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# MODEL CLAUSES FOR CIVIL ENGINEERING WORKS

## SECTION 80 STRUCTURAL CONCRETE

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## SECTION 80

## STRUCTURAL CONCRETE

### Application of standards and codes of practice

**80.001**

Concrete shall be produced and placed in accordance with this Section when it is used for all structural concrete except as identified in Section 85 of the Model Clauses.

Concrete and the constituent materials shall comply with BS 5400: Part 7:1978 except where qualified, amended or replaced by the following Clauses.

All numbers in parentheses within the heading margin are the relevant clause numbers within BS 5400: Part 7:1978.

### Classification of concrete mixes generally (3.1.1)

**80.002**

Delete BS 5400: Part 7, clause 3.1.1, and the following shall apply.

Structural concrete shall be a designed mix, and shall be either ordinary structural concrete or special structural concrete.

**(3.7)**

Delete BS 5400: Part 7, clause 3.7.

Each concrete mix shall be in accordance with Schedule 80/A, in Appendix 80/1.

### Cement for ordinary structural concrete (3.2.1)

**80.003**

Delete BS 5400: Part 7, clause 3.2.1, and the following shall apply:

Cement for ordinary structural concrete shall be one of the following:

- (i) Portland cement to BS EN 197-1:2000, (CEM 1),
- (ii) Portland blast furnace cement to BS EN 197-1:2000 (CEM 111A, CEM 111B),
- (iii) Sulphate resisting Portland cement to BS 4027:1996 (SRPC),
- (iv) Portland pulverised fuel ash (PFA) cement to BS EN 197-1:2000 (CEM 11A, CEM 11B),
- (v) Portland cement to BS EN 197-1:2000 mixed with PFA in accordance with BS EN 450-1+A1:2007, subject to the limits specified in BS 5400:Part 7 and Clause 80.005 (C11B, C1V B),
- (vi) Portland cement to BS EN 197-1:2000 mixed with ground granulated blast furnace slag to BS 6699 subject to the limits specified in BS 5400:Part 7 and Clause 80.005 (C11, C111A, C111B).

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All Portland cements shall be obtained from a company that has a quality system for product conformity approved in accordance with BS EN ISO 9001 by a body accredited by the United Kingdom Accreditation Service (UKAS) or equivalent.

**Cement for special structural concrete (3.3.1)**

**80.004**

Delete BS 5400: Part 7, clause 3.3.1, and the following shall apply:

Cement for special structural concrete shall comply with Clause 80.003 or, subject to the agreement of the Employer's Representative, with the following:

- (i) high alumina cement to BS EN 14647: 2005. High alumina cement shall only be used where early and rapid strength gain is required, and the required strength gain cannot be obtained using the other cements specified in this Clause with, where appropriate, an accelerating admixture to BS EN 934-2:2001,
- (ii) low heat Portland cement to BS 1370,
- (iii) high slag blast furnace cement to BS EN 197,
- (iv) Portland cement to BS EN 197-1:2000 mixed with ground granulated blast furnace slag to BS 6699 subject to the limits specified in Clause 80.005,
- (v) modified Portland cements to BS EN 197-1:2000,
- (vi) Portland cement to BS EN 197-1:2000 mixed with additional silica fume slurry having a current British Board of Agrément certificate and source accepted by the Employer's Representative, subject to the limits specified in Clause 80.005.

**Cement replacement 80.005**

Pulverised fuel ash (PFA) used as a cement replacement shall not be less than 21% or more than 35% by weight of the total cementitious content, except as qualified below.

The maximum limit of PFA may be increased to 55% provided that the resultant concrete will have a minimum strength class of C20/25, a maximum water cement ratio of 0.65, a minimum cement content of 260 kg/m<sup>3</sup> and the concrete is to be either:

- (i) located below final ground level,
- (ii) located permanently underwater,

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- (iii) coated by an approved protective treatment which inhibits the passage of carbon dioxide.

Cement replacement in sprayed concrete shall not exceed the limits specified in the 'European Specification for Sprayed Concrete' published by the European Federation of Specialist Construction Chemicals and Concrete Systems (EFNARC).

Where PFA is proposed to be used in the concrete mix, the Employer's Representative shall be provided with a certificate to show that the material is in accordance with BS EN 450-1:2005+A1:2007, with the grading and name of the power station.

Ground granulated blast furnace slag (ggbs) used as a cement replacement in ordinary structural concrete shall not exceed 65% by weight of the total cement.

Ggbs used as a cement replacement in special structural concrete shall not be less than 50% or more than 80% by weight of the total cement.

Where ggbs is proposed to be used in a concrete mix, the Employer's Representative shall be provided with a certificate to show that the material complies with BS 6699.

Silica fume used in special structural concrete shall not exceed 15% by weight of the total cement.

#### **Aggregate for ordinary structural concrete (3.2.2)**

**80.006**

Delete BS 5400: Part 7, clause 3.2.2, and the following shall apply.

Aggregates for ordinary structural concrete shall be one of the following:

- (i) aggregates from natural sources to BS EN 12620:2002, as qualified by this Clause,
- (ii) air cooled blast furnace slag to BS EN 12620:2002.

When air cooled blast furnace slag is included in the concrete mix, the aggregate shall be sampled and tested at a frequency agreed with the Employer's Representative to confirm its bulk density. Where significant variation from that used in the mix design is found, the mix shall be adjusted to allow for the variation in the bulk density of the aggregate.

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The shell content of the aggregates included as calcium carbonate determined in accordance with BS 812-106:1985 shall not exceed the values stated in BS EN 12620:2002.

Where no nominal maximum size of aggregate is specified in Schedule 80/A the nominal maximum size of the aggregate shall be as specified below such that the concrete can be placed and compacted around the reinforcement without segregation.

The nominal maximum size of the aggregate shall not exceed:

- (i) 0.25 x the smallest dimension of the structural member,
- (ii) the clear distance between reinforcing bars less 5mm, or 0.75 x the clear distance between reinforcing bars, whichever is the less,
- (iii) 0.75 x the concrete cover.

The chloride levels of the aggregates shall be determined in accordance with BS 812-117:1988 at a frequency agreed with the Employer's Representative.

The flakiness index of the coarse aggregate determined in accordance with BS 812-105.1: 1989 shall not exceed 40%, except for natural, uncrushed aggregates included in concrete grade 40 or lower, when the flakiness index shall not exceed 50%. No limit shall apply to concrete grade C12/15 or less.

The drying shrinkage determined in accordance with BS 812-120:1989 shall not exceed 0.075%.

#### **Aggregate for special structural concrete (3.3.2)**

**80.007**

Delete BS 5400: Part 7, clause 3.3.2, and the following shall apply:

Aggregates for special structural concrete shall comply with Clause 80.006 except that aggregate to BS EN 12620:2002 shall not be used with high alumina cement.

Lightweight aggregate shall be in accordance with BS EN 13055-1:2002.

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### Water (3.2.3)

**80.008** Delete BS 5400: Part 7, clause 3.2.3 and the following shall apply.

Water for use in the concrete mix shall be clean and free from harmful matter and, where possible, shall be obtained from a water supply company.

Should the Contractor wish to use any other source of water, the Employer's Representative shall be advised of the proposed source, and the water shall be tested in accordance with BS EN 1008 at a frequency agreed with the Employer's Representative.

Such water shall not be incorporated in the Works without the agreement of the Employer's Representative.

If the pH value of such water is less than 4, the water shall not be incorporated in the concrete mix.

The sodium oxide and potassium oxide content of such water shall be reported to the Employer's Representative, and shall be taken into account when calculating the total reactive alkali content of the concrete mix in accordance with Clause 80.015.

### Admixtures (3.3.4)

**80.009** Delete BS 5400: Part 7, clause 3.3.4.1, and the following shall apply.

The quantity and method of use of admixtures shall be in accordance with the manufacturer's recommendations and shall be subject to the agreement of the Employer's Representative.

Except when used in sprayed concrete, admixtures in a concrete mix shall not exceed 50g/kg of cement nor, unless dispersed in the mixing water, be less than 2g/kg of cement. Liquid admixtures in excess of 3 litres/m<sup>3</sup> shall be taken into account when calculating the water/cement ratio.

Accelerating admixtures to be used in sprayed concrete shall not exceed the following:

- (i) powder admixtures: 6% of cementitious material by weight,
- (ii) liquid admixtures: 8% of cementitious material by weight.

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When used in a grout mix, the optimum dosage of the admixture shall be determined by trial mixes with the cement to be used in the grout. The dosage shall be within the range recommended by the supplier and shall not exceed 5% by mass of the cement.

The method of measuring dosage and checking the weights of pre-packed dry materials shall be agreed with the Employer's Representative.

Admixtures shall comply with one of the following:

- (i) pigments to BS EN 12878:2005,
- (ii) accelerating, retarding or water reducing admixtures to BS EN 934-2:2001,
- (iii) air entrainment admixtures to BS EN 934-2:2001,
- (iv) superplasticizers to BS EN 934-2:2001.

Admixtures not included in BS EN 12878 or BS EN 934-2:2001 shall be permitted provided that such admixtures comply with the requirements for identification, compatibility, chloride content and alkali content included in this Section and that:

- (i) full account of their effect on the finished concrete is taken in determining the concrete mix,
- (ii) there are sufficient data regarding their suitability, including previous use in similar concrete mixes and applications.

Admixtures shall not impair the durability of the concrete or grout nor increase the risk of corrosion of reinforcement. Thiocyanate, nitrates, formate and sulphides shall not be included in admixtures.

Admixtures shall be manufactured and supplied by a company which has a quality system for product conformity approved in accordance with BS EN ISO 9001 by a body accredited by the United Kingdom Accreditation Service (UKAS) or equivalent.

For each proposed admixture the Employer's Representative shall be supplied with the following information:

- (i) proposed dosage rate per 100 kg of cement,

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- (ii) details of the effects of underdosage and overdosage,
- (iii) generic type of the active constituents in the admixture,
- (iv) whether or not for the proposed dosage the admixture leads to entrainment of air,
- (v) where two or more admixtures are to be used in the same concrete mix, information on the interaction and compatibility of the admixtures, including confirmation obtained from each respective admixture manufacturer on the compatibility of the admixtures to be used.

Where practicable, admixtures for inclusion in a concrete mix shall be added at the batching plant. Admixtures for inclusion in grout may be added at Site.

Admixtures shall not be used with high alumina cement.

#### **Miscellaneous aggregates (3.4)**

**80.010** In BS 5400: Part 7, clause 3.4.1, delete reference to BS 877, and amend reference to BS 882 (coarse ... 3 and 4) to "BS 882, table 4, Zones M or F".

Delete BS 5400: Part 7, clause 3.4.2 and the following shall apply.

Aggregate for use as a concrete wearing surface shall be in accordance with the Manual of Contract Documents for Highway Works, Volume 1, Specification for Highway Works, Series 1000.

#### **Concrete grade (3.5.1)**

**80.011** Delete BS 5400: Part 7, clause 3.5.1 and the following shall apply.

The compressive strength grade of the concrete shall be in accordance with the design assumptions as detailed in Schedule 80/A of Appendix 80/1 and also with BS 8500-1:2002 Clause A7.

The minimum strength grade shall be in accordance with BS 8500-1:2002 clause A5. The class of concrete shall be specified by the grade and nominal maximum aggregate size.

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**Minimum cement content and maximum water/cement ratio (3.5.2)**

**80.012**

The minimum cement content shall be not less than the minimum stated in BS 8500-1:2002 clause A5 appropriate to the condition exposure, sulphate class of the surrounding soil or water, and cement type, as modified by BS 8500-1:2002 clause A5 according to the nominal maximum aggregate size.

For reinforced concrete below ground level, the minimum cement content shall be 300 kg/m<sup>3</sup>. Where concrete is to be placed under water or is to support fluid, the minimum cement content shall be 380 kg/m<sup>3</sup>. Concrete that will be exposed to sea water shall have a minimum cement content not less than 400 kg/m<sup>3</sup>.

The maximum water/cement ratio shall be in accordance with BS 8500-1:2002 Clause A5 appropriate to the condition exposure and sulphate class of the surrounding soil or ground water.

The minimum cement content when high alumina cement to BS EN 14647:2005 is used shall be 400 kg/m<sup>3</sup>, and the maximum water/cement ratio mix shall be 0.40.

For the limits specified in this Clause, the minimum converted strength should not be less than 32/40 N/mm<sup>2</sup>.

**(3.9.3, 3.9.5)**

Delete BS 5400: Part 7, clauses 3.9.3 and 3.9.5.

**Maximum chloride content**

**80.013**

The total chloride content of a concrete mix from the cement, aggregate and any other source shall not exceed the relevant limit stated in BS 8500-1:2002 Clause A9 determined in accordance with BS 812-117:1988.

**Maximum sulphate content**

**80.014**

The maximum sulphate content of a concrete mix expressed as sulphuric anhydride (SO<sub>3</sub>) shall not exceed 4 % by weight of cement. The sulphate content shall be calculated from the sulphate content of the concrete mix constituents in accordance with the relevant British Standard for the constituent.

**Control of alkali-silica reaction**

**80.015**

Except where all the aggregates to be used in the concrete mix have been certified by a qualified chemist competent in concrete chemistry as having normal or low reactivity as defined in clauses 19.2(a) to 19.2(c) of the Concrete Society's Technical Report No. 30, the reactive alkali content of the concrete mix shall not exceed 3 kg/m<sup>3</sup>.

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The reactive alkali content of the concrete mix, in terms of sodium oxide equivalent ( $\text{Na}_2\text{O}$ ), shall be expressed as specified in BS 8500-1:2002 Annex C, using the guaranteed alkali limits of the constituents of the concrete mix.

The Employer's Representative shall be provided with copies of test certificates showing the average value of the acid soluble alkali content determined in accordance with BS EN 196-2:2005 for:

- (i) cement during the period of manufacture,
- (ii) any pulverised fuel ash or ground granulated blast furnace slag for the preceding 25 week period.

The equivalent sodium oxide content of the aggregate shall be calculated from the quality of chloride ion present measured in accordance with BS 812-117:1988.

**Current margin for  
designed mixes  
(3.6.1)**

**80.016**

In addition to BS 5400: Part 7, clause 3.6.1, for concrete up to grade C12/15, the current margin for a designed mix shall be determined by the Contractor and shall be taken as the lesser of:

- (a) 1.64 times the standard deviation of cube compressive strength test results on at least 100 separate batches of concrete of nominally similar proportions of similar materials and produced over a period not exceeding 12 months, by the same plant under similar supervision, but not less than one sixth of the characteristic strength for concrete up to grade 12/15 or  $3.0/3.75 \text{ N/mm}^2$  for concrete of grade 16/20 or above.
- (b) 1.64 times the standard deviation of cube compressive strength test results on at least 40 separate batches of concrete of nominally similar proportions of similar materials and produced over a period not less than 5 days but not exceeding 6 months, by the same plant under similar supervision, but not less than one third of the characteristic strength for concrete up to grade 12/15 or  $6.0/7.5 \text{ N/mm}^2$  for concrete of grade 16/20 or above.

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Where there is insufficient data to satisfy sub-clauses (a) or (b) above, the margin for the initial mix design shall be taken as two thirds of the characteristic strength for concrete up to grade 12/15 or 12/15 N/mm<sup>2</sup> for concrete of grade 16/20 or above. This margin shall be used as the "current margin" only until sufficient data are available to satisfy sub-clauses (a) or (b) above. However, when the specified characteristic strength approaches the maximum possible strength of concrete made with a particular aggregate, a smaller margin (not less than one third of the characteristic strength for concrete up to grade 12/15 or 6.0/7.5 N/mm<sup>2</sup> for concrete of grade 16/20 or above) may be used for the initial mix design.

**Suitability of  
proposed mix  
proportions (3.6.2)**

**80.017**

Delete the alternative specified in BS 5400: Part 7, clause 3.6.2(b)(3), and the last paragraph of BS 5400: Part 7, clause 3.6.2. The following paragraphs shall apply.

The types and sources of cement, aggregates, pulverised fuel ash, and ground granulated blast furnace slag to be included in the concrete mix shall be agreed by the Employer's Representative.

The cement type used in the concrete mix shall be suitable for the application of the concrete (plain, reinforced, post-tensioned or prestressed), the heat development in the concrete mass, the dimensions of the structure, and the sulphate class listed in BS 8500-1:2002 Clause A5.

In addition the concrete mix shall be selected to satisfy all the performance criteria for fresh and hardened concrete, and to give a workability consistent with the proposed method of construction. The concrete mix shall minimise segregation, permeability, bleeding, plastic settlement, shrinkage and thermal cracking, and shall produce the surface finishes specified on the Contract Drawings and in accordance with Clause 80.030.

Where practicable, plastic settlement, shrinkage and thermal cracking shall be minimised by the use of pulverised fuel ash or ground granulated blast furnace slag in accordance with Clause 80.005 and provided the use of such materials has no deleterious effects.

Synthetic fibres included in the mix to limit plastic settlement, plastic shrinkage, thermal cracking, or as an alternative to air entrainment for freeze/ thaw resistance, shall comply with Clause 80.057.

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Where the proposed concrete mix is to be pumped, the Employer's Representative shall be provided with evidence that the mix can be pumped without segregation, bleeding or persistent blockages.

For a concrete mix specified to be suitable for water impermeable concrete, the resistance to water penetration when tested according to BS EN 12390-8:2000 shall have a maximum penetration of less than 50 mm, and mean average values of penetration less than 20 mm. The water/cement ratio shall not exceed 0.55.

Any change in the source of the concrete mix constituent material or in mix proportions, shall be agreed by the Employer's Representative, except changes in total cementitious material content of not more than 20 kg/m<sup>3</sup>, and where included changes in the content of pulverised fuel ash or ground granulated blast furnace slag of not more than 10 kg/m<sup>3</sup>.

### **Trial mixes (3.6.3)**

#### **80.018**

Further to BS 5400: Part 7, clause 3.6.3, trial mixes are not required for concrete where the concrete supplier can demonstrate to the Employer's Representative that, for the proposed concrete mix, 40 recent test and sampling results for a related mix (including admixtures, where applicable), confirm the attainment of the specified strength, including early high strength where applicable, within the current margin in accordance with the Clause 80.016.

Where trial mixes are not proposed to be carried out, the following information shall be provided to the Employer's Representative:

- (i) confirmation that the relationship for the family of mixes exists and is current,
- (ii) the 40 most recent results for the materials at the reference mix level that exist to justify the reference mix cement content (results at the reference mix or transformed to the reference mix),
- (iii) the difference in the cement content of the reference mix, and the specified mix,
- (iv) confirmation that the data has been produced in accordance with the Quality Scheme for Ready-Mixed Concrete Regulations.

Where the above information for a concrete mix cannot be provided, trial mixes shall be carried out.

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Where trial mixes are carried out to demonstrate high early strength, for each mix a set of nine test cubes shall be made from each of three consecutive batches. Test cubes shall be tested at the following ages:

- (i) 8 hours, or as specified in Appendix 80/2,
- (ii) 24 hours,
- (iii) 28 days.

For any trial mix the average strength of the nine cubes tested at 28 days shall exceed the specified characteristic strength by the lesser of:

- (i) 11.5 N/mm<sup>2</sup>, or,
- (ii) the current margin less 3.5 N/mm<sup>2</sup>.

Where high alumina cement to BS EN 14647:2005 is used in the mix, three additional cubes shall be taken, and shall be subjected to an agreed accelerated curing regime, and tested to determine the converted strength.

Trial mixes of proposed concrete mixes shall demonstrate the workability of the concrete mix and the action of admixtures and/or silica fume slurry, and shall prove the ability of the proposed concrete mix to attain the specified characteristic strength.

Trial mixes shall be carried out a minimum of six weeks before the concrete is programmed to be incorporated in the Works.

The workability of each batch of the concrete mix shall be tested three times at equal intervals within one hour of mixing using one of the methods appropriate to the workability of the concrete mix specified in Clause 80.024.

#### **Concrete production 80.019 (3.8.2)**

Delete BS 5400: Part 7, clause 3.8.2, and the following shall apply.

Cement, pulverised fuel ash, and ground granulated blast furnace slag shall be stored and used in accordance with BS 8500-2:2002 clause 11.

The Employer's Representative shall be provided with a certificate confirming that the cement complies with the relevant British Standard, and including results of tests carried out to verify such compliance.

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### (3.8.3)

Further to BS 5400: Part 7, clause 3.8.3, for each aggregate type proposed to be used, the Employer's Representative shall be provided with all the information listed in BS EN 12620:2002 Annex A, and a copy of the relevant test results.

For concrete with exposed faces, surface-marring aggregates such as pyrites shall not be used.

Concrete to be placed in situ or to form precast concrete units to be constructed at the Site shall be produced only from a batching plant holding current Quality Scheme for Ready-Mixed Concrete certification for product conformity except as follows:

- (i) dry process sprayed concrete,
- (ii) concrete pours less than 3 m<sup>3</sup>,
- (iii) as specified in Appendix 80/3.

For concrete produced by an on-site batching plant, prior to any concrete being placed in the Works, the Employer's Representative shall be provided with confirmation of the concrete supplier's quality assurance certification in accordance with BS 8500-2:2002 clause A5 and a copy of the certification for product conformity for the site batching plant.

Concrete for precast concrete units to be constructed off-site shall be produced either by a batching plant holding current Quality Scheme for Ready-Mixed Concrete certification for product conformity, or at the precast concrete manufacturer's works where the Contractor can demonstrate that concrete production is included in the quality system for product conformity specified in Clause 80.041.

Lightweight concrete such as foamed concrete shall be produced under controlled conditions by blending cement in accordance with Clause 80.004, sand, and water with a foaming admixture to produce a free flowing, self levelling, non combustible lightweight concrete with a density not exceeding 1200 kg/m<sup>3</sup>.

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