

BRITISH STANDARD CODE OF PRACTICE
CP 115: 1969

THE STRUCTURAL USE OF
PRESTRESSED CONCRETE
IN BUILDINGS

Incorporating amendments issued August 1973 (AMD 1242),
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and July 1977 (AMD 2305)

THE COUNCIL FOR CODES OF PRACTICE
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This Part of CP 115 makes reference to the following British Standards and British Standard Codes of Practice:

- B.S. 12 Portland cement (ordinary and rapid-hardening)
- B.S. 18 Methods for tensile testing of materials
- B.S. 146 Portland-blastfurnace cement
- B.S. 648 Schedule of weights of building materials
- B.S. 812 Methods for the sampling and testing of mineral aggregates, sands and fillers
- B.S. 882 Aggregates from natural sources for concrete (including granolithic)
- B.S. 1014 Pigments for Portland cement and Portland cement products
- B.S. 1881 Methods of testing concrete
- B.S. 2691 Steel wire for prestressed concrete
- B.S. 2787 Glossary of terms for concrete and reinforced concrete
- B.S. 3617 Seven-wire steel strand for prestressed concrete
- B.S. 3763 International system (SI) units
- B.S. 3892 Pulverized-fuel ash for use in concrete
- B.S. 4027 Sulphate-resisting Portland cement
- B.S. 4248 Supersulphated cement
- B.S. 4449 Hot rolled steel bars for the reinforcement of concrete
- B.S. 4461 Cold worked steel bars for the reinforcement of concrete
- B.S. 4757 Nineteen-wire steel strand for prestressed concrete
- B.S. 5075 Concrete admixtures
- CP 3 Code of basic data for the design of buildings
 - Chapter V. Loading
 - Part 1. Dead and imposed loads
 - Part 2. Wind loads

- CP 110 The structural use of concrete
 CP 114 The structural use of reinforced concrete in buildings
 CP 2007 Design and construction of reinforced and pre-stressed concrete structures for the storage of water and other aqueous liquids

The following BSI reference relates to the work of this Code of Practice:
 Committee reference BLC/8.

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This Code of Practice represents a standard of good practice and therefore takes the form of recommendations. Compliance with it does not confer immunity from relevant statutory and legal requirements.

BRITISH STANDARD CODE OF PRACTICE CP 115

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FOREWORD

This metric edition of CP 115, originally designated Part 2, has been prepared, in accordance with the change to the metric system in the Construction Industry, giving values in terms of SI units. For further information on SI units, reference should be made to BS 3763, 'International system (SI) units' and PD 5686 'The use of SI units'.

*As amended
Aug 1974*

The values represent the equivalents of the values in imperial units in CP 115 : 1959, rounded to convenient numbers. Although the values are not exact equivalents of the imperial ones, this is not a technical revision.

Attention is drawn to CP 110 'The structural use of concrete' published in 1972. However clauses from this Code must not be used with clauses from CP 110 in the same design.

*As amended
Mar. 1976*

NOTE. The amendment to Clause 301 provides guidance on design for stability of prestressed concrete construction. Although this amendment bears a later date than CP 110, 'The structural use of concrete', it should not be assumed that the clauses are in any way a later version than the stability clauses in CP 110.

CP 115 : 1969

SECTION ONE: GENERAL

101. Scope. This Code deals with the structural use of prestressed concrete in buildings. It covers both work carried out on site and the manufacture of precast prestressed concrete units.

It has been assumed in drafting this Code that the design of prestressed concrete is entrusted to chartered structural or civil engineers, experienced in the structural use of concrete, and that the execution of the work is carried out under the direction of a competent supervisor. The supervisor should not only be familiar with the technique of making high quality concrete, but should also be experienced in the various stressing operations involved. The stressing operations should be carried out under his direct supervision.

The recommendations given in this Code may often be applicable, with suitable modifications, to the design and construction of structures other than buildings. Recommendations for the use of prestressed concrete for liquid retaining structures are given in CP 2007, Liquid retaining structures.

In this document, it has been necessary to restrict the cements to those specified in B.S. 12 and B.S. 146 and the aggregates to those specified in B.S. 882. It may be possible to extend the scope where adequate data are available.

These recommendations may also be applicable to the design and construction of prestressed members using materials other than concrete, including composite materials, provided that their different properties are taken into account.

*As amended
July 1977* The recommendations for stability given in this Code have been prepared on the assumption that all the load bearing elements (e.g. slabs, columns, walls etc.) are of concrete. In a building where concrete elements such as floor slabs, walls etc. are used in conjunction with load bearing elements of other materials, the principles recommended for stability in Clause 301 (amended by AMD 1242 and AMD 1922) remain appropriate. However, the ties recommended in Clause 361 of CP 116 (inserted by AMD 1239 and amended by AMD 1924) as part of the means of satisfying the principles of Clause 301 will be required only when adequate stability is not provided by other means.

102. Definitions. For the purposes of this Code the following definitions as given in B.S. 2787 apply and the term 'tendon' has been added:

Prestressed concrete Concrete in which effective internal stresses are induced artificially, usually by means of tensioned steel, prior to loading the structure.

Tendon A stretched element used in a concrete member or structure to impart prestress to the concrete. For the purpose of this Code tendons are assumed to be of steel.

Transfer The action of transferring load in the prestressing tendons to the concrete.

Pre-tensioning A method of prestressing in which tendons are tensioned before the concrete is placed.

The following definitions apply when the prestressing is induced by the use of tendons:

Post-tensioning A method of prestressing in which tendons are tensioned after the concrete has hardened.

103. Symbols.

- A_{su} cross-sectional area of the untensioned reinforcement in the tensile zone.
- A_{st} cross-sectional area of the tendons in the tensile zone.
- b breadth of the compressive zone of the concrete.
- c the creep of the concrete per unit length for unit applied stress for the period considered.
- d overall depth of beam.
- d_1 distance of the centroid of the tendons in the tensile zone from the outer compression surface under ultimate load conditions.
- d_n distance of the neutral axis from the outer compression surface under ultimate load conditions.
- e_s eccentricity of the tendons relative to the centroid of the concrete section.
- E_1 the modulus of elasticity of the concrete corresponding to the cube strength at transfer.
- E_2 the modulus of elasticity of the concrete corresponding to the cube strength after the period considered.
- f_m maximum stress which would be reached in the tendon at failure of the beam.
- f_u tensile strength of the prestressing steel.
- f_y yield stress for mild steel (or the appropriate proof stress for high tensile steel) used as reinforcement.
- K constant (depending on the type of duct, etc.) used in calculating the loss of prestress due to friction.
- L effective span of beam for the purpose of calculating bending moments.
- M_u failing moment of beam, or other member in bending.
- μ coefficient of friction between the tendon and the material against which it bears.

- P prestressing force in the tendon.
- P_x prestressing force in the tendon during tensioning at a distance x from the jack.
- P_0 prestressing force in the tendon at the jacking end.
- P_1 prestressing force after transfer.
- P_2 prestressing force after the period considered.
- p_e effective prestress in the tendons, that is, the remaining prestress in the tendons after allowing for all losses.
- R radius of curvature of the tendon.
- u_t the specified minimum concrete cube strength at transfer for concrete cubes made in accordance with the requirements of B.S. 1881 'Methods of testing concrete', but cured under similar conditions to the concrete in the work.
- u_w specified works cube strength of the concrete at twenty-eight days determined in accordance with the requirements of B.S. 1881, 'Methods of testing concrete'.

104. Safety precautions. A prestressing tendon when tensioned contains a considerable amount of stored energy. In the rare event of a tendon breaking while it is under full tension or during tensioning or of an anchorage failure, serious injury to personnel and damage to equipment can be caused by the sudden release of this energy.

Whilst it is not possible to safeguard personnel completely from the risks of such an accident, reasonable precautions should always be taken when working with or near tendons which have been tensioned or are in the process of being tensioned. For instance, personnel should not stand in line with the tendons, their anchorages or jacking equipment, neither should they walk on the tendons. Simple protective measures such as stout timber shields sheathed with steel should be placed in line with tendons and behind the jacks to protect personnel passing in the usual course of their duties.

Each factory or site undertaking will call for separate consideration in regard to what measures constitute the most reasonable form of protection without unduly interfering with the normal production processes.

It must be emphasized that experience has shown that the most effective form of safety precautions is the proper training of personnel in the relevant prestressing techniques, and in the way they should conduct themselves in the vicinity of tendons during prestressing.

SECTION TWO: MATERIALS

201. Cement. The cement used should be Portland cement or Portland-blast-furnace cement.

Portland cement should comply with the requirements of B.S. 12, 'Portland cement (ordinary and rapid-hardening)'.

Portland-blastfurnace cement should comply with the requirements of B.S. 146, 'Portland-blastfurnace cement'.

Other cements, such as low heat and sulphate resisting cements may be desirable in certain circumstances but they should only be used with the Engineer's approval.

202. Aggregates. This Code is based on the assumption that aggregates comply with the requirements of B.S. 882. 'Aggregates from natural sources for concrete (including granolithic)'.

The Engineer responsible for the prestressed concrete design may approve the use of other aggregates subject to the availability of data on the properties of concrete made with these aggregates, such as density, strength, creep, shrinkage, modulus of elasticity and durability. Where these properties differ from those of concrete made with the aggregates assumed in the preceding paragraph, he should make corresponding variations to the basis of design, permissible stresses and workmanship given later in this Code.

Aggregates containing salt or shell. Some aggregates, particularly those from marine and estuarine sources, naturally contain proportions of salts, especially chlorides. These aggregates are suitable for use in structural concrete depending on the type of concrete and total chloride content of the mix (see Clause 207).

*As added
July 1977*

These aggregates, both coarse and fine, may contain hollow and/or flat shells which, like any flaky material if present in sufficient quantities, may affect adversely the workability of the concrete. Some workability problems can be eased by the inclusion of an appropriate admixture.

In hardened concrete, both hollow and flat shells in coarse aggregates may, if present in sufficient quantities, affect adversely the qualities of the concrete though no limit on shell content is at present thought necessary for the majority of work. Generally, shell is comparatively unimportant in fine aggregates.

202A. Admixtures. a. General. Suitable admixtures may be used in concrete mixes but only with the prior approval of the Engineer. Both the amount added and the method of use should be to the approval of the Engineer who should be provided with the following data:

*As added
July 1977*

(i) the typical dosage and detrimental effects, if any, of underdosage and overdosage;

(ii) the chemical name(s) of the main active ingredient(s) in the admixture;

(iii) whether or not the admixture contains calcium chloride and, if so, the chloride ion content expressed as a percentage by weight of admixture;

(iv) whether or not the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage.

An admixture should be specified as one that complies with the following British Standards: BS 1014, BS 3892 and BS 5075; for admixtures for which there is no British Standard, the type and/or proprietary brand should be specified.

In admixtures for use in:

1. concrete containing prestressing tendons, and embedded metal and made with any type of cement, and

2. concrete without embedded metal made with cement in accordance with BS 4027 and BS 4248

the chloride ion content should not exceed 2 % by weight of the admixture or 0.03 % by weight of the cement.

Admixtures should never be regarded as a replacement for good concrete practice and should never be used indiscriminately. Their suitability should generally be verified by trial mixes. Certain admixtures contain highly active chemicals and may impart undesirable as well as desirable properties to the concrete. If two or more admixtures are thought to be required in any one mix, the manufacturer of each should be consulted. The behaviour of admixtures with supersulphated cement may differ from their behaviour with Portland cement and advice should be sought before use.

b. Calcium Chloride. Experience has shown that corrosion of prestressing tendons, reinforcement and embedded metal usually results from a combination of factors including excess addition of calcium chloride due to failure to maintain specified dosage, departure from specified mix proportions, poor compaction, inadequate cover and poor detail design.

It is therefore strongly recommended that calcium chloride should never be added in prestressed concrete, reinforced concrete and concrete containing embedded metal.

This recommendation does not apply to concrete which is not prestressed or reinforced or which does not contain embedded metal because there is then no problem of corrosion. In these cases calcium chloride may be used with cement to BS 12 with the prior approval of the Engineer. In specifying the dosage and manner of adding the calcium chloride, attention should be paid to specialist literature and the manufacturer's instructions.

203. Water. The water should be clean and free from harmful matter.

204. Quality of steel and concrete. The full advantages of prestressing can be obtained only if the concrete and the prestressing steel are of high quality.

205. Prestressing steel. a. General. When reliance is to be placed on the bond between the steel and the concrete, wires or bars should be free from grease or other material likely to impair the bond. A slight film of rust is not necessarily harmful and may improve the bond. The steel, however, should not be pitted. (See Clause 502a.)

b. Material. The prestressing steel should be one of the following:

(i) Plain hard-drawn steel wire complying with the requirements of B.S. 2691, 'Steel wire for prestressed concrete'.

(ii) Indented or crimped hard-drawn steel wire complying with the requirements of B.S. 2691 in all respects except that for the bend test.

(iii) Steel strand complying with the requirements of B.S. 3617, 'Seven-wire steel strand for prestressed concrete', or B.S. 4757, 'Nineteen-wire steel strand for prestressed concrete'.

*As amended
Mar. 1976*

(iv) High tensile steel bars of open hearth steel with sulphur and phosphorus contents each below 0.05 per cent.

Bars whether plain or deformed should have a tensile strength of not less than 925 N/mm² with a 0.2 per cent proof stress of not less than 75 per cent or more than 92 per cent of the actual tensile strength. For methods of testing see B.S. 18, 'Methods for tensile testing of metals'.

(v) Such other wires, strand, or bars having properties not inferior to those laid down in B.S. 2691 or Sub-clause (iv) above respectively.

206. Reinforcement. Where steel reinforcement is introduced in prestressed concrete, it should be one of the following:

(i) Steel complying with the requirements for the following:
B.S. 4449 'Hot rolled steel bars for the reinforcement of concrete'

B.S. 4461 'Cold worked steel bars for the reinforcement of concrete'.

*As added
Mar. 1976*

(ii) Steel complying with Clause 205 b.

(iii) Such other reinforcement as may be suitable having regard to the yield stress, ductility, tensile strength and other essential properties.

207. Concrete. a. Design of mix. The concrete mix should be designed to comply with a specified requirement for works cube strength.

For ordinary or rapid hardening Portland cement concrete or Portland-blast-furnace cement concrete, the mix should contain not less than 300 kg nor more than 540 kg of cement per cubic metre of finished concrete. The specified works cube strength at twenty eight days should not be less than:

for work with pre-tensioned steel 40 N/mm²

for work with post-tensioned steel 30 N/mm²

In order to allow for unavoidable variations, the mix should be designed to have a mean strength that is greater than the specified works cube strength by a margin governed by the standard of quality control to be adopted. Two methods of quality control are envisaged (see Sub-clauses *d* (iii) and (iv)), which are designated respectively as the normal method of quality control and the special method of quality control.

The normal method of quality control is based on the requirement that the works cube strength obtained from cubes made during the concreting operations should not be less than the specified works cube strength (see Sub-clause *d* (iii)). For this method of control, the mix should be designed to have a mean strength which exceeds the specified works cube strength by a margin of 14 N/mm^2 . Where it can be shown to the satisfaction of the Engineer that the standard of acceptance for works cube strength can be maintained with a smaller margin, the mix may be redesigned using a reduced margin which should not be less than 10 N/mm^2 .

The special method of quality control is based on the maintenance of a mean concrete strength and on the limitation of standard deviation of cube strength during the concreting operations (see Sub-clause *d* (iv)). The method is used in order to provide for higher standards than those obtained with the normal method of quality control, and should not be used where the standard deviation is likely to exceed 5 N/mm^2 . For this method of control, the mix should be designed to have a mean strength which exceeds the specified works cube strength by twice the expected standard deviation.

The proportions chosen should be such that the concrete is of adequate workability for proper compaction by the means specified. (See Clause 501 *f* (iii)).

b. Control of aggregates. The grading of the aggregates should be controlled by obtaining the coarse aggregate in one size for aggregate of 10 mm nominal maximum size, in two sizes for aggregate of 19 mm nominal maximum size, or three sizes for aggregate of 38 mm nominal maximum size. The maximum size of coarse aggregate should be as large as possible, within the limit specified in B.S. 882, provided that the concrete can be placed without difficulty so as to surround the steel and to fill the corners of the formwork.

The size of the coarse and the grading of the fine aggregates should be determined at least once for every 100 tonnes supplied and at least once a week to check whether the suppliers are maintaining the grading uniform with that of the samples used in preliminary tests.

c. Measuring. The quantity of cement, fine and coarse aggregate should be determined by weight. The fine aggregate and the various sizes of coarse aggregate should be weighed separately. The amount of added water should be either measured by volume in calibrated tanks or weighed. Due allowance should be made for the water content in the aggregate. (See also Clause 501 *b* and *c*.)