

**BRITISH STANDARD CODE OF PRACTICE
CP 114: 1969**

**THE STRUCTURAL USE OF
REINFORCED CONCRETE
IN BUILDINGS**

**Incorporating amendments issued August 1973 (AMD 1241),
August 1974 (AMD 1552), March 1976 (AMD 1923)
and July 1977 (AMD 2304)**

**THE COUNCIL FOR CODES OF PRACTICE
BRITISH STANDARDS INSTITUTION
British Standards House, 2 Park Street, London, W.1**

CP 114 has been prepared by a Committee convened by the Codes of Practice Committee for Building. Having been endorsed by the Council for Codes of Practice, it was published under the authority of the Executive Board on 16th January, 1969.

SBN: 580 00469 4

First published, April, 1948.

First revision, June, 1957.

Reset and reprinted, February, 1965.

Published in metric form as Part 2, January, 1969.

This Code incorporates the amendments to CP114 issued in February, 1965 (PD 5463) and May, 1967 (PD 6151).

This Code of Practice makes reference to the following British Standards and British Standard Codes of Practice:

- | | |
|------------|--|
| B.S. 12. | Portland cement (ordinary and rapid hardening). |
| B.S. 146. | Portland-blastfurnace cement. |
| B.S. 449. | The use of structural steel in building. |
| B.S. 648. | Schedule of weights of building materials. |
| B.S. 693. | General requirements for oxy-acetylene welding of mild steel. |
| B.S. 785. | Rolled steel bars and hard drawn steel wire for concrete reinforcement. |
| B.S. 812. | Methods for sampling and testing of mineral aggregates, sands and fillers. |
| B.S. 877. | Foamed blastfurnace slag for concrete aggregate. |
| B.S. 882. | Concrete aggregates from natural sources. |
| B.S. 1014. | Pigments for Portland cement and Portland cement products. |
| B.S. 1047. | Air-cooled blastfurnace slag coarse aggregate for concrete. |
| B.S. 1200. | Building sands from natural sources. |
| B.S. 1370. | Low heat Portland cement. |
| B.S. 1881. | Methods of testing concrete. |
| B.S. 3148. | Tests for water for making concrete. |
| B.S. 3763. | International systems (SI) units. |

*As added
July, 1977*

- B.S. 3892. Pulverized-fuel ash for use in concrete. *As added July, 1977*
B.S. 3921. Clay bricks and blocks.
B.S. 4027. Sulphate-resisting Portland cement. *As added July, 1977*
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. 4466. Bending dimensions and scheduling of bars for the reinforcement of concrete.
B.S. 4483. Steel fabric for the reinforcement of concrete.
B.S. 5075. Concrete admixtures.
B.S. 5135. Metal-arc welding of carbon and carbon manganese steels.
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 111. Structural recommendations for load-bearing walls.
CP 116. Structural use of precast concrete.
CP 231. Painting.

British Standard Codes of Practice are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users ascertain that they are in possession of the latest amendments or editions.

The following B.S.I. reference relates to the work on this Code of Practice:
Committee reference BLCP/7

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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 legal requirements, including byelaws.

Attention is however drawn to the fact that in certain byelaws, notably those building byelaws based upon one of the models issued for England and Wales and for Northern Ireland, and in the Scottish Building Regulations, compliance with the provisions of certain British Standards or British Standard Codes of Practice, or of specific clauses therein, is 'deemed to satisfy' the requirements of certain of the byelaws in the fields covered by the British Standards and Codes of Practice, or by the specific clauses referred to.

FOREWORD

This metric edition of CP 114, 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 114 : 1957, rounded to convenient numbers. Although the values are not exact equivalents of the imperial ones, this is not a technical revision.

Recent research following structural collapses in 1973 and 1974 has considerably altered the understanding of the behaviour and sensitivity of high alumina cement concrete. As a result of both the research and the events themselves there is not, at this time, the consensus of opinion necessary for agreement on recommendations for the structural use of this material. Appendix B of the 1969 issue of this Code has therefore been withdrawn and the Code no longer covers the structural use of concrete made with high alumina cement. Consequently, an engineer wishing to specify concrete made with high alumina cement must rely entirely on his own engineering judgement without guidance from this Code of Practice.

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*

This Code does not cover the design of flat slabs. Structures containing flat slabs should be designed in accordance with CP 110.

BRITISH STANDARD CODE OF PRACTICE CP 114

THE STRUCTURAL USE OF REINFORCED CONCRETE IN BUILDINGS

Part 2. Metric units

SECTION ONE: GENERAL

101. Scope. This Code deals with the structural use of reinforced concrete in buildings. It is a revision of Code of Practice CP 114 (1948).

In the revision, Sub-Codes CP 114.100–114.104 (1951), 'Suspended concrete floors and roofs', have been merged into this code. Sub-Code 114.105, 'Filler joist construction', has not been included since this form of construction is dealt with in B.S. 449, 'The use of structural steel in building'.

The Code does not deal with prestressed concrete or with recommendations for the manufacture of precast factory-made reinforced concrete units. Other reinforced concrete constructions of a specialized character, such as water-retaining structures, are not included.

*As amended
Aug., 1974*

This Code does not cover the structural use of concrete made with high alumina cement.

It has been assumed in drafting this Code that the design of reinforced concrete is entrusted to chartered structural or civil engineers, qualified in reinforced concrete, for whose guidance it has been prepared, and that the execution of the reinforced concrete work is carried out under the direction of a qualified supervisor.

*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 353 (inserted by AMD 1241 and amended by AMD 1923) remain appropriate. However, the ties recommended in Clause 354 (inserted by AMD 1241 and amended by AMD 1923) as part of the means of satisfying the principles of Clause 353 will be required only when adequate stability is not provided by other means.

102. Definitions. For the purposes of this Code the following definitions apply:

Bands

Diagonal band. A band of reinforcing bars parallel to a diagonal of a flat slab panel which is reinforced in four directions (i.e. edgewise and diagonally).

	Direct band. A band of reinforcing bars parallel to an edge of a flat slab panel which is reinforced in four directions (i.e. edgewise and diagonally).
Column head	An enlargement of the top of a column supporting a flat slab so designed and constructed as to act monolithically with both the column and the flat slab.
Columns, long	Columns having a ratio of effective column length, as given in Table 19, to least lateral dimension greater than 15.
Columns, short	Columns having a ratio of effective column length, as given in Table 19, to least lateral dimension not exceeding 15.
Core of helically reinforced column	The portion of the concrete enclosed within the centre line of the helical reinforcement.
Drop	The portion of a flat slab above and immediately surrounding the column head and of greater thickness than the remainder of the flat slab panel.
Effective area of reinforcement in the diagonal bands of flat slabs	The area obtained by multiplying the normal cross-sectional area of the reinforcement by the cosine of the angle at which the band is inclined to the direction for which its effectiveness is required.
Effective depth of a beam or slab	The distance between the centre of tension and the edge of the compression section.
Effective span	The lesser of the two following distances: (i) the distance between centres of bearings. (ii) the clear distance between supports plus the effective depth of the beam or slab.
Exterior panel in a flat slab	A panel having at least one edge which is non-continuous.
Flat slab	A reinforced concrete slab with or without drops, supported, generally without beams, by columns with or without flared column heads.
Slender beams	Beams whose length between lateral restraints exceeds thirty times the breadth of their compression flange.

103. Symbols. The symbols used in this Code are as follows:

- A_b = equivalent area of helical reinforcement (volume of helix per unit length of column).
 A_c = cross-sectional area of concrete, excluding any finishing material and reinforcing steel.

- A_k = cross-sectional area of concrete in column core, excluding area of longitudinal reinforcement.
 A_{sc} = cross-sectional area of steel in compression.
 A_{st} = cross-sectional area of steel in tension.
 A_w = cross-sectional area of stirrup.
 b = breadth of a rectangular beam or breadth of flange of a T-beam or L-beam.
 b_r = breadth of the rib of a T-beam or L-beam.
 D = diameter generally.
 d = overall depth.
 d_1 = effective depth to the tensile reinforcement in a beam.
 d_2 = depth to the compressive reinforcement in a beam.
 d_n = depth of concrete in compression in a beam.
 d_s = depth of slab forming the flange of a T-beam or L-beam.
 e = eccentricity of a load on a column.
 f_y = guaranteed yield or proof stress.
 K_b = stiffness of beam.
 K_{b1} = stiffness of beam on one side of a column.
 K_{b2} = stiffness of beam on the opposite side of a column.
 K_l = stiffness of lower column.
 K_u = stiffness of upper column.
 L = length of a column or beam between adequate lateral restraints (in flat slabs, L is the average of L_1 and L_2).
 L_1 = (in flat slabs) length of panel in the direction of span.
 L_2 = (in flat slabs) width of panel at right angles to direction of span.
 l = effective span of beam or slab or effective height of column.
 l_a = lever arm of the resistance moment.
 l_x = length of shorter side of slab spanning in two directions.
 l_y = length of longer side of slab spanning in two directions.
 M = bending moment (suffixes as required).
 M_e = bending moment at end of beam framing into a column, assuming fixity at both ends of the beam.
 M_{em} = the maximum difference between the moments at the ends of two beams framing into opposite sides of a column, each calculated on the assumption that the ends of the beams are fixed and that one of the beams is not loaded.
 M_r = moment of resistance of a section to bending.
 M_x and
 M_y = maximum bending moments, for spans l_x and l_y respectively, on strips of unit width in slabs spanning in two directions.
 m = modular ratio.
 o = sum of perimeters of the bars in the tensile reinforcement.

- P = permissible load on a short column subject to both direct load and bending.
 P_b = load on a column as defined by equation 17.
 P_o = axial load permissible on a short column.
 p_{cc} = permissible stress in concrete in direct compression.
 p_{cb} = permissible compressive stress in concrete in bending.
 p_{cs} = permissible compressive stress in the reinforcement.
 p_{st} = permissible tensile stress in the reinforcement.
 Q = total shear across a section.
 q = shear stress at a section of a beam or slab.
 R = modulus of rupture.
 s = spacing or pitch of stirrups.
 u = cube crushing strength of concrete.
 u_p = u for preliminary test.
 u_w = u for works test.
 W = total load on beam or slab.
 W_d = dead load.
 W_s = superimposed load.
 w = total load per unit area of slab or per unit length of beam.
 α_x and
 α_y = bending moment coefficients for the short and long spans respectively, for slabs spanning in two directions and simply supported on four sides.
 β_x and
 β_y = bending moment coefficients for the short and long spans respectively, for rectangular panels supported on four sides and with provision for torsion at corners.

SECTION TWO: MATERIALS, APPLIANCES AND COMPONENTS

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

*As amended
Aug., 1974*

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

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

Low heat Portland cement should comply with B.S. 1370, 'Low heat Portland cement'.

*As amended
July, 1977*

Other cements, such as sulphate-resisting Portland and super-sulphated slag cements, are desirable in certain circumstances and may be used provided that any necessary modifications are made to the normal recommendations of this Code

202. Aggregates.

a. Permissible materials. The aggregates should consist of one of the following:

1. fine and coarse aggregates complying with B.S. 882, 'Concrete aggregates from natural sources'; in the case of fine aggregates, Zones 1-3 only should be used for nominal mixes but Zone 4 may be suitable for designed mixes;
2. air-cooled blastfurnace slag coarse aggregate complying with B.S. 1047, 'Air-cooled blastfurnace slag (coarse aggregate)';
3. foamed blastfurnace slag complying with B.S. 877, 'Foamed blastfurnace slag for concrete aggregate', provided that the grading is suitable for reinforced concrete; or
4. fine and coarse expanded clay, slate, shale or slag and sintered pulverized fuel ash, and other types of aggregate for which there is no British Standard, provided that such materials are suitable for reinforced concrete having regard to the properties of concrete made with these aggregates, such as strength, density, shrinkage and durability.

b. Grading. The grading of the aggregates should be such as to produce a concrete of the specified proportions which will work readily into position without segregation and without the use of an excessive water content. The grading should be controlled throughout the work so that it conforms closely to that used for the preliminary tests.

*As added
July, 1977*

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

These aggregates, both coarse and fine, may contain hollow and/or flat shells which, like any other 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.

203. Maximum size of coarse aggregates. The maximum size of coarse aggregate should be as large as possible, within the limit specified in the appropriate British Standard as given in Subclause 202*a*, but in no case greater than one-quarter of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and to fill the corners of the formwork. (See also Clause 308.)

For heavily reinforced concrete members, e.g. the ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to 5 mm less than the minimum lateral distance between the main bars, or 5 mm less than the cover to the reinforcement, whichever is the smaller.

Where, however, as in solid slabs, the reinforcement is widely spaced, limitation of the size of aggregate is not so important and the nominal maximum size may sometimes be as great as, or greater than, the minimum cover, except where porous aggregates are used.

204. Sands for mortar. Where mortar is used in the construction of floors and roofs, e.g. in the jointing of blocks, the fine aggregate for the mortar should consist of one of the following:

1. Natural sand or crushed natural stone sand complying with B.S. 1200, 'Sands for mortar for plain and reinforced brickwork; block walling and masonry'.
2. Such other types of fine aggregate as may be suitable, having regard to their strength, durability and freedom from harmful matter.

All fine aggregates should comply with the requirements for quality and grading in B.S. 1200.

205. Water. The water should be clean and free from harmful matter. Attention is drawn to B.S. 3148, 'Tests for water for making concrete'.

205A. 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*

1. the typical dosage and detrimental effects, if any, of underdosage and overdosage;
2. the chemical name(s) of the main active ingredient(s) in the admixture;
3. whether or not the admixture contains calcium chloride and, if so, the chloride ion content expressed as a percentage by weight of admixture;
4. 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 requirements of the following British Standards: B.S. 1014, B.S. 3892 and B.S. 5075; for admixtures for which there is no British Standard, the type and/or proprietary brand should be specified.

*As added
July, 1977*

In admixtures for use in:

- (i) concrete containing reinforcement and embedded metal and made with any type of cement, and
- (ii) concrete without embedded metal made with cement in accordance with B.S. 4027 and B.S. 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 that is not prestressed or reinforced or that does not contain embedded metal because there is then no problem of corrosion. In these cases calcium chloride may be used with cement to B.S. 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.

206. Reinforcement.

a. General. The reinforcement should be one of the following:

1. Steel bars complying with B.S. 4449, 'Hot rolled steel bars for the reinforcement of concrete' and B.S. 4461, 'Cold worked steel bars for the reinforcement of concrete'.
2. Steel fabric complying with B.S. 4483, 'Steel fabric for the reinforcement of concrete'.
3. such other reinforcement as may be suitable having regard to the yield or proof stress, ductility, tensile strength and other essential properties.

*As amended
Mar., 1976*

b. Effective diameter of a bar. For the purposes of this Code, the effective diameter of a bar should be calculated as follows:

1. for a bar whose cross-sectional area is constant along the length, the effective diameter is that of a circle having the same area as the cross-section of the bar;
2. for a bar whose cross-sectional area varies along its length, the effective diameter is that of a circle having an area equal to the least area of any cross-section of the bar; an allowance, not exceeding 3 per cent, may however be added to the least area of the cross-section on account of any non-continuous ribs.

207. Concrete. Two methods of proportioning concrete mixes are permitted by this Code. Nominal concrete mixes may be adopted in accordance with Clause 208, where the quality control requirements for designed mixes are impracticable, but the proportions should preferably be specified by weight and correspond where appropriate with those of the standard mixes given in Clause 209. On small jobs, however, where the concrete is mixed on the site it is permissible to use volume batching of the aggregates for nominal mixes.

In general, it is preferable to design the concrete mix in accordance with Clause 209 to produce a concrete having the desired strength. Where designed concrete mixes are adopted, the designer may use higher compressive stresses in the concrete; if so, the specification for the construction should make it clear that designed mixes are to be used, with the appropriate control of quality. Clause 209 includes the proportions for some standard mixes, which are primarily intended to replace the trial mixes that are usually necessary for designed concrete mixes, but which may also be used as nominal mixes for the purpose of compliance with Clause 208.

Chloride content. The total chloride content of the concrete mix arising from the aggregate together with that from any admixtures and any other source should not in any circumstances exceed the following limits expressed as a percentage relationship between chloride ion and weight of cement in the mix.

*As added
July, 1977*

Type or use of concrete	Maximum total chloride content expressed as percentage of chloride ion by weight of cement
Structural concrete that is steam cured Concrete for any use made with cement complying with B.S. 4027 and B.S. 4248	0.06
Reinforced concrete made with cement complying with B.S. 12 Plain concrete made with cement complying with B.S. 12 and containing embedded metal	0.35 for 95 % of test results with no result greater than 0.50

NOTE: $\% \text{ chloride ion} \times 1.648 = \% \text{ equivalent sodium chloride}$
 $\% \text{ chloride ion} \times 1.565 = \% \text{ equivalent anhydrous calcium chloride}$

208. Nominal concrete mixes.**a. PROPORTIONS.**

- (i) *Cement and aggregates.* The fine aggregate and the coarse aggregate should be measured separately. The proportions of cement to fine aggregate and coarse aggregate should be as set out in Tables 1 and 2, or, in the case of Table 1, in any intermediate proportions in which the volume of coarse aggregate is twice the volume of fine aggregate.

Where, however, a denser or more workable concrete can be produced by a variation in the ratio of the volume of coarse aggregate to that of fine aggregate, this ratio may be varied within the limits $1\frac{1}{2}$ to 1 and 3 to 1.

The sum of the volumes of coarse and fine aggregate, each measured separately, should nevertheless equal the sum of the volumes of coarse and fine aggregate appropriate to the nominal mix (or intermediate mix where applicable) in Tables 1 and 2.

It is moreover desirable to adjust the ratio to suit the maximum size of the coarse aggregate and also the grading of the fine aggregate. For example, when the fine aggregate is within Grading Zone 2 of B.S. 882 : 1954, ratios of $1\frac{1}{2}$ to 1, 2 to 1 and 3 to 1 may be suitable for maximum sizes of 10 mm, 19 mm and 38 mm respectively. For fine aggregates within other grading zones, the ratio should be increased as the fine aggregate gets finer, that is, passes from Zone 1 to Zone 3. For example, using a coarse aggregate of 19 mm maximum size, ratios of $1\frac{1}{2}$ to 1, 2 to 1 and 3 to 1 may be suitable for fine aggregates within Zones 1, 2 and 3 respectively. Fine aggregate within Zone 4 is unsuitable for use with nominal concrete mixes for structural work, whatever coarse aggregate size is adopted, but can be used in special mixes.

In proportioning concrete, the quantity of cement should be determined by weight. The quantities of fine and coarse aggregates may be determined by volume, but this should preferably be done by weight. In the latter case the weight should be determined from the volume required by the table and the weight per cubic metre of the aggregate. The proportions given in this sub-clause and in Tables 1 and 2 are based on the assumption that the aggregates are dry. If the fine aggregate is moist, due allowance must be made for bulking (see Clause 602).

As provided for in Clause 207, the standard mixes given in Table 5 may also be adopted for nominal mixes instead of those given in this Subclause.

- (ii) *Water/cement ratio.* The quantity of water used for reinforced concrete should be sufficient, but not more than sufficient, to produce a dense concrete of adequate workability for its purpose, which will surround and properly grip all the reinforcement. So far as possible, the work-

ability of the concrete should be controlled by maintaining a water/cement ratio that is found to give a concrete which is just sufficiently wet to be placed and compacted without difficulty, with the means available.

- (iii) *Workability*. The workability should be controlled by direct measurement of water content, making allowance for any water in the fine and coarse aggregates. The slump test or the compacting factor test described in B.S. 1881, 'Methods of testing concrete', may be used as a guide. The latter test is primarily designed for laboratory conditions and is particularly useful for concrete mixes of very low workability.

b. STRENGTH REQUIREMENTS FOR CONCRETE.

- (i) *Portland cement concrete or Portland-blastfurnace cement concrete with aggregates complying with B.S. 882 or B.S. 1047*. Concrete made with Portland cement or Portland-blastfurnace cement should comply with the strength requirements of Table 1, Cols. 3 and 4 (works test). Where intermediate proportions of aggregate to cement are used, as provided in Subclause 208a(i), the cube strengths required should be obtained by proportion from the two nearest nominal mixes.

If the required cube strengths at 7 days, given in Table 1, Column 4, are not reached, the concrete may still be accepted if the 28 day strengths given in Column 3 are attained.

Where difficulty is found in reaching the requisite cube strengths in Table 1, figures lower than those given may be accepted, but not more

TABLE 1. PROPORTIONS AND STRENGTH REQUIREMENTS FOR NOMINAL CONCRETE MIXES WITH PORTLAND CEMENT OR PORTLAND-BLASTFURNACE CEMENT AND WITH AGGREGATES COMPLYING WITH B.S. 882 OR B.S. 1047

(1) Mix proportions	(2) Cubic metres of aggregate per 50 kg of cement		(3) Cube strength within 28 days after mixing		(4) Alternative cube strength within 7 days after mixing	
	Fine	Coarse	Preliminary test	Works test	Preliminary test	Works test
			N/mm ²	N/mm ²	N/mm ²	N/mm ²
1 : 1 : 2	0.035	0.07	40	30	26.7	20
1 : 1½ : 3	0.05	0.10	34	25.5	22.7	17
1 : 2 : 4	0.07	0.14	28	21	18.7	14

than 25 per cent lower, provided that the permissible stresses are reduced in accordance with Subclause 303a(ii).

Where, on the other hand, the materials used for the concrete, and the standard of workmanship employed, are such that the cube strength requirements for both the preliminary and works tests for any nominal mix are consistently exceeded by a certain percentage, the permissible stresses for the concrete can be increased in accordance with Subclause 303a(ii).

Sub clause (ii) and Table 2 deleted August 1974.

- (iii) *Concretes with aggregates not complying with B.S. 882 or B.S. 1047.* No provision is made in this Code for the use of nominal mixes with aggregates not complying with B.S. 882 or B.S. 1047, except where lightweight aggregates in accordance with 3 or 4 in Subclause 202a are used, and concrete made with these aggregates satisfies the strength requirements of Table 1. For other aggregates, the concrete should be designed in accordance with Clause 209.

C. TESTS OF CONCRETE QUALITY.

- (i) *Preliminary cube strength tests.* Unless satisfactory evidence of strength is produced from reliable sources, preliminary strength tests should be made in accordance with B.S. 1881, 'Methods of testing concrete' (see Subclause 601b), both prior to the commencement of the constructional work and subsequently whenever any important change is to be made in the materials or in the proportions of the materials to be used. The strengths should comply with the requirements of Subclause 208b for preliminary tests.
- (ii) *Works cube strength tests.* Works cube strength tests should be made in accordance with B.S. 1881 (see Subclause 601c) as may be necessary and particularly whenever materials or proportions are changed, to prove the quality of the concrete. A record of such tests, identifying them with the part of the work executed, should be kept on the works.
- (iii) *Standard of acceptance for cube strength tests.* Three test cubes should be made for each age at which tests are required. The cube strength should be calculated from the maximum load sustained by the cube at failure. The appropriate strength requirement may be considered to be satisfied if none of the strengths of the three cubes is below the specified cube strength, or if the average strength of the three cubes is not less than the specified cube strength and the difference between the greatest and the least strengths is not more than 20 per cent of that average.
- (iv) *Transverse works strength tests.* Check tests of the quality of the concrete may also be made by means of the transverse tests on 406.4 mm × 101.6 mm × 101.6 mm* beams described in Subclause 601d. The modulus

of rupture of the concrete determined from this test may be expected to reach the values given in Table 3 when aggregates complying with B.S. 882 or B.S. 1047 are used.

Where it is impracticable to make cube tests, and the transverse test is employed as the only control on the strength of the concrete, the figures given in the table should be increased by 10 per cent.

The method of testing beams described in Subclause 601*d* differs from that in B.S. 1881 in respect of the length of the supporting span, the method of loading, and the orientation of the beam under test in relation to its position during moulding. The figures given in Table 3 are based on a large number of tests obtained over many years before B.S. 1881 was published. Since the two methods of test give different values of modulus of rupture for the same concrete, it has been thought advisable not to introduce the B.S. 1881 method into this Code until sufficient data have been collected to enable such modifications as become necessary to the figures in Table 3 to be made with confidence.

It should be noted that the modulus of rupture varies roughly with the square root of the cube strength.

TABLE 3. TRANSVERSE STRENGTHS OF CONCRETE

*As amended
Aug., 1974*

Mix proportions	Modulus of rupture		Corresponding loads from test described in Subclause 601 <i>d</i>	
	3 days after mixing	7 days after mixing	3 days after mixing	7 days after mixing
	N/mm ²	N/mm ²	kg	kg
Portland cement concretes				
1 : 1 : 2	2.05	3.10	480	725
1 : 1½ : 3	1.90	2.75	445	645
1 : 2 : 4	1.70	2.40	400	565

* It is anticipated that there will be no rational metric sized beam to replace the 16 in × 4 in × 4 in beam, as this size is regarded as obsolete. Exact equivalent values of 16 in × 4 in × 4 in are given.

209. Designed concrete mixes.

a. General. The concrete mix should be designed to satisfy any specified works cube strength requirement within the range given in Table 4, provided that the mix limitations given in Column 1 of that table are observed and that the mix is in accordance with this Clause.

In order to allow for unavoidable variations, the mix should be designed to have a mean strength that exceeds the specified works cube strength by twice

the expected standard deviation.* The standard deviation should be calculated from at least 40 individual cube results, each representing separate batches of similar concrete produced by the same plant and under the same supervision, except that no standard deviation less than 3.5 N/mm^2 should be used as a basis for designing the mix, i.e. the minimum margin between the specified works cube strength and the designed mean strength will thus be 7 N/mm^2 . In the absence of previous information, a standard deviation of 7 N/mm^2 , i.e. a margin of 14 N/mm^2 , should be used initially for mix design purposes.

**TABLE 4. STRENGTH REQUIREMENTS FOR
DESIGNED CONCRETE MIXES**

(1)	(2)
Mix limitations	Specified works cube strength
<i>As amended Aug., 1974</i> For Portland cement or Portland blast-furnace cement concrete, not less than 240 kg nor more than 540 kg of cement per cubic metre of finished concrete; and designed for the required concrete strength at 28 days, within the range given in Column (2)	N/mm^2 15 to 50 at 28 days

Although the strength requirement is normally related to an age of 28 days, it is useful in the trial mixes and in the subsequent control of concrete quality to take appropriate action on the results obtained earlier from 7-day strength tests. The concrete mix may be provisionally accepted on the basis of the 7-day results, when these satisfy the requirements for the 28-day results except that the strengths at 7 days are not less than two-thirds of those required at 28 days. Where there are sufficient data available to establish the relationship between the 7-day and 28-day strengths for the materials and proportions used, the 7-day results may be adopted as the criterion for control.

b. Trial mixes. Unless there are existing data showing that the proposed mix proportions will produce the grade of concrete required with adequate workability for full compaction by the method to be used, trial mixes should be prepared under full-scale conditions and tested in accordance with B.S. 1881, 'Methods of testing concrete'. As a preliminary it may be convenient to prepare trial mixes in a laboratory in accordance with B.S. 1881. Trial mixes should also be made subsequently whenever a change is intended in the materials or in the proportions of the materials to be used.

Representative samples of the materials to be used should be taken and a trial mix using the proposed proportions should be made on each of three

* If the differences between the individual results and their average are squared and added together and the total then divided by the number of the results minus one, the standard deviation is the square root of the resulting figure.

different days. The workability of each of these three trial mixes should be determined, and a batch of six cubes from each should be made, three for test at 7 days and three for test at 28 days. The proposed mix proportions should not be accepted if the average strength of the three trial mixes is less than the specified works cube strength plus the designed standard deviation. Further trial mixes should usually be made if the range of the three cube results in any batch exceeds 15 per cent of the average of that batch, or if the range of the three batch averages exceeds 20 per cent of the overall average of the batches.

Where high alumina cement is used, the recommendations in this Subclause should be modified in that only three cubes need be made for each trial mix, and the strengths should be determined at an age of one day.

c. Works cube tests for control purposes. Samples of concrete should be taken at the mixer and works cubes made, cured and tested in accordance with the requirements of B.S. 1881.

When a mix is used for the first time it is important to get a large number of results as soon as possible in order to establish the level of control and the suitability of the mix proportions. A sample of concrete should be taken at random on eight separate occasions during each of the first five days of using that mix. Thereafter at least one sample should be taken each day any concrete of a particular strength is made. The number of samples per day and the times at which they are taken should be varied at random.

From each sample two cubes should be made, one for test at 7 days and the other for test at 28 days. To ensure that the mix proportions are suitable for a particular strength of concrete, a comprehensive statistical check should be made continuously during the progress of the work. This requirement may be deemed to be satisfied if the 28-day works cube strength results are shown to satisfy the four conditions given below.

The works cube results should be examined both individually and in consecutive (but not overlapping) sets of four, for which the average and the range of each set is calculated. The mix proportions should be modified to increase the strength if, in the first ten consecutive (but not overlapping) sets, any of the following conditions are not satisfied:

1. not more than two individual results of the 40 cube tests should fall below the specified works cube strength;
2. no value of the range in any set should exceed four times the designed standard deviation;
3. not more than one set should have an average which is less than the specified strength plus $\frac{4}{3}$ times the designed standard deviation; and
4. no value of the average for any set should be less than the specified strength plus the designed standard deviation.

After ten consecutive sets of results have been obtained, the overall average and the standard deviation of the forty results should be calculated and any appropriate modifications made.

Subsequently, if any of the foregoing conditions are not satisfied, the overall average and the standard deviation of the previous consecutive forty results, including the non-complying set, should be calculated and appropriate steps taken if the overall average strength minus twice the standard deviation is less than the specified works cube strength.

When high alumina cement is used, the recommendations of this Subclause should be modified, in that only one cube should be made from each sample of concrete and control should be based on the results of tests on the cubes at an age of one day.

d. Quality control requirements. In order to maintain a high standard of quality, the following should be observed:

1. *Supervision.* A competent person should be employed whose first duty it will be to supervise all stages in the preparation and placing of the concrete. All tests on materials, the making and testing of cubes and the maintenance and calibration of all mixing and measuring plant should be carried out under his direct supervision.
2. *Aggregates.* Separate storage bins with adequate provision for drainage should be provided for each size of aggregate used, e.g. for the following nominal single sizes where applicable: 38–19 mm, 19–10 mm, 10–5 mm and 5 mm down.

The grading of the coarse and fine aggregates should be determined at least once a week to check whether the gradings are similar to those of the samples used in the trial mixes or of those used as the basis for the selection of the weights of aggregates in Table 5 and in the case of standard mixes. Some variation may occur, and in the case of sands it would not be unreasonable for the grading to vary by a range equivalent to that of a single grading zone in B.S. 882. For example, if the grading of the sample corresponded to the middle of Zone 2, then provided the sand remained within Zone 2 no adjustment to the mix would be required. Similarly, if the sample grading was close to the finer limit of Zone 2, then it might vary from the middle of Zone 2 to the middle of Zone 3.

For any given maximum size the grading of the coarse aggregate, provided this is within the appropriate limits of B.S. 882, is unlikely to affect the properties of concrete unless a high degree of control is exercised. Where the range permitted by B.S. 882 for graded aggregates is considered to be too wide, it is recommended that single-sized aggregates are used, the relative proportions being determined on the basis of the trial mixes.