

Steel, concrete and composite bridges —

Part 8: Recommendations for materials and workmanship, concrete, reinforcement and prestressing tendons

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- British Precast Concrete Federation Ltd.
- British Railways Board
- British Steel Industry
- Cement and Concrete Association
- Concrete Society Limited
- Constructional Steel Research and Development Organization
- Department of the Environment (Building Research Establishment)
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- London Transport Executive
- Ministry of Defence
- Sand and Gravel Association Ltd.
- Scottish Development Department
- Welding Institute

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Foreword

BS 5400 is a document combining codes of practice to cover the design and construction of steel, concrete and composite bridges and specifications and recommendations for the loads, materials and workmanship. It comprises the following Parts:

- *Part 1: General statement;*
- *Part 2: Specification for loads;*
- *Part 3¹⁾: Code of practice for design of steel bridges;*
- *Part 4: Code of practice for design of concrete bridges;*
- *Part 5¹⁾: Code of practice for design of composite bridges;*
- *Part 6¹⁾: Specification for materials and workmanship, steel;*
- *Part 7: Specification for materials and workmanship, concrete, reinforcement and prestressing tendons;*
- *Part 8: Recommendations for materials and workmanship, concrete, reinforcement and prestressing tendons;*
- *Part 9¹⁾: Code of practice for bearings;*
- *Part 10¹⁾: Code of practice for fatigue.*

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

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 28, an inside back cover and a back cover.

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

¹⁾ In course of preparation

NOTE The numbering of the clauses and subclauses of this Part is similar to that in Part 7 for ease of cross-reference. In this context "See Part 7" instructs the user to refer to the corresponding clause or subclause in Part 7.

1 Scope

This Part of this British Standard is in the form of notes for the guidance of engineers using the detailed specification clauses covered by Part 7 and gives a greater understanding of the reasons for their choice.

2 References

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

3 Concrete

3.1 Specification of concrete. In this British Standard the concept of concrete as a single material has been adopted. It is therefore the responsibility of the engineer to specify the type of concrete he requires to ensure both the strength and the durability of the finished structure.

3.1.1 Classification of concrete mixes. When specifying concrete, the following terms should be used to describe the class of concrete required.

3.1.2 Ordinary structural concrete. Ordinary structural concrete is concrete of any grade that is used in reinforced, prestressed or plain concrete construction and that does not contain admixtures or materials other than those specified in 3.2 of Part 7.

3.1.3 Special structural concrete. The structural concrete should be considered as special when it contains admixtures or materials other than those specified in 3.2 of Part 7.

3.1.4 and 3.1.5 Designed mix and prescribed mix. When a designed mix is specified, the contractor or manufacturer should be responsible for selecting the mix proportions in accordance with 3.6 to achieve the required strength and workability, but the engineer should be responsible for specifying the minimum cement content and other properties required to ensure durability.

When a prescribed mix is specified, the engineer should specify the mix proportions and the contractor or manufacturer should undertake to provide a properly mixed concrete containing the constituents in the specified proportions in accordance with the appropriate provisions of 3.7. The engineer should be responsible for ensuring that the mix proportions prescribed provide the strength and durability he requires. The class of concrete mix required is covered by one of the following descriptions:

- Designed mix for ordinary structural concrete
- Prescribed mix for ordinary structural concrete
- Designed mix for special structural concrete
- Prescribed mix for special structural concrete

These descriptions may be used to describe in broad terms the type of concrete required, but they do not in any way constitute a complete specification.

3.1.6 Form of specification. The engineer should decide the class and grade designation of the concrete required for each part of the work and determine suitable limitations on the constituent materials and mix proportions in accordance with the recommendations of 3.5. On the basis of these data, together with any other requirements of the work, the engineer should specify the concrete in accordance with 3.1.2 or 3.1.3, and 3.1.4 or 3.1.5, of Part 7 as appropriate. For constructional convenience the number of types and grades of concrete used on one site or in one factory should be kept as few as possible.

Recommendations regarding the assessment of compliance with the specified requirements are given in 3.9.

3.1.7 Designed mix for ordinary structural concrete. By the definition given in 3.1.2, limitations on the constituent materials are already established and therefore the engineer need only specify the following:

Designed mix for ordinary structural concrete	Clause in Part 7
Grade designation	3.5.1
Type of cement	3.2.1
Minimum cement content	3.5.2
Nominal maximum size of aggregate	3.2.2

Unless specified otherwise, the contractor should decide the workability of the fresh concrete (see 3.9.4 of Part 7).

3.1.8 Prescribed mix for ordinary structural concrete

3.1.8.1 When the engineer intends to adopt one of the prescribed mixes given in Table 2 of Part 7 that are relatively rich in cement and are intended for use where the cost of trial mixes or of acceptance cube testing is not justified, the limitations on constituent materials are defined in 3.2 of Part 7, and therefore the engineer need only specify the following:

Prescribed mix in accordance with Table 2 of Part 7	Clause in Part 7
Grade designation	3.5.1
Type of cement	3.2.1
Nominal maximum size of aggregate	3.2.2

Provided that the materials used are those described, the weights given in Table 2 of Part 7 are appropriate for the large majority of cases except where poor control is allied to the use of poor materials.

3.1.8.2 When the engineer intends to adopt a prescribed mix for ordinary structural concrete other than those given in Table 2 of Part 7, the limitations on constituent materials and mix proportions should be fully described in the specification. Before prescribing such a mix he should be sure that with the materials and workmanship available in the particular locality a concrete of the required standard can be readily obtained. For this purpose he should arrange for preliminary strength tests to be carried out unless satisfactory evidence is available from previous use of the mix. He may also arrange for strength tests to be carried out during the progress of the work in accordance with 3.9.2.2 to satisfy himself that his specified mix proportions are suitable. Admixtures should not be specified or used.

The information to be given in the specification should include the following:

Prescribed mix for ordinary structural concrete not specified in Table 4 of Part 7	Clause in Part 7
Grade designation	3.5.1
Proportion of cement : fine aggregate : coarse aggregate	3.2.2
Nominal maximum size of aggregate	3.2.2
Types of cement that may be used	3.2.1
Types of aggregate that may be used	3.2.2
Required workability	3.9.4

3.1.9 Designed mix for special structural concrete.

This broad class of concrete mixes includes those using admixtures, those using cements other than Portland, lightweight aggregates, heavyweight aggregates etc., and those specially designed to have a special property or to produce a particular surface finish. It is important, therefore, to specify the requirements in detail and, where possible, to state the reasons for any special requirements so that the contractor can more fully appreciate the object of the work.

In appropriate circumstances any of the following information may be included, but great care should be taken to ensure that the requirements specified do not conflict with each other.

Designed mix for special structural concrete	Clause in Part 7
Grade designation	3.5.1
Minimum cement content	3.5.2
Nominal maximum size of aggregate	3.2.2
Required workability	3.9.4
Maximum cement content	3.5.3
Required brand or type of cement	3.3.1
Required source or special type of aggregate	3.3.2 or 3.4.2
Required admixture	3.3.4
Air content of fresh concrete	3.9.6
Min. or max. temperature of fresh concrete	3.11.8 or 3.11.9
Rate of sampling and testing	3.9.2.1
Other requirements	3.9.1 and 3.10.2

Unless specified otherwise, the contractor should decide the workability and the mix should be designed in accordance with the provisions of 3.9.4 of Part 7.

3.1.10 Prescribed mix for special structural concrete.

Mixes in this class should only be specified when the engineer is confident that, with the materials and workmanship available, a concrete of the required standard can be readily obtained.

An engineer with expert knowledge or previous experience of mix design using particular cements, special aggregates or unusual gradings (such as gap grading) may wish to specify the ingredients for a special mix.

An engineer may wish to use a prescribed mix to obtain a special finish. Strength may be of secondary importance.

When an engineer intends to specify, or allow, the use of an admixture in what would otherwise be an ordinary structural concrete, it becomes a special structural concrete and should be treated as such (see 3.3.4).

3.1.11 Requirements for fresh concrete. The requirements for the concrete in the fresh or plastic state, particularly its workability (see 3.9.4 of Part 7), should be decided by or in consultation with the contractor.

It may be necessary when working in cold or hot weather to control the temperature of fresh concrete (see 3.11.6 and 3.11.7).

Where the minimum dimension of concrete to be placed at a single time is greater than 600 mm and especially where the cement content is likely to be 400 kg/m³ or more, measures to reduce the temperature, such as the selection of a cement type with a slower release of heat of hydration, should be considered. In exceptional cases other measures to reduce the temperature or to remove evolved heat may be necessary.

3.2 Constituent materials of ordinary structural concrete

3.2.1 Cement. Where cements other than those complying with the requirements of BS 12 and BS 146 are used, account should be taken of their properties and any particular conditions of use.

Supersulphated cement should not be mixed with any other type of cement.

3.2.2 Aggregates

3.2.2.1 General. The engineer may specify or approve on request the use of aggregates other than those specified in 3.2.2, 3.3.2 or 3.4.2 of Part 7, including types or gradings not covered by the appropriate British Standards, provided that there are satisfactory data on the properties of concrete made with them.

When high strength concrete is required, the source as well as the type of aggregate may need careful selection based on the results of trial mixes.

Where it is known that any property of any aggregate is likely to have an unusual effect on the strength, density, shrinkage, moisture movement, thermal properties, creep, modulus of elasticity or durability of concrete made with it, the engineer should take account of these factors in the design and workmanship requirements.

Aggregates having a high drying shrinkage, such as some dolerites and whinstones, and gravels containing these rocks produce concrete having a higher drying shrinkage than that normally expected. This can result in deterioration of exposed concrete and excessive deflections of reinforced concrete unless special measures are taken. For further information see BRS Digest 35.

3.2.2.2 Nominal maximum size. The preferred nominal maximum sizes of aggregate are 40 mm and 20 mm, but if a smaller size is necessary it should be either 14 mm or 10 mm.

3.2.2.3 Marine aggregates. Marine aggregates may be used provided that the total chloride content of the concrete mix arising from the aggregate and any other source does not exceed the following limits, expressed as a percentage relationship between chloride ion and weight of cement in the mix.

Table 1 — Limits on total chloride content

Type or use of concrete	Maximum total chloride content (expressed as percentage of chloride ion by weight of cement)
Concrete for any use made with cement complying with BS 4027 or BS 4248	0.06
Reinforced concrete with cement complying with BS 12	0.35 for 95 % of test results with no result greater than 0.50
Plain concrete made with cement complying with BS 12 and containing embedded metal	
NOTE % chloride ion $\times 1.648$ = % equivalent sodium chloride; % chloride ion $\times 1.565$ = % equivalent anhydrous calcium chloride.	

The shell content of the aggregate included as calcium carbonate should not exceed the following amounts:

Nominal size (mm)	%
40	2
20	5
10	15
fine	30

Hollow shells or other shells of unsuitable shape in quantities that may adversely affect the quality of, or cause permeability to, the concrete should not be permitted.

3.2.3 Water. See Part 7.

3.3 Constituent materials of special structural concrete

3.3.1 Cement. See 3.2.1.

3.3.2 Aggregates. See 3.2.2.

3.3.3 Water. See Part 7.

3.3.4 Admixtures

3.3.4.1 General. Admixtures may be specified by type and effect or by brand and dosage.

For admixtures for which there is no British Standard, the type and/or proprietary brand may be specified.

Admixtures should never be regarded as replacement for good concreting practice and should never be used indiscriminately.

Many admixtures are highly active chemicals and may impart undesirable as well as desirable properties to the concrete; their suitability should generally be verified by trial mixes. The trial mix should contain cement of the same make and from the same source as that intended to be used for the permanent works. If two or more admixtures are thought to be required in any one mix, the manufacturers of each should be consulted. The engineer should satisfy himself that the admixture is compatible with all of the other constituents of the concrete mix and ascertain whether it accelerates or retards the setting time and loss of workability.

In particular the behaviour of admixtures with supersulphated cements may differ from that with Portland cements, and advice should be sought before use.

3.3.4.2 Pulverized-fuel ash. The grading zone and the maximum sulphate content of pulverized-fuel ash in accordance with BS 3892 should be specified. Where pulverized-fuel ash is used, the total sulphate content, expressed as sulphuric anhydride (SO_3) of the concrete mix, should never exceed 4 % by weight of the cement. The sulphate content should be calculated from the known sulphate content of the cement, aggregates (where applicable) and pulverized-fuel ash as determined by tests carried out in accordance with BS 4550, BS 1047 and BS 3892 respectively.

Pulverized-fuel ash should not be used in conjunction with a cement complying with the requirements of BS 4027 in concrete required to be resistant to sulphates.

3.3.4.3 Air-entraining agents. The admixture should be of such a type that the air content (see 3.5.6) can be maintained within the limits specified (see 3.9.6) irrespective of extension of mixing time to 30 min.

3.4 Miscellaneous aggregates

3.4.1 Sands for mortar. See Part 7.

3.4.2 Aggregate for concrete wearing surface. See Part 7.

3.5 Requirements for hardened concrete

3.5.1 General. The minimum requirements for the strength and durability of the concrete in the hardened state should be decided by the engineer from considerations of the limit state requirements of Part 4, but if in addition a special property or a particular surface finish is required, these minimum requirements may have to be considerably exceeded.

The grade of concrete required depends partly on the particular use and the characteristic strength needed to provide the structure with adequate ultimate strength (Table 2) and partly on the exposure conditions and the cover provided to any reinforcement or tendons (see 6.8.2, 7.9.2 and Table 11 of Part 4).

Table 2 — Grades of concrete and appropriate uses

Grade	Characteristic strength	Lowest grade for compliance with appropriate use
15	N/mm ² 15.0	Plain concrete or reinforced concrete with lightweight aggregate
20	20.0	Reinforced concrete with normal aggregate
25	25.0	Concrete with post-tensioned tendons Concrete with pretensioned tendons
30	30.0	
40	40.0	
50	50.0	
60	60.0	

3.5.2 Minimum cement content. The engineer should state in the contract the minimum cement content required for each concrete mix. One of the main characteristics influencing the durability of any concrete is its permeability. With strong dense aggregates, a suitably low permeability is achieved by having a sufficiently low water/cement ratio, by ensuring sufficient hydration of the cement through proper curing methods, and by ensuring maximum compaction of the concrete. Therefore for given aggregates the cement content should be sufficient to provide adequate workability with a low water/cement ratio so that the concrete can be fully compacted with the means available.

Table 3 gives the minimum cement content required, when using a particular size of aggregate in a Portland cement concrete, to provide acceptable durability under the appropriate conditions of exposure. The reduced minimum cement contents given in Table 3 should only be used when trial mixes (see 3.6.3) have verified a) that a concrete with a maximum free water/cement ratio not greater than that given for the particular condition can be consistently produced and b) that it is suitable for the conditions of placing and compaction.

Table 4 gives the minimum cement content required when using a particular size of aggregate and a particular type of cement to provide a concrete having acceptable durability under exposure to a particular degree of sulphate attack. It should be noted that this durability is only obtained if the appropriate maximum free water/cement ratio is not exceeded, in addition it should be noted that the table gives the absolute minimum requirements for the average case and that additional recommendations for rather more severe conditions are given in the notes to the table.

3.5.3 Maximum cement content. Cement contents in excess of 550 kg/m^3 should not be used unless special consideration has been given in design to the increased creep, risk of cracking due to drying shrinkage in thin sections, and higher thermal stresses in thicker sections. In order to make the higher grades of lightweight aggregate concrete, cement contents in excess of 550 kg/m^3 may be used provided that the engineer is satisfied that the concrete produced is suitable in all respects.

3.5.4 Type of cement. The type of cement used in the concrete mix affects the properties of the hardened concrete. Table 4 indicates how the resistance of concrete to attack by sulphate solutions depends on the type of cement used.

It should be noted that special care is needed in the storage of supersulphated cement as it deteriorates rapidly in poor storage conditions. The rate of strength development of concrete made with supersulphated cement is considerably reduced at low temperatures. Unless adequately cured, the surface of supersulphated cement concrete is liable to become friable or dusty. This concrete should be kept moist for at least 4 days after placing; this is essential during hot weather.

3.5.5 Type of aggregate. The type of aggregate used in the concrete may affect the creep, shrinkage, durability and other properties (see 3.2.2.1) of the hardened concrete.

3.5.6 Type of admixture. Certain admixtures have a considerable effect on the properties of hardened concrete and great care should be taken when specifying or allowing their use in special concretes.

Air-entraining agents used to entrain controlled percentages of air in the concrete generally improve its durability and in particular its resistance to frost damage.

When a concrete of grade 40 or lower is required to provide resistance to the effects of salt used for de-icing, it should contain entrained air and the appropriate admixture should be used for the special concrete required. The average air content of the fresh concrete should be specified as follows:

for natural aggregates of 10 mm nominal maximum size: 7 %

for natural aggregates of 14 mm nominal maximum size: 6 %

for natural aggregates of 20 mm nominal maximum size: 5 %

for natural aggregates of 40 mm nominal maximum size: 4 %