal cover to reinforcement are selected from BS 8500–1, table A.6. It is necessary to check that the strength class associated with the selected designated concrete is adequate for structural purposes.

Table 2 gives the designated concretes associated with what is expected to be the minimum cover to reinforcement in the European design code.

For housing and foundation applications, the appropriate designated concrete can be selected directly from BS 8500–1, table A.7.

Some examples of these procedures are given in *Examples of the specification of designated concrete* in this series.

**Table 2:** Designated concretes for the covers to reinforcement expected to be given in EC2 for an intended working life of at least 50 years

Exposure class(es) and design chemical class	Nominal cover <sup>[1], [2]</sup>	Designated concrete
XC1	15 + Δc	RC25
XC2 + ACEC class 1 <sup>[3]</sup>	25 + Δc	RC30
XC2 + DC-2	25 + Δc	FND 2
XC2 + DC-4m*	25 + Δc	FND 4M*
XC2 + ACEC class 1 <sup>[3]</sup> + XF3	25 + Δc	RC50XF or PAV1
XC3-4 + XF1	25 + Δc	RC40
	30 + Δc	RC35
XC3-4 + XF3	25 + Δc	RC50XF or PAV2
	30 + Δc	RC50XF or PAV1
<b>Notes</b>		
[1] Expressed as the minimum cover to normal reinforcement plus a tolerance, Δc, to accommodate fixing precision.		
[2] The minimum cover to any pretensioned bonded prestressing steel is increased by 10 mm.		
[3] See <i>Concrete resistant to chemical attack</i> in this series.		

**Designed** concrete specification is suitable for all situations as it has complete flexibility. In this case the inputs are the relevant exposure classes and the intended working life.

From each of the identified exposure classes and the intended working life, the recommended limiting values given in BS 8500–1, **A.5** are noted. The most onerous values are selected for specification, with one exception. The exception is where a freeze/thaw exposure class occurs in combination with one or more other exposure classes that have a higher strength class for durability. In this case, the strength class may be reduced by one class for air-entrained concrete provided the higher strength is not required for structural purposes.

Some examples of this procedure are given in *Examples of the specification of designated concrete* in this series.

Where the cover and either a compressive strength class or a designated concrete have been selected from considerations of durability, check that:

- the strength is adequate for structural purposes;

- the cover is satisfactory for structural and fire resistance purposes;
- the maximum aggregate size is compatible with the cover specified.

The appropriate design codes of practice should be consulted.

### COMPRESSIVE STRENGTH CLASS

Compressive strength is specified by a dual classification comprising the characteristic strength of 300 x 150 mm diameter cylinders followed by the characteristic strength of 150 mm cubes. This is expressed as C25/30, for example. BS EN 206 - 1 permits conformity to be established using 100 mm cubes and BS 8500 –2 gives a 1:1 relationship between 150 and 100 mm cubes.

The reason for the dual classification is that the European concrete design codes use the cylinder strength for design purposes, but concrete conformity is based on the cube in all but two EU Member States. The compromise reached was a dual classification system.

Table 7 of BS EN 206–1 gives a range of strength classes from C8/10 to C100/115. BS 8500–1 gives two additional classes, C28/35

and C32/40, as these are used in the UK durability provisions.

As the durability requirements often control the concrete quality, structural design can often be achieved economically by using the compressive strength class for durability. Therefore the specifier should start by selecting the concrete strength class for durability as the basis for structural design.

The designated concrete system does not provide the option of selecting a higher strength class for the same maximum water/cement ratio. Where a higher strength class is needed for structural design purposes, a designated concrete with the required strength class should be selected or a designed concrete used.

### LIMITING VALUES FOR CONCRETE COMPOSITION

The recommended limiting values for concrete composition are given in BS 8500–1, A.5 for designed concrete and the requirements for designated concrete are given in BS 8500–2, clause 6. The values given in informative Annex F of BS EN 206–1 should be disregarded.

### MAXIMUM AGGREGATE SIZE

The maximum aggregate sizes should be selected from:

- 10 mm;
- 20 mm;
- 40 mm.

Whilst concretes made with maximum aggregate sizes of 20 and 10 mm are widely available throughout the UK, the availability of 40 mm aggregate needs to be checked with local concrete suppliers.

As the minimum cover to reinforcement is related to the maximum aggregate size, a check should be made on its adequacy. If the cover is not adequate, another combination of minimum cover and concrete quality should be selected or the maximum aggregate size changed.

### CHLORIDE CONTENT CLASS

The chloride class should be specified from the guidance given in Table 3.

**Table 3:** Chloride content classes for the UK

Class	Application
Class 0,10	Prestressed concrete
Class 0,20	Heat cured concrete Reinforced concrete made with cement conforming to BS 4027
Class 0,40	Reinforced concrete or concrete containing embedded metal made with other cement types
Class 1,0	Concrete without reinforcement or other embedded metal

### CONSISTENCE CLASS

BS EN 206–1 uses consistence classes as the main method of specifying what was traditionally called ‘workability’, and is now called consistence. Clause 4 of BS EN 206–1 gives classes for slump, flow, Vebe and degree of compactability. The degree of compactability test is not the same as the BS 1881: Part 103 compaction factor test, but it covers the same applications and it is likely that BS 1881: Part 103 will be withdrawn in December 2003 to avoid having two tests for the same application. Requirements for some slump and flow classes are reproduced in Tables 4 and 5.

**Table 4:** Slump classes

Class	Slump, mm
S1	10 to 40
S2	50 to 90
S3	100 to 150

**Table 5:** Flow classes

Class	Flow diameter, mm
F2	350 to 410
F3	420 to 480
F4	490 to 550
F5	560 to 620
F6	≥ 630

Target values of consistence for special applications are provided in BS EN 206–1, but

the classes given above are suitable for most normal uses.

Select a consistence class appropriate for the intended method of placement. Guidance on suitable classes is given in BS 8500–1, A.6.

### EXCHANGE OF INFORMATION

The satisfactory and confident use of concrete will benefit all parties. A discussion between the user and producer will help to ensure that the right concrete is supplied for a particular purpose and will minimize any misunderstandings.

Information about the concrete to be supplied, the sources of materials, back-up supply facilities and the status of quality assurance of the constituent materials and the concrete supplying plant are available from the producer.

By prior agreement, information is supplied during the period of delivery on changes to the sources of supply of constituent materials and changes to the status of quality assurance.

The producer is not permitted to make any changes to the mix proportions that override any specification requirement, e.g. a maximum water/cement ratio.

### SUPPLY

The specification is reviewed by the concrete producer using the requirements in BS EN 206–1/BS 8500–2 to provide concrete that satisfies **all** the specified requirements. To provide concrete with the specified consistence, strength and, where relevant, air content, the producer will select materials available to him that have been identified in BS 8500–2 as being suitable for the specified concrete and that will work within the specified mix limitations.

The producer then calculates batch quantities that provide the correct yield of concrete.

### CONFORMITY

The factory production control system in BS EN 206–1 requires the **producer** to demonstrate conformity. This philosophy is a fundamental difference from that of previous UK standards for concrete.

In the past, the concrete producer operated a production control system and the user established compliance.

All concrete is subject to conformity testing by the producer as specified in BS EN 206–1. Each result is assessed individually and in groups. Concrete can be grouped into families for control of both production and conformity. Guidance on the application of the BS EN 206–1 conformity requirements is given in *Guidance on the application of the EN 206–1 conformity rules* available for free downloading from [www.qpa.org](http://www.qpa.org).

BS EN 206–1 requires the specifier to be informed of any non-conformity not obvious at delivery. Where there is third-party involvement, the actions taken with respect to non-conformities are audited to ensure that they were appropriate.

Compliance testing by the user is not part of the philosophy of BS EN 206–1, but provision has been made for identity testing. This is required where:

- there are doubts about the concrete quality;
- extra assurance is needed for a critical concrete element.

Identity testing can also be used to confirm conformity information supplied by the producer.

The identity testing criteria given in Annex B of BS EN 206–1 are based on the presumption of concrete conformity, i.e. they test for evidence that this hypothesis is **not** correct.

### FURTHER READING

The other publications from this series will be helpful. Visit [www.cementindustry.co.uk](http://www.cementindustry.co.uk) and click ‘information’/‘library’/‘BCA publications’ to check availability and for free download.

*Standards for fresh concrete – a composite of BS EN 206-1 and BS 8500*

*Specifying concrete to BS EN 206–1/BS 8500:*

*Concrete for normal uses*

*Concrete resistant to chemical attack*

*Guide to the selection of concrete quality and cover for reinforcement for normal concrete structures*

*Examples of the specification of designated concrete*

*Examples of the specification of designed concrete*

*Guidance on additional requirements for designed concrete*

*Lightweight concrete*

*Visual concrete*

*Coloured concrete*

*Concrete for industrial floors*

*Specifying constituent materials for concrete to BS EN 206-1/BS 8500:*

*Cements*

*Additions*

*Admixtures*

*European replacements for British Standards:*

*Concrete and its constituent materials*

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**ANNEX A - Proforma**

**Proforma for designed concrete specification for use on contract**

The concrete shall conform to the relevant clauses in BS EN 206–1 and BS 8500–2

Requirement	BS 8500 reference	Designed concrete specification			
Concrete reference					
Compressive strength class	BS 8500–1, Table A.20				
Maximum w/c ratio and minimum cement content, kg/m <sup>3</sup> or DC-class	BS 8500–1, A.2.4 and A.5				
Cement or combination group or types	BS 8500-1, Table A.17				
Maximum aggregate size, mm	BS 8500–1, A.1				
Aggregate drying shrinkage, at most	BS 8500–1, A.10.3				
Chloride class	BS 8500–1, A.9				
Consistence class (one of): Slump Flow Other:	BS 8500–1, A.6				
Other requirements	BS 8500–1, 4.3.3				
<b>Information from the specifier to producer</b>					
<b>Information</b>	<b>BS 8500 reference</b>				
Method of placing and finishing					
Other information	BS 8500–1, 5.1				

See ANNEX B for example specifications

## ANNEX B - Example

## Specification of designed concretes for use on contract

Any building, Smith Street, London .....

The concrete shall conform to the relevant clauses in BS EN 206-1 and BS 8500-2

Requirement	BS 8500 reference	Designed concrete specification			
		Parking	Slabs	Foundations	
Concrete reference		<i>Parking</i>	<i>Slabs</i>	<i>Foundations</i>	
Compressive strength class	BS 8500-1, Table A.20	C32/40	LC32/40	C28/35	
Maximum w/c ratio and minimum cement content, kg/m <sup>3</sup> or DC-class	BS 8500-1, A.2.4 and A.5	0.55, 300	0.55, 300	DC-3*	
Cement or combination group or types	BS 8500-1, Table A.17	I, II, IIIA	I, II, IIIA	–	
Maximum aggregate size, mm	BS 8500-1, A.1	20	20	40	
Aggregate drying shrinkage, at most	BS 8500-1, A.10.3	0.075%	0.075%	–	
Chloride class	BS 8500-1, A.9	Cl 0,40	Cl 0,40	Cl 0,40 or Cl 0,20 if SRPC is used	
Consistence class (one of): Slump Flow Other:	BS 8500-1, A.6	S2	F5	S3	
Other requirements	BS 8500-1, 4.3.3	Freeze/thaw resisting aggregate Minimum air content 3.5%	Target density ≤ 1840 kg/m <sup>3</sup>	Maximum cement content of 450 kg/m <sup>3</sup>	
<b>Information from the specifier to producer</b>					
<b>Information</b>	<b>BS 8500 reference</b>				
Method of placing and finishing		Dumper	Pumping and power floating	Direct discharge	
Other information	BS 8500-1, 5.1	Identity testing of air content of the first load and every 24 m <sup>3</sup>	–	–	