
British Standard

Structural use of concrete

Part 1. Code of practice for design and construction

Utilisation du béton en construction

Partie 1. Code de bonne pratique pour le calcul et la construction

Beton im Hochbau

Teil 1. Leitfaden für Berechnung, und Konstruktion

Amendment No. 3
published and effective from 15 March 1993
to BS 8110 : Part 1 : 1985

Structural use of concrete
Part 1. Code of practice for design and
construction

NOTE. This amendment does not take account of the 1991 revisions of the British Standard cement and concrete specifications, but this will be covered by a future amendment.

Revised text

AMD 7583
March 1993

Contents (as amended by Amendment No. 1)

In the list of tables, delete '3.19 Bending moment and shear force coefficients for flat slabs of three or more equal spans' and substitute '3.19 *Table deleted*'.

In the list of figures, delete '3.17 Punching shear zones' and substitute '3.17 Zones for punching shear reinforcement'.

AMD 7583
March 1993

Clause 2.2.7 Lightning

In line 2 delete 'CP 326' and substitute 'BS 6651'.

AMD 7583
March 1993

Clause 2.4.1.2 Normal earth loads, E_n

In line 3 delete 'CP 2004' and substitute 'BS 8004'.

AMD 7583
March 1993

Clause 3.1.7.4 Characteristic strengths of reinforcement

In line 3 delete 'BS 4461' and substitute 'BS 4482'.

AMD 7583
March 1993

Clause 3.4.4.4 Design formulae for rectangular beams

In the last line of the equations delete ' $A_s = K'f_{cu}bd^2/0.87 f_{yz} + A_s'$ ' and substitute ' $A_s = (K'f_{cu}bd^2/0.87 f_{yz}) + A_s'$ '.

AMD 7583
March 1993

Clause 3.4.4.5 Design ultimate moments of resistance (flanged beams where the neutral axis falls below the flange)

In lines 1 and 2 delete the existing title and substitute '*Design formulae for flanged beams where the neutral axis falls below the flange.*'

In line 3 delete ' $0.87 f_y$ ' and substitute ' $0.87 f_{yv}$ '.

Delete the existing figure 3.1 and substitute the following new figure 3.1.

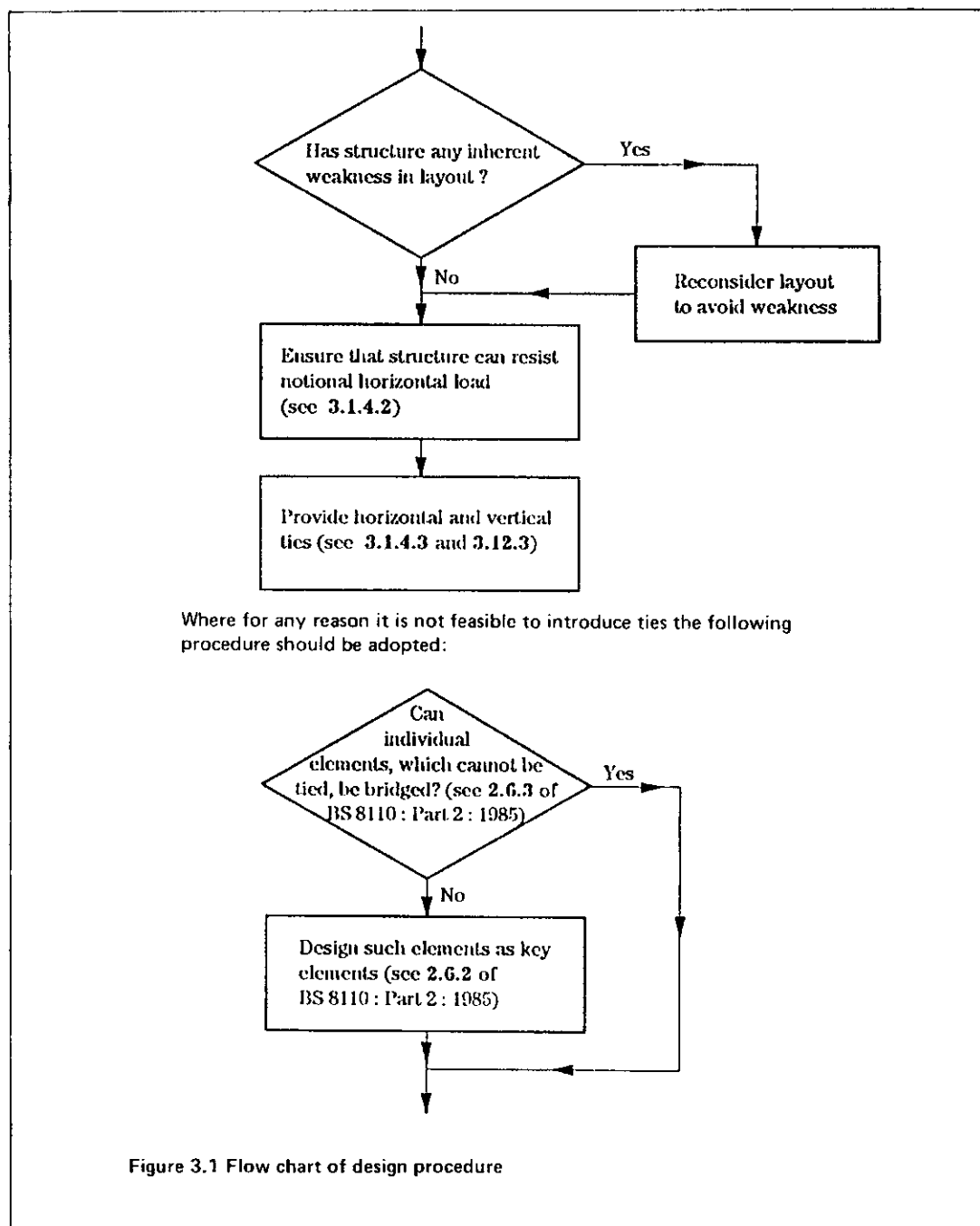


Figure 3.1 Flow chart of design procedure

Clause 3.4.5.12 Shear and axial compression

Delete the existing clause and substitute the following.

'3.4.5.12 Shear and axial load. The design shear stress, v_c' , that can be supported by a section subjected to shear and axial compression without shear reinforcement can be calculated from equation 6(a). Both adverse and beneficial load combinations should be considered (see table 2.1).

$$v_c' = v_c + 0.6 \frac{NVh}{A_c M} \quad \text{equation 6(a)}$$

where

v_c is the shear stress obtained from table 3.9. This should not be adjusted in accordance with 3.4.5.8;

N , V , and M are the applied axial load, shear and moment respectively;

The value of Vh/M should be taken as greater than 1.

A_c should be taken as the gross area of the concrete section. (N/A_c is intended to be the average stress in the concrete acting at the centroid of the section.)

Where it is considered necessary to avoid shear cracking prior to the ultimate limit state, the shear stress should be limited to the value given by equation 6(b).

$$v_c' = v_c \sqrt{1 + N/(A_c v_c)} \quad \text{equation 6(b)}$$

If v exceeds v_c' shear reinforcement should be provided in accordance with table 3.8 where v_c is replaced by v_c' .

v should not exceed $0.8 \sqrt{f_{cu}}$ or 5 N/mm^2 .

For situations where the axial load is tensile, equations 6(a) and 6(b) may be used with N taken as negative.'

Clause 3.4.6.5 Modification of span/depth ratios for tension reinforcement

In line 5 delete 'area of reinforcement provided and its' and substitute 'ultimate design moment and the'.

AMD 7583
March 1993

Table 3.13 Ultimate bending moment and shear forces in one-way spanning slabs

Delete the existing table 3.13 and substitute the following new table 3.13.

Table 3.13 Ultimate bending moment and shear forces in one-way spanning slabs							
	End support/slab connection				At first interior support	Middle of interior spans	Interior supports
	Simple		Continuous				
	At outer support	Near middle of end span	At outer support	Near middle of end span			
Moment	0	$0.086Fl$	$-0.04Fl$	$0.075Fl$	$-0.086Fl$	$0.063Fl$	$-0.063Fl$
Shear	$0.4F$	—	$0.46F$	—	$0.6F$	—	$0.5F$
NOTE. F is the total design ultimate load ($1.4G_k + 1.6Q_k$); l is the effective span.							

AMD 7583
March 1993

Clause 3.5.2.4 One-way spanning slabs of approximately equal span
(as amended by Amendment No. 1)

In lines 1 and 2 delete the existing title and substitute '*One-way spanning slabs of approximately equal span: uniformly distributed loads.*'

AMD 7583
March 1993

Clause 3.5.3.6 Restrained slab with unequal conditions at adjacent panels

Delete item (a) and substitute the following.

'(a) Calculate the sum of the midspan moment and the average of the support moments (neglecting signs) for each panel.'

Delete item (d) and substitute the following.

'(d) Adjust midspan moment for each panel: this should be such that when it is added to the average of the support moments from (c) (neglecting signs) the total equals that from (a).'

AMD 7583
March 1993

Figure 3.10 Distribution of load on a beam supporting a two-way spanning slab

Above the title insert the following.

'NOTE. $v_s = v_{sx}$ when $l = l_y$;
 $v_s = v_{sy}$ when $l = l_x$.'

AMD 7583
March 1993

Table 3.17 Form and area of shear reinforcement in solid slabs (as amended by Amendment No. 1)

In note 2 delete '3.4.5.8 and 3.4.5.9' and substitute '3.4.5.8, 3.4.5.9 and 3.4.5.10'.

AMD 7583
March 1993

Clause 3.7.1.1 Symbols (as amended by Amendment No. 1)

In line 7 delete 'figure 3.11' and substitute 'figure 3.13'.

Delete lines 10 and 11 and substitute:

' F total design ultimate load on the full width of panel between adjacent bay centre lines ($= 1.4G_k + 1.6Q_k$)'.

Delete line 14 and substitute:

' l given in table 3.13 should be taken as the full panel length in the direction of span'.

AMD 7583
March 1993

Clause 3.7.2.7 Simplified method for determining moments

In line 3 delete 'table 3.19' and substitute 'table 3.13'.

After item (b) insert the following.

- '(c) for definitions of l and F see 3.7.1.1;
- (d) moments at supports taken from table 3.13 may be reduced by $0.15Fh_c$;
- (e) the limitation of 3.7.2.6 need not be checked. Allowance has been made to the coefficients of table 3.13 for 20 % redistribution in accordance with 3.5.2.3. '

AMD 7583
March 1993

Clause 3.7.2.10 Division of moments between column and middle strips

In line 3 delete 'table 3.19' and substitute 'table 3.13'.

AMD 7583
March 1993

Clause 3.7.4.4 Negative moments at free edge

In line 7 delete '0.1' and substitute '0.15'.

AMD 7583
March 1993

Clause 3.7.7.2 Maximum design shear capacity

At the end of 3.7.7.2 insert the following new sentence.

'The maximum shear capacity may also be limited by the provisions of 3.7.7.5.'

AMD 7583
March 7583

Table 3.19 Bending moment and shear force coefficients for flat slabs of three or more equal spans

Delete table 3.19.

AMD 7583
March 1993

Clause 3.7.7.3 Calculation of design shear stress for a failure zone

Delete the existing clause and substitute the following.

'3.7.7.3 Calculation of design shear stress. The nominal design shear stress, v , appropriate to a particular perimeter is calculated from the following equation:

$$v = \frac{V}{ud} \quad \text{equation 28'}$$

AMD 7583
March 1993

Clause 3.7.7.4 Shear capacity of a failure zone without shear reinforcement

In line 1 delete 'of a failure zone'.

AMD 7583
March 1993

Figure 3.16 Definition of a shear perimeter for typical cases

Above the title insert the following.

NOTE. l_p is defined in 1.2.3.1.'

AMD 7583
March 1993

Clause 3.7.7.5 Provision of shear reinforcement in a failure zone

Delete the existing clause and substitute the following.

'3.7.7.5 Provision of shear reinforcement. The use of shear reinforcement other than links is not covered specifically by this code and should be justified separately.

If $v_c < v < 2v_c$, shear reinforcement in the form of links may be provided in accordance with equations 29(a) and 29(b) in slabs over 200 mm deep to increase the shear resistance.

For cases where $v \leq 1.6v_c$, shear reinforcement should be provided in accordance with the following equation:

$$\Sigma A_{sv} \sin \alpha \geq \frac{(v - v_c)ud}{0.87f_{yv}} \quad \text{equation 29(a)}$$

For cases where $1.6v_c < v \leq 2v_c$, shear reinforcement should be provided in accordance with:

$$\Sigma A_{sv} \sin \alpha \geq \frac{5(0.7v - v_c)ud}{0.87f_{yv}} \quad \text{equation 29(b)}$$

Equations 29(a) and 29(b) should not be applied where the shear stress v exceeds $2v_c$.

Where $v > 2v_c$ and a reinforcing system is provided to increase the shear resistance, justification should be provided to demonstrate the validity of the design.

In the above equations:

f_{yv} is the characteristic strength of shear reinforcement (in N/mm^2);

ΣA_{sv} is the area of the shear reinforcement (in mm^2);

α is the angle between the shear reinforcement and the plane of the slab.

In equations 29(a) and 29(b), $(v - v_c)$ should not be taken as less than 0.4 N/mm^2 .

AMD 7583
March 1993

Clause 3.7.7.6 Design procedure

Delete the existing clause and substitute the following.

‘3.7.7.6 Design procedure. The shear capacity is checked first on a perimeter $1.5d$ from the face of the loaded area. If the calculated shear stress does not exceed v_c then no further checks are needed.

If shear reinforcement is required, then it should be provided on at least two perimeters within the zone indicated in figure 3.17. The first perimeter of reinforcement should be located at approximately $0.5d$ from the face of the loaded area and should contain not less than 40 % of the calculated area of reinforcement.

The spacing of perimeters of reinforcement should not exceed $0.75d$ and the spacing of the shear reinforcement around any perimeter should not exceed $1.5d$. The shear reinforcement should be anchored round at least one layer of tension reinforcement. The shear stress should then be checked on successive perimeters at $0.75d$ intervals until a perimeter is reached which does not require shear reinforcement.

In providing reinforcement for the shear calculated on the second and subsequent perimeters, that provided for the shear on previous perimeters and which lies within the zone shown in figure 3.17 should be taken into account.’

AMD 7583
March 1993

Clause 3.8.2.3 Columns in column-and-beam construction, or in monolithic braced structural frames

Delete the existing clause and substitute the following.

‘3.8.2.3 Columns in column-and-beam construction, or in monolithic braced structural frames. The axial force in a column may be calculated on the assumption that beams and slabs transmitting force into it are simply supported.

When a column is subject only to an axial load with no significant applied moment, as in the case of columns supporting a symmetrical arrangement of approximately equally loaded beams, only the design ultimate axial force need be considered in design together with a design moment representing a nominal allowance for eccentricity, equal to that recommended in 3.8.2.4.’

AMD 7583
March 1993

Clause 3.8.4.6 Shear in columns (as amended by Amendment No. 1)

Delete the existing clause and substitute the following.

'3.8.4.6 Shear in columns. The design shear strength of columns may be checked in accordance with 3.4.5.12. For rectangular sections in compression no check is required provided that M/N does not exceed $0.6h$ and v does not exceed the maximum value given in 3.4.5.12.'

AMD 7583
March 1993

Clause 3.11.4.4 Design shear resistance

In line 2 delete 'carried out' and substitute 'determined'.

AMD 7583
March 1993

Clause 3.11.4.5 Punching shear

In line 4, after 'whichever is the lesser,' insert the following new sentence.

'The maximum shear capacity may also be limited by the provisions of 3.7.7.5.'

AMD 7583
March 1993

Clause 3.12.3.1 General

Delete the existing item (d) and substitute the following.

'(d) vertical ties.'

AMD 7583
March 1993

Clause 3.12.3.7 Vertical ties (generally required in buildings of five or more storeys) (as amended by Amendment No. 1)

In lines 1 and 2 delete '(generally required in buildings of five or more storeys)'.

AMD 7583
March 1993

Clause 3.12.5.3 Minimum percentages of reinforcement

After paragraph 1 insert the following new paragraph.

'The minimum number of longitudinal bars in a column should be four in rectangular columns and six in circular columns, and the size of bar should be not less than 12 mm.'

AMD 7583
March 1993

Clause 3.12.5.4 Minimum size of bars in side faces of beams to control cracking (as amended by Amendment No. 1)

In lines 5 and 6 delete 'considered (or 500 mm if less).' and substitute 'considered, or 500 mm if b exceeds 500 mm.'

AMD 7583
March 1993

Clause 3.12.7.1 Diameter of links for containment of beam or column
compression reinforcement

In line 1 delete '*Diameter of links*' and substitute '*Links*'.

AMD 7583
March 1993

Clause 3.12.7.4 Diameter of horizontal bars for support of small amounts of
compression reinforcement in walls (as amended by Amendment No. 1)

In line 1 delete '*Diameter of horizontal*' and substitute '*Horizontal*'.

AMD 7583
March 1993

Clause 3.12.7.5 Arrangement of links for containment of large amounts of
compression reinforcement in walls

In line 1 delete '*Arrangement of links*' and substitute '*Links*'.

Delete the last sentence and substitute the following.

'All vertical compression bars should be enclosed by a
link. No bar should be further than 200 mm from a
restrained bar, at which a link passes round the bar with
an included angle of not more than 90°.'

Figure 3.17 Punching shear zones

Delete the existing figure 3.17 and substitute the following new figure 3.17.

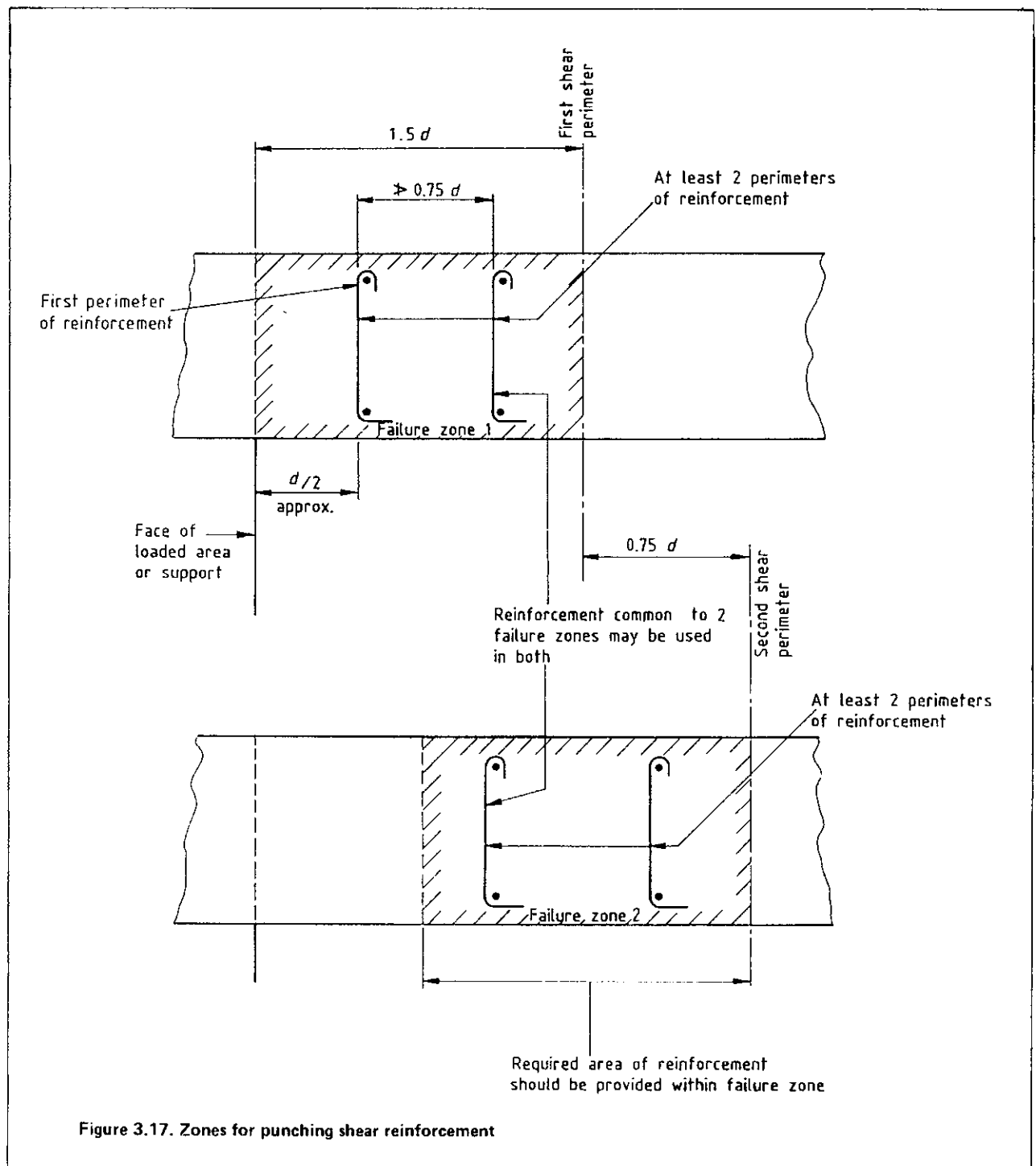
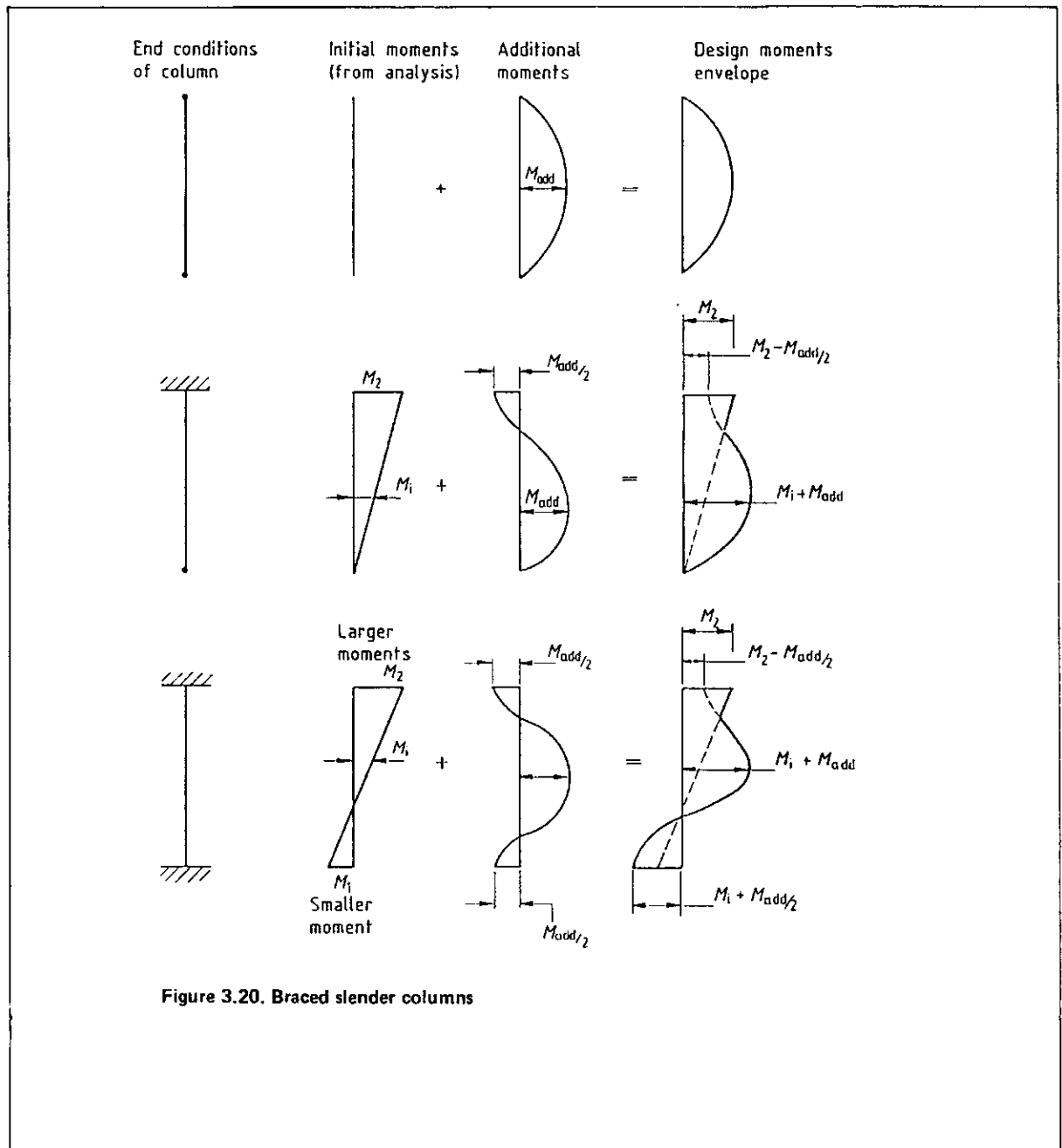


Figure 3.20 Braced slender columns

Delete the existing figure 3.20 and substitute the following new figure 3.20.



AMD 7583
March 1993

Clause 3.12.8.5 Design ultimate anchorage bond stresses for fabric

In lines 3 and 4 delete 'as defined in BS 4449, BS 4461 and BS 4482,' and substitute 'manufactured from bars complying with BS 4449 or wires complying with BS 4482.'

AMD 7583
March 1993

Clause 3.12.11.2.5 Clear distance between the corner of beam and nearest longitudinal bar in tension

In line 1 delete 'corner' and substitute 'face'.

In line 3, delete 'corner' and substitute 'face'.

In the last line delete 'table 3.30.' and substitute 'table 3.30 or as derived from 3.12.11.2.4.'

AMD 7583
March 1993

Clause 3.12.11.2.7 Slabs

In item (a) (3) line 4 delete ' A_s is the minimum recommended area;' and substitute:

' A_s is the area of tension reinforcement required for the ultimate limit state;'

AMD 7583
March 1993

Clause 4.1.6 Stability and other considerations

In line 1 delete the existing title and substitute 'Stability, robustness and other considerations'.

In line 2, after 'stability' insert 'and robustness'.

AMD 7583
March 1993

Clause 5.2.3.6 Detailing for simple bearing

In line 5 delete '3.12.8' and substitute '3.12.8 and 3.12.9'.

AMD 7583
March 1993

Clause 5.2.7.2.2 Reinforcement anchorage

In item (a) line 3 delete 'face of the support' and substitute 'transverse bar'.

AMD 7583
March 1993

Clause 5.3.7 Joints transmitting shear (as amended by Amendment No. 1)

In item (e) line 1 delete '*Resistance*' and substitute '*Resistance*'.

AMD 7583
March 1993

Clause 6.1.3.2 Aggregate specifications

In line 6 delete 'BS 8710 : Part 2 : 1985' and substitute 'BS 8110 : Part 2 : 1985'.

AMD 7583
March 1993

Clause 6.11.2 In situ concrete

Delete the second sentence and substitute the following new sentence.

'Guidance for designers on the accuracy that can be achieved
is provided in table 1 of BS 5606 : 1990.'

Delete the footnote:

'* Under revision.'

AMD 7583
March 1993

Clause 6.11.3 Precast concrete members

In paragraph 3, line 4, delete 'DD 22' and substitute 'BS 6954'.

Delete the note given after paragraph 3.

In paragraph 7, line 2, delete '(see 6.8.3 of BS 5606 : 1978)' and substitute '(see BS 5606)'.

AMD 7583
March 1993

Clause 6.14 Handling and erection of precast concrete units

In item (g), line 2, delete 'given in tables 2 and 3 of BS 5606 : 1978;' and substitute 'given in
table 1 of BS 5606 : 1990;'.

AMD 7583
March 1993

Clause 7.1 General

In line 1 delete 'BS 4461,'.

AMD 7583
March 1993

Clause 8.9.11 Checking the effectiveness of grouting

In line 3 delete 'BS 4408 : Part 3.' and substitute 'BS 1881 : Part 205.'

Delete the existing list of publications referred to and substitute the following new list.

Publications referred to

BS 12	Specification for Portland cement
BS 146	Specification for Portland blastfurnace cement
BS 410	Specification for test sieves
BS 499	Welding terms and symbols
BS 877	Foamed or expanded blastfurnace slag lightweight aggregate for concrete
BS 882	Specification for aggregates from natural sources for concrete
BS 1014	Specification for pigments for Portland cement and Portland cement products
BS 1047	Specification for air-cooled blastfurnace slag aggregate for use in construction
BS 1370	Specification for low heat Portland cement
BS 1881	Testing concrete
	Part 108 Method for making test cubes from fresh concrete
	Part 111 Method of normal curing of test specimens (20 °C method)
	Part 116 Method for determination of compressive strength of concrete cubes
	Part 205 Recommendations for radiography of concrete
BS 3148	Methods of test for water for making concrete (including notes on the suitability of the water)
BS 3797	Specification for lightweight aggregates for masonry units and structural concrete
BS 3892	Pulverized-fuel ash
	Part 1 Specification for pulverized-fuel ash for use as a cementitious component in structural concrete
BS 3921	Specification for clay bricks
BS 4027	Specification for sulfate-resisting Portland cement
BS 4246	Specification for high slag blastfurnace cement
BS 4248	Specification for supersulphated cement
BS 4447	Specification for the performance of prestressing anchorages for post-tensioned construction
BS 4449	Specification for carbon steel bars for the reinforcement of concrete
BS 4466	Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete
BS 4482	Specification for cold reduced steel wire for the reinforcement of concrete
BS 4483	Specification for steel fabric for the reinforcement of concrete
BS 4486	Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete
BS 4757	Nineteen-wire steel strand for prestressed concrete
BS 5075	Concrete admixtures
	Part 1 Specification for accelerating admixtures, retarding admixtures and water-reducing admixtures
	Part 2 Specification for air-entraining admixtures
	Part 3 Specification for superplasticizing admixtures
BS 5135	Specification for arc welding of carbon and carbon manganese steels
BS 5328	Concrete
BS 5531	Code of practice for safety in erecting structural frames
BS 5606	Guide to accuracy in building
BS 5628	Code of practice for use of masonry
BS 5896	Specification for high tensile steel wire and strand for the prestressing of concrete
BS 5975	Code of practice for falsework
BS 6399	Loading for buildings
	Part 1 Code of practice for dead and imposed loads
BS 6588	Specification for Portland pulverized-fuel ash cements
BS 6651	Code of practice for protection of structures against lightning
BS 6699	Specification for ground granulated blastfurnace slag for use with Portland cement
BS 6954	Tolerances for building
BS 8004	Code of practice for foundations
BS 8110	Structural use of concrete
	Part 2 Code of practice for special circumstances
	Part 3 Design charts for singly reinforced beams, doubly reinforced beams and rectangular columns
CP 3	Code of basic data for the design of buildings
	Chapter V Loading
	Part 2 Wind loads
ISO 3443	Tolerances for building
	Part 3 The calculation of joint clearance and the prediction of fit

NOTE 1. The titles of publications BS 12, BS 4027, BS 4246, BS 6588 and BS 5328, which were revised in 1990 and 1991, have been updated in this list. The references in the text however refer to the previous editions of these standards.

NOTE 2. Recent changes to BS 877, BS 4757 and BS 5135 have not been taken into account in this amendment but will be covered by a future amendment.

Amendment No. 4
published and effective from 15 September 1993
to BS 8110 : Part 1 : 1985

Structural use of concrete
Part 1. Code of practice for design and construction

Corrections

AMD 7973
September 1993

Clause 3.4.5.12 Shear and axial load (as amended by Amendment No. 3)

In line 12, delete 'The value of Vh/M should be taken as greater than 1.' and substitute 'The value of Vh/M should be taken as not greater than 1.'

AMD 7973
September 1993

Clause 3.7.7.5 Provision of shear reinforcement (as amended by Amendment No. 3)

Delete the last sentence beginning 'In equations 29 (a),' entirely and substitute the following:

'When using equations 29 (a) and 29 (b), $\Sigma A_{sv} \sin \alpha$ should not be taken as less than $0.4ud/0.87f_{yv}$.'

9309--1k-B

B/525/2

British Standard

Structural use of concrete

Part 1. Code of practice for design and construction

Utilisation du béton en construction

Partie 1. Code de bonne pratique pour le calcul et la construction

Beton im Hochbau

Teil 1. Leitfaden für Berechnung, und Konstruktion

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Foreword

This Part of BS 8110 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee. Together with BS 8110 : Part 2 it supersedes CP 110 : Part 1 : 1972, which is withdrawn.

This code covers the fields of CP 110 and encompasses the structural use of reinforced and prestressed concrete both cast in situ and precast. Although there are no major changes in principle from the previous edition the text has largely been rewritten with alterations in the order and arrangement of topics. The redrafting and alterations have been made in the light of experience of the practical convenience in using CP 110. They have also been made to meet the criticism of engineers preferring the form of CP 114. In this respect sections two to five have been rewritten with shorter clauses, avoiding as much as possible lengthy paragraphs dealing with matters that could be broken down into separate subclauses, to make specific references easier to identify.

Consideration had been given to including the load factor method which had been introduced into CP 114 in 1957.

The basic approach to design for safety in all codes is the following. A level of loading is assessed that leads to the worst conditions in the structure which can reasonably be expected to occur in practice. This is commonly referred to as the 'working' or 'service' load. Similarly, the stresses induced in the structure by this load are referred to as 'working' or 'service' stresses. A substantial margin of strength is required between this working condition and the strength of structure which the designer aims to provide. This margin is necessary to take account of uncertainties in the loading, the strengths of the materials, the construction process and in the current state of knowledge of structural behaviour. It is in the way in which this margin is provided that the elastic, ultimate load and limit state methods of design differ. The elastic (or permissible stress) approach aims at ensuring that the working stresses do not exceed a set of defined permissible stresses which are obtained by reducing the material strengths by a safety factor. The ultimate load or load factor method uses ultimate loads obtained by increasing the working loads by a safety factor and it aims to ensure that the strength of the structure, calculated using the expected actual material strengths, is sufficient to support this ultimate loading.

It might appear that these two approaches are, in effect, identical but, in fact, this is only strictly so for materials that are fully elastic up to failure. Nevertheless, by appropriate choice of coefficients in the various design equations, the two methods can be made to give very similar results for most common types of structure. In drafting CP 114 : 1957 it was felt that if the two methods were to be expressly permitted in one document then the strict interpretation of load factor theory would have to be modified in order to avoid the confusion of having different design loads and stresses in the two processes. The load factor method was consequently presented in terms of working loads and the stresses specified for the elastic method with the difference that the plastic stress strain relations were to be assumed in place of Hooke's law. This has led ever since to a confusion in the minds of designers as to what their calculations were actually predicting.

The limit state method of design, introduced in CP 110 in 1972, develops the logic of load factor design rather further. Instead of allowance for all the uncertainties being lumped together into a single, global, safety factor, a set of partial safety factors are defined, one for each material and type of load. The relative values of these reflect an assessment of the relative uncertainty associated with the various loads and materials strengths. As well as treating uncertainty more logically, the partial safety factor approach avoids a serious weakness inherent in design methods using a global safety factor when used for structures subjected simultaneously to different types of loading (for example, vertical load and wind load) where a critical design condition arises when one loading is at its maximum value and the other at its minimum value. The global factor approach automatically increases both the maximum and the minimum load giving a less critical condition than if only the maximum load is increased.

Although the standard is in three Parts, the contents of the Parts are different from those in CP 110. This Part excludes sections 9 to 11 of CP 110 : Part 1, together with the appendices and the treatment of torsion. BS 8110 : Part 2 comprises these exclusions and an enhanced section on fire resistance covering a range of sections not covered by the simple recommendations now included in table 3.5 and figure 3.2 of this Part. BS 8110 : Part 3 contains design curves similar to those in CP 110 : Parts 2 and 3, the number of which it has been found possible to reduce now that there are only two grades of reinforcement.

The requirements for cover for durability and fire resistance have been brought forward to the beginning of section three of this Part. Attempts to deal with cover for both durability and fire resistance in a single table were not successful and two consecutive tables followed by a figure for the minimum section dimensions for fire resistance have been introduced (see tables 3.4, 3.5 and figure 3.2).

Changes in the stress-strain curves for steel in compression, in conformity with the Euro-International Concrete Committee (CEB) Model Code 1978, have been made with the result that the ultimate design stresses in tension and compression are now equal. A change in the equivalent rectangular stress block for concrete in compression brings this convenient simplification more into line with the short-term design stress-strain curve over the whole range of neutral axis depths.

The term 'nominal cover' has been introduced to describe the design cover shown on the drawings to all reinforcement including links. The cover for fire resistance is almost invariably the cover to the main reinforcement and in drawing up table 3.5 in terms of nominal cover an allowance of 10 mm for links has been made which is considered acceptable for links not exceeding 12 mm diameter.

Several changes to the old edition have been made to make the use of the standard as convenient and practical as possible. A flow chart (see figure 3.1) has been introduced for guidance in the design procedure envisaged for ensuring robustness, the stability requirements consequent on the Ronan Point enquiry. For frames not providing lateral stability, the loading cases (combinations) to be considered have been reduced from three to two by the substitution of

all spans loaded with the maximum ultimate design load for the previous adjacent spans arrangement. The treatment of span/depth ratios has been simplified by rearrangement. Throughout the standard algebraic equations have been included giving the derivation of the tables. Similarly, implied gamma factors have been stated numerically in these equations. For everyday slabs, the design has been simplified by requiring only a single loading case, which is the ultimate maximum throughout. Everyday flat slabs have been treated similarly and also made easier to design by changes in the matters of column and middle strips.

The clauses on long columns for which stability considerations are inescapable have been recast completely. For braced columns the slenderness ratio above which further consideration is required has been lifted from twelve to fifteen. For unbraced columns, although the critical slenderness ratio has been reduced from twelve to ten, there are more than compensating advantages in the new edition. The length of section six has been reduced by the exclusion of material now found in BS 5328. Greater emphasis has been placed on the problem of durability and information on design for durability (see 6.2.2) has been included.

Fifteen years ago, at the time of the final drafting of CP 110, there seemed three good reasons for launching that code as a parallel document to CP 114, although this was a break with precedent. The first was the recent introduction of the SI metrication. Secondly, running the two codes in parallel gave the more cautious a chance to familiarize themselves with the feel of SI units as a first step in the translation to new numbers enhanced by unfamiliar gamma factors. Lastly there were some reservations about the workability of the new code. In retrospect the worst fears did not materialize.

Notwithstanding the acceptability of CP 110 to engineers fully accustomed to applying its provisions, that code has proved somewhat daunting to engineers who have not used it regularly. Having in mind the withdrawal of CP 114 at a future date the drafting Committee has undertaken the current standard to present the material in CP 110 brought up to date wherever appropriate in as clear, concise and easy to use form as possible.

It has been assumed in the drafting of this standard that the design of reinforced, prestressed and precast concrete is entrusted to chartered structural or civil engineers and that the execution of the work is carried out under the direction of appropriately qualified supervisors.

Following the practice in previous codes for the structural use of concrete a handbook† has been prepared which gives further guidance and background information on many of the provisions of this code. A further document may also be of assistance in carrying out designs to this code. This is 'The Standard Method of Detailing Reinforced Concrete'‡ produced jointly by the Concrete Society and the Institution of Structural Engineers.

No attempt has been made to adopt a legal style of wording. The full list of the organizations who have taken part in the work of the Technical Committee is given on the back cover. The Chairman of the Committee was Dr D D Matthews F Eng, FICE, FI Struct E and the following people were members of the Technical Committee.

R Anderson C Eng, MICE
 P R Bartle C Eng, FI Struct E
 Dr S C C Bate CBE, C Eng, FICE, FI Struct E
 Dr A W Beeby C Eng, MICE, MI Struct E
 B V Brown C Phys, M Inst P, MICT
 E W Bunn C Eng, FI Struct E
 P G Cobb C Eng, MICE
 F G Coffin C Eng, FI Struct E
 A T Corish C Eng, MICE
 J A Derrington F Eng, FICE, FI Struct E
 J E C Farebrother C Eng, FICE, FI Struct E
 Dr F W Gifford C Eng, FICE, FI Struct E
 J E Gravenor MICW
 H B Gould C Eng, FICE, FI Struct E
 P K Jaitley C Eng, FI Struct E
 T W Kirkbride C Eng, MICE
 R I Lancaster C Eng, FICE, FI Struct E
 M E R Little C Eng, FICE, FI Struct E
 M W Loaring C Eng, MICE
 Dr J F A Moore C Eng, MI Struct E
 Prof A M Neville C Eng, FICE
 K Newman C Eng, MICE
 B J Osborne C Eng, MI Struct E
 D J Pearce C Eng, MICE, FI Struct E
 J B Price C Eng, FI Struct E
 K Robson C Eng, MI Struct E
 J Rodin C Eng, FICE, FI Struct E
 D N Rogers C Eng, FI Mun E
 P D Rowden C Eng, FICE, FI Struct E
 Dr R E Rowe CBE, F Eng, FICE, FI Struct E
 Dr A Short C Eng, FICE, FI Struct E
 R M Silber C Eng, FI Struct E
 Dr G Somerville C Eng, FICE, FI Struct E
 Dr H P J Taylor C Eng, FICE, FI Struct E
 R G Thwaites C Eng, FICE, FI Struct E
 Dr F Walley CB, C Eng, FICE, FI Struct E
 F P D Ward C Eng, MICE, FI Struct E
 J D Whiteley C Eng, MIM
 R T Whittle C Eng, MICE

ISE R W J Milne B Sc

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

† 'Handbook to British Standard BS 8110 : 1985 Structural Use of Concrete', available from A.B.P. (UK) Ltd, 11 New Fetter Lane, London EC4P 4EE.

‡ 'Standard Method of Detailing Reinforced Concrete', available from the British Cement Association and from the Concrete Society, Devon House, 12-15 Dartmouth Street, London SW1H 9BL.

Section one. General

1.1 Scope

This Part of BS 8110 gives recommendations for the structural use of concrete in buildings and structures, excluding bridges and structural concrete made with high alumina cement.

The recommendations for robustness have been prepared on the assumption that all load-bearing elements, e.g. slabs, columns and walls are of concrete. In a structure where concrete elements such as floor slabs are used in conjunction with load-bearing elements of other materials, similar principles are appropriate but, when adequate robustness is provided by other means, the ties recommended by this code may not be required.

NOTE 1. Where appropriate British Standards are available for precast concrete products, e.g. kerbs and pipes, it is not intended that this code should replace their more specific requirements.

NOTE 2. The titles of the publications referred to are listed on the inside back cover.

1.2 Definitions

For the purposes of this Part of BS 8110, the following definitions apply.

1.2.1 General

1.2.1.1 design ultimate load*. The design load for the ultimate limit state.

1.2.1.2 design service load*. The design load for the serviceability limit state.

1.2.2 Terms specific to flat slabs (see 3.7)

1.2.2.1 flat slab. A slab with or without drops and supported, generally without beams, by columns with or without column heads. It may be solid or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions (waffle or coffered slab).

1.2.2.2 column head. Local enlargement of the top of a column providing support to the slab over a larger area than the column section alone.

1.2.2.3 drop. Thickening of a slab in the region of a column.

1.2.3 Terms specific to perimeters (see 3.7.7)

1.2.3.1 perimeter. A boundary of the smallest rectangle that can be drawn round a loaded area which nowhere comes closer to the edges of the loaded area than some specified distance l_p (a multiple of $0.75d$).

NOTE. See 3.7.7.8 for loading close to a free edge, and figure 3.16 for typical cases.

1.2.3.2 failure zone. An area of slab bounded by two perimeters $1.5d$ apart.

NOTE. See 3.7.7.8 for loading close to a free edge.

1.2.3.3 effective length of a perimeter. The length of the perimeter reduced, where appropriate, for the effects of holes or external edges.

1.2.3.4 effective depth (d). The average effective depth for all effective reinforcement passing through a perimeter.

1.2.3.5 effective steel area. The total area of all tension reinforcement that passes through a zone and that extends at least one effective depth (see 1.2.3.4) or 12 times the bar size beyond the zone on either side.

NOTE. The reinforcement percentage used to calculate the design ultimate shear stress v_c is given by:

$$\frac{100 \times \text{effective reinforcement area}}{ud}$$

where

u is the outer perimeter of the zone considered;

d is as defined in 1.2.3.4.

1.2.4 Terms specific to walls (see 3.9)

1.2.4.1 wall. A vertical load-bearing member whose length exceeds four times its thickness.

1.2.4.2 unbraced wall. A wall providing its own lateral stability.

1.2.4.3 braced wall. A wall where the reactions to lateral forces are provided by lateral supports.

1.2.4.4 lateral support. An element (which may be a prop, a buttress, a floor, crosswall or other horizontal or vertical element) able to transmit lateral forces from a braced wall to the principal structural bracing or to the foundations.

1.2.4.5 principal structural bracing. Strong points, shear walls or other suitable bracing providing lateral stability to the structure as a whole.

1.2.4.6 reinforced wall. A concrete wall containing at least the minimum quantities of reinforcement given in 3.12.5.

1.2.4.7 plain wall. A wall containing either no reinforcement or insufficient to comply with 3.12.5.

NOTE. Any reinforcement is ignored when considering the strength of the wall.

1.2.4.8 stocky wall. A wall where the effective height divided by the thickness (l_e/h) does not exceed 15 (braced) or 10 (unbraced).

1.2.4.9 slender wall. A wall other than a stocky wall.

1.2.5 Terms relating to bearings for precast members (see 5.2.3)

1.2.5.1 simple bearing. A supported member bearing directly on a support, the effect of projecting steel or added concrete being discounted.

1.2.5.2 dry bearing. A bearing with no intermediate padding material.

1.2.5.3 bedded bearing. A bearing with contact surfaces having an intermediate padding of cementitious material.

*Design loads are obtained by multiplying the characteristic loads by the appropriate partial safety factors for loading (see 3.1).

1.2.5.4 non-isolated member. A supported member which, in the event of loss of an assumed support, would be capable of carrying its load by transverse distribution to adjacent members.

1.2.5.5 bearing length. The length of support, supported member or intermediate padding material (whichever is the least) measured along the line of support.

1.2.5.6 bearing width. The overlap of support and supported member measured at right-angles to the line of support.

1.2.5.7 net bearing width (of a simple bearing). The bearing width after allowance for ineffective bearing and for constructional inaccuracies (see figure 5.4).

1.3 Symbols

For the purposes of this Part of BS 8110, the following symbols apply.

γ_f	partial safety factor for load
γ_m	partial safety factor for strength of materials
E_n	nominal earth load
G_k	characteristic dead load
Q_k	characteristic imposed load
W_k	characteristic wind load
f_{cu}	characteristic strength of concrete
f_y	characteristic strength of reinforcement
f_{pu}	characteristic strength of a prestressing tendon

Other symbols are defined in the text where they occur.

Section two. Design objectives and general recommendations

2.1 Basis of design

2.1.1 Aim of design

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and have adequate resistance to the effects of misuse and fire.

2.1.2 Design method

The method recommended in this code is that of limit state design. Account should be taken of accepted theory, experiment and experience and the need to design for durability. Calculations alone do not produce safe, serviceable and durable structures. Suitable materials, quality control and good supervision are equally important.

2.1.3 Durability, workmanship and materials

It is assumed that the quality of the concrete, steel and other materials and of the workmanship, as verified by inspections, is adequate for safety, serviceability and durability (see sections six, seven and eight).

2.1.4 Design process

Design, including design for durability, construction and use in service should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, production, workmanship and also maintenance and use of the structure in service.

2.2 Structural design

NOTE. See 1.2.1 for definitions of design ultimate load and design service load.

2.2.1 General

Well-detailed and properly-erected structures designed by the limit state method will have acceptable probabilities that they will not reach a limit state, i.e. will not become unfit for their purpose by collapse, overturning, buckling (ultimate limit states), deformation, cracking, vibration, etc. (serviceability limit states) and that the structure will not deteriorate unduly under the action of the environment over the design life, i.e. will be durable. The usual approach is to design on the most critical limit state and then to check that the remaining limit states will not be reached.

2.2.2 Ultimate limit state (ULS)

2.2.2.1 Structural stability. The structure should be so designed that adequate means exist to transmit the design ultimate dead, wind and imposed loads safely from the highest supported level to the foundations. The layout of the structure and the interaction between the structural members should be such as to ensure a robust and stable design. The engineer responsible for the overall stability of

the structure should ensure the compatibility of the design and details of parts and components, even where some or all of the design and details of those parts and components are not made by this engineer.

The design strengths of materials and the design loads should be those given in 2.4, as appropriate for the ULS. The design should satisfy the requirement that no ULS is reached by rupture of any section, by overturning or by buckling under the worst combination of ultimate loads. Account should be taken of elastic or plastic instability, or sway when appropriate.

2.2.2.2 Robustness. Structures should be planned and designed so that they are not unreasonably susceptible to the effects of accidents. In particular, situations should be avoided where damage to small areas of a structure or failure of single elements may lead to collapse of major parts of the structure.

Unreasonable susceptibility to the effects of accidents may generally be prevented if the following precautions are taken.

(a) All buildings are capable of safely resisting the notional horizontal design ultimate load as given in 3.1.4.2 applied at each floor or roof level simultaneously.

(b) All buildings are provided with effective horizontal ties (see 3.12.3):

(1) around the periphery;

(2) internally;

(3) to columns and walls.

(c) The layout of buildings of five or more storeys is checked to identify any key elements the failure of which would cause the collapse of more than a limited portion close to the element in question. Where such elements are identified and the layout cannot be revised to avoid them, the design should take their importance into account. Recommendations for the design of key elements are given in 2.6 of BS 8110 : Part 2 : 1985.

(d) Buildings of five or more storeys are detailed so that any vertical load-bearing element other than a key element can be removed without causing the collapse of more than a limited portion close to the element in question. This is generally achieved by the provision of vertical ties in accordance with 3.12.3 in addition to satisfying (a), (b) and (c) above. There may, however, be cases where it is inappropriate or impossible to provide effective vertical ties in all or some of the vertical load-bearing elements. Where this occurs, each such element should be considered to be removed in turn and elements normally supported by the element in question designed to 'bridge' the gap in accordance with the provisions of 2.6 of BS 8110 : Part 2 : 1985.

2.2.2.3 Special hazards. The design for a particular occupancy, location or use, e.g. flour mills or chemical plant, may need to allow for the effects of particular hazards or for any unusually high probability of the structure's surviving an accident even though damaged. In such cases, partial safety factors greater than those given in 2.4 may be required.

2.2.3 Serviceability limit states (SLS)

2.2.3.1 General. The design properties of materials and the design loads should be those given in section three of BS 8110 : Part 2 : 1985 as appropriate for SLS. Account should be taken of such effects as temperature, creep, shrinkage, sway, settlement and cyclic loading, as appropriate.

2.2.3.2 Deflection due to vertical loading. The deformation of the structure or any part of it should not adversely affect its efficiency or appearance. Deflections should be compatible with the degree of movement acceptable by other elements including finishes, services, partitions, glazing and cladding; in some cases a degree of minor repair work or fixing adjustment to such elements may be acceptable. Where specific attention is required to limit deflections to particular values, reference should be made to 3.2 of BS 8110 : Part 2 : 1985; otherwise it will generally be satisfactory to use the span/effective depth ratios given in section three for reinforced concrete.

2.2.3.3 Response to wind loads. The effects of lateral deflection should be considered, particularly for a tall, slender structure. However the accelerations associated with the deflection may be more critical than the deflection itself (see 3.2.2 of BS 8110 : Part 2 : 1985).

2.2.3.4 Cracking

2.2.3.4.1 Reinforced concrete. Cracking should be kept within reasonable bounds by attention to detail. It will normally be controlled by compliance with the detailing rules given in 3.12.11. Where specific attention is required to limit the design crack width to particular values, reference should be made to 3.2.4 of BS 8110 : Part 2 : 1985.

2.2.3.4.2 Prestressed concrete. In the assessment of the likely behaviour of a prestressed concrete structure or element the amount of flexural tensile stress determines its class, as follows:

- class 1: no flexural tensile stresses;
- class 2: flexural tensile stresses but no visible cracking;
- class 3: flexural tensile stresses but surface width of cracks not exceeding 0.1 mm for members in very aggressive environments (e.g. exposure to sea or moorland water) and not exceeding 0.2 mm for all other members.

2.2.3.5 Vibration. Discomfort or alarm to occupants, structural damage, and interference with proper function should be avoided. Isolation of the source of vibration or of part or all of the structure may be needed. Flexible structural elements may require special consideration.

NOTE. Acceptable vibration limits are described in specialist literature.

2.2.4 Durability

To produce a durable structure requires the integration of all aspects of design, materials and construction.

The environmental conditions to which the concrete will be exposed should be defined at the design stage. The design should take account of the shape and bulk of the structure,

and the need to ensure that surfaces exposed to water are freely draining (see 6.2). Adequate cover to steel has to be provided for protection (see 3.3 and 4.1.5). Consideration may also be given to the use of protective coatings to either the steel or the concrete, or both, to enhance the durability of vulnerable parts of construction.

Concrete should be of the relevant quality; this depends on both its constituent materials and mix proportions. There is a need to avoid some constituent materials which may cause durability problems and, in other instances, to specify particular types of concrete to meet special durability requirements (see 6.2).

Good workmanship, particularly curing, is essential and dimensional tolerances and the levels of control and inspection of construction should be specified. Use should be made of suitable quality assurance schemes where they exist (see 2.3, 6.1, 7.1 and 8.1).

NOTE. For exceptionally severe environments additional precautions may be necessary and specialist literature should be consulted.

2.2.5 Fatigue

When the imposed load on a structure is predominantly cyclical it may be necessary to consider the effects of fatigue.

2.2.6 Fire resistance

A structure or structural element required to have fire resistance should be designed to possess an appropriate degree of resistance to flame penetration, heat transmission and collapse. Recommendations are given in section four of BS 8110 : Part 2 : 1985.

2.2.7 Lightning

Reinforcement may be used as part of a lightning protection system in accordance with CP 326.

2.3 Inspection of construction

To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records, workmanship and construction.

Tests should be made on reinforcement and the constituent materials of concrete in accordance with the relevant standards; the production and testing of concrete should comply with BS 5328. Where applicable, use should be made of suitable quality assurance schemes.

Care should be taken to see that:

- (a) design and detail are capable of being executed to a suitable standard, with due allowance for dimensional tolerances;
- (b) there are clear instructions on inspection standards;
- (c) there are clear instructions on permissible deviations;
- (d) elements critical to workmanship, structural performance, durability and appearance are identified, and
- (e) there is a system to verify that the quality is satisfactory in individual parts of the structure, especially the critical ones.

2.4 Loads and material properties

2.4.1 Loads

2.4.1.1 Characteristic values of loads. The following loads should be used in design:

- (a) characteristic dead load, G_k , i.e. the weight of the structure complete with finishes, fixtures and partitions;
- (b) characteristic imposed load, Q_k ; and
- (c) characteristic wind load, W_k .

The characteristic load in each case should be the appropriate load as defined in and calculated in accordance with BS 6399 : Part 1 and CP 3 : Chapter V : Part 2.

2.4.1.2 Nominal earth loads, E_n . Nominal earth loads should be obtained in accordance with normal practice (see, for example, CP 2004).

2.4.1.3 Partial safety factors for load, γ_f . The design load for a given type of loading and limit state is obtained from:

$$G_k \gamma_f \text{ or } Q_k \gamma_f \text{ or } W_k \gamma_f \text{ or } E_n \gamma_f$$

where γ_f is the appropriate partial safety factor. It is introduced to take account of unconsidered possible increases in load, inaccurate assessment of load effects, unforeseen stress redistribution and variations in dimensional accuracy and the importance of the limit state being considered. The values of γ_f chosen also ensure that the serviceability requirements can generally be met by simple rules.

2.4.1.4 Loads during construction. The loading conditions during erection and construction should be considered in design and should be such that the structure's subsequent compliance with the limit state requirements is not impaired.

2.4.2 Material properties

2.4.2.1 Characteristic strengths of materials. Unless otherwise stated in this code the term characteristic strength means that value of the cube strength of concrete, f_{cu} , the yield or proof strength of reinforcement, f_y , or the ultimate strength of a prestressing tendon, f_{pu} , below which 5 % of all possible test results would be expected to fall.

2.4.2.2 Partial safety factors for strength of materials, γ_m . For the analysis of sections, the design strength for a given material and limit state is derived from the characteristic strength divided by γ_m , where γ_m is the appropriate partial safety factor given in 2.4.4.1 and 2.4.6.2. γ_m takes account of differences between actual and laboratory values, local weaknesses, and inaccuracies in assessment of the resistance of sections. It also takes account of the importance of the limit state being considered.

2.4.2.3 Stress-strain relationships. The short-term stress-strain relationships may be taken as follows:

- (a) for normal-weight concrete, from figure 2.1 with γ_m having the relevant value given in 2.4.4 or 2.4.6;
- (b) for reinforcement, from figure 2.2 with γ_m having the relevant value;

- (c) for prestressing tendons, from figure 2.3 with γ_m having the relevant value.

When sustained loading is being considered, for reinforcement the short-term stress-strain curves should be taken to apply; for prestressing tendons, appropriate allowance for relaxation should be made. For concrete, information on creep and shrinkage is given in section seven of BS 8110 : Part 2 : 1985.

2.4.2.4 Poisson's ratio for concrete. Where linear elastic analysis is appropriate, Poisson's ratio may be taken as 0.2.

2.4.3 Values of loads for ultimate limit state (ULS)

2.4.3.1 Design loads

2.4.3.1.1 General. In ULS design of the whole or any part of a structure each of the combinations of loading given in table 2.1 should be considered and the design of cross sections based on the most severe stresses produced.

For load combinations 1 and 2 in table 2.1, the 'adverse' partial factor is applied to any loads that tend to produce a more critical design condition while the 'beneficial' factor is applied to any loads that tend to produce a less critical design condition at the section considered. For load combinations 2 and 3, see 3.1.4.2 for minimum horizontal force.

2.4.3.1.2 Partial factors for earth pressures. The overall dimensions and stability of earth retaining and foundation structures, e.g. the area of pad footings, should be determined by appropriate geotechnical procedures which are not considered in this code. However, in order to establish section sizes and reinforcement areas which will give adequate safety and serviceability without undue calculation, it is appropriate in normal design situations to apply values of γ_f comparable to those applied to other forms of loading.

The factor γ_f should be applied to all earth and water pressures unless they derive directly from loads that have already been factored, in which case the pressures should be derived from equilibrium with other design ultimate loads. When applying the factor, no distinction is made between adverse and beneficial loads.

Where a detailed investigation of the soil conditions has been undertaken and account has been taken of possible structure-soil interaction in the assessment of the earth pressure, it may be appropriate to derive design ultimate values for earth and water pressure by different procedures. In this case, additional consideration should be given to conditions in the structure under serviceability loads. This approach is also recommended for all design situations which involve uncommon features. Further guidance is given in section two of BS 8110 : Part 2 : 1985.

2.4.3.2 Effects of exceptional loads or localized damage. If in the design it is necessary to consider the probable effects of excessive loads caused by misuse or accident, γ_f should be taken as 1.05 on the defined loads, and only

Table 2.1 Load combinations and values of γ_f for the ultimate limit state						
Load combination	Load type					
	Dead		Imposed		Earth and water pressure	Wind
	Adverse	Beneficial	Adverse	Beneficial		
1. Dead and imposed (and earth and water pressure)	1.4	1.0	1.6	0	1.4	—
2. Dead and wind (and earth and water pressure)	1.4	1.0	—	—	1.4	1.4
3. Dead and wind and imposed (and earth and water pressure)	1.2	1.2	1.2	1.2	1.2	1.2

those loads likely to be acting simultaneously need be considered. Again, when considering the continued stability of a structure after it has sustained localized damage, γ_f should be taken as 1.05. The loads considered should be those likely to occur before temporary or permanent measures are taken to repair or offset the effect of the damage.

For these exceptional cases all the following should be taken into account:

- (a) dead load;
- (b) one-third of the wind load;
- (c) for buildings used predominantly for storage or industrial purposes or where the imposed loads are permanent, 100 % of the imposed load or, for other buildings, one-third of the imposed load.

2.4.3.3 Creep, shrinkage and temperature effects. For the ULS, these effects will usually be minor and no specific calculations will be necessary.

2.4.4 Strengths of materials for the ultimate limit state

2.4.4.1 Design strengths. In the assessment of the strength of a structure or any of its parts or cross sections, appropriate γ_m values should be taken from table 2.2.

Table 2.2 Values of γ_m for the ultimate limit state	
Reinforcement	1.15
Concrete in flexure or axial load	1.50
Shear strength without shear reinforcement	1.25
Bond strength	1.4
Others (e.g. bearing stress)	≥ 1.5

A more detailed method for the assessment of γ_m is given in section two of BS 8110 : Part 2 : 1985. In sections three, four and five of this Part these values have been used in the preparation of the various tables associated with the ULS.

2.4.4.2 Effects of exceptional loads or localized damage. In the consideration of these effects γ_m may be taken as 1.3 for concrete in flexure and 1.0 for steel.

2.4.5 Design loads for serviceability limit states

For SLS calculations the design loads should be those appropriate to the SLS under consideration as discussed in 3.3 of BS 8110 : Part 2 : 1985.

2.4.6 Material properties for serviceability limit states

2.4.6.1 General. For SLS calculations, the material properties assumed (modulus of elasticity, creep, shrinkage, etc.) should be taken as those appropriate to the SLS under consideration as discussed in 3.2 of BS 8110 : Part 2 : 1985.

2.4.6.2 Tensile stress criteria for prestressed concrete. In assessing the cracking strength for a class 2 member, γ_m should be taken as 1.3 for concrete in tension due to flexure. Allowable design stresses are given in 4.3.4.3.

2.4.7 Material properties for durability

Some durability problems are associated with the characteristics of the constituent materials whilst others require particular characteristics of the concrete to overcome them. Guidance on these is given in the following sections and subclauses:

(a) *durability and constituent materials:*

- (1) chlorides and corrosion of steel (see 6.2.5.2);
- (2) disruption due to excess sulphates (see 6.2.5.3);
- (3) disruption due to alkali-silica reaction (see 6.2.5.4);

- (4) aggregates with high drying shrinkage (see 6.1.3.7);
- (5) aggregates and fire resistance (see section four of BS 8110 : Part 2 : 1985);
- (b) *durability and concrete characteristics*:
 - (1) concrete quality and cover to reinforcement (see 3.3 and 4.12.3);
 - (2) air-entrained concrete for frost resistance (see 6.2.3.2);
 - (3) concrete subject to exposure to aggressive chemicals (see 6.2.3.3);
 - (4) concrete properties and durability (see 6.2);
 - (5) fire resistance (see section four of BS 8110 : Part 2 : 1985).

2.5 Analysis

2.5.1 General

The analysis that is carried out to justify a design can be broken into two stages as follows:

- (a) analysis of the structure;
- (b) analysis of sections.

In the analysis of the structure, or part of the structure, to determine force distributions within the structure, the properties of materials may be assumed to be those associated with their characteristic strengths, irrespective of which limit state is being considered. In the analysis of any cross section within the structure, the properties of the materials should be assumed to be those associated with their design strengths appropriate to the limit state being considered.

The methods of analysis used should be based on as accurate a representation of the behaviour of the structure as is reasonably practicable. The methods and assumptions given in this clause are generally adequate but, in certain cases, more fundamental approaches in assessing the behaviour of the structure under load may be more appropriate.

2.5.2 Analysis of structure

The primary objective of structural analysis is to obtain a set of internal forces and moments throughout the structure that are in equilibrium with the design loads for the required loading combinations.

Under design ultimate loads, any implied redistribution of forces and moments should be compatible with the ductility of the members concerned. Generally it will be satisfactory to determine envelopes of forces and moments by linear elastic analysis of all or parts of the structure and allow for redistribution and possible buckling effects using the methods described in sections three and four. Alternatively plastic methods, e.g. yield line analysis, may be used.

For design service loads, the analysis by linear elastic methods will normally give a satisfactory set of moments and forces.

When linear elastic analysis is used, the relative stiffnesses of members may be based on any of the following.

- (a) *The concrete section*: the entire concrete cross section, ignoring the reinforcement.
- (b) *The gross section*: the entire concrete cross section, including the reinforcement on the basis of modular ratio.
- (c) *The transformed section*: the compression area of the concrete cross section combined with the reinforcement on the basis of modular ratio.

In (b) and (c) a modular ratio of 15 may be assumed in the absence of better information.

A consistent approach should be used for all elements of the structure.

2.5.3 Analysis of sections for the ultimate limit state

The strength of a cross section at the ULS under both short and long term loading may be assessed assuming the short term stress/strain curves derived from the design strengths of the materials as given in 2.4.4.1 and figures 2.1 to 2.3 as appropriate. In the case of prestressing tendons the moduli of elasticity in figure 2.3 are those given for information in BS 4486 and BS 5896.

2.5.4 Analysis of sections for serviceability limit states

The behaviour of a section at a SLS may be assessed assuming plane sections remain plane and linear stress/strain relationships for both steel and concrete.

Allowance should be made where appropriate for the effects of creep, shrinkage, cracking and prestress losses.

The elastic modulus for steel should be taken as 200 kN/mm². Information on the selection of elastic moduli for concrete may be found in section seven of BS 8110 : Part 2 : 1985.

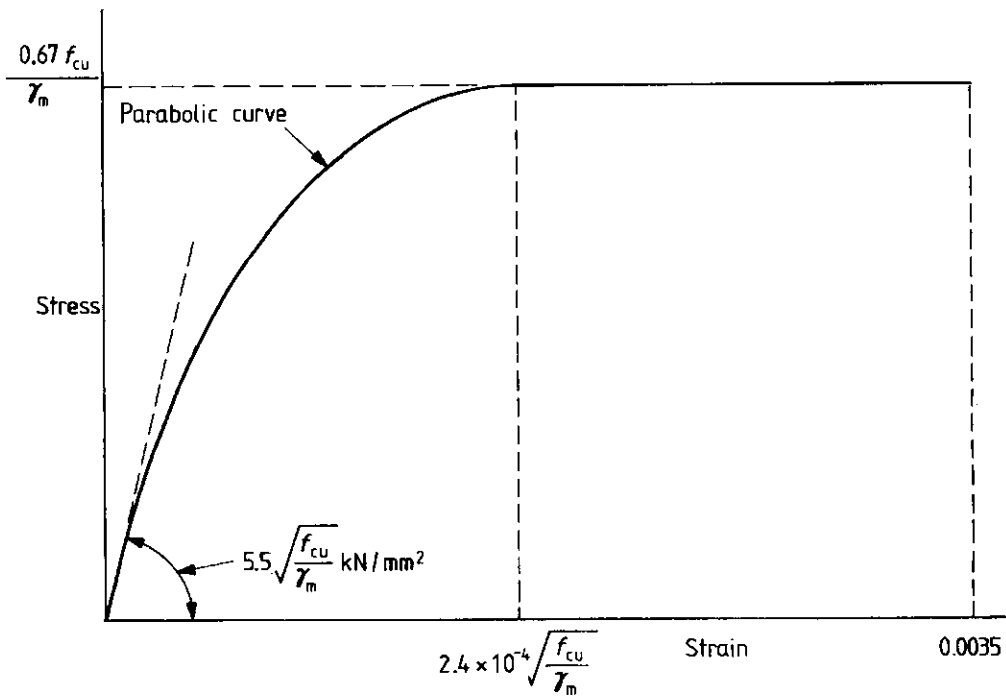
2.6 Designs based on tests

2.6.1 Model tests

A design may be deemed satisfactory on the basis of results from an appropriate model test coupled with the use of model analysis to predict the behaviour of the actual structure, provided the work is carried out by engineers with relevant experience using suitable equipment.

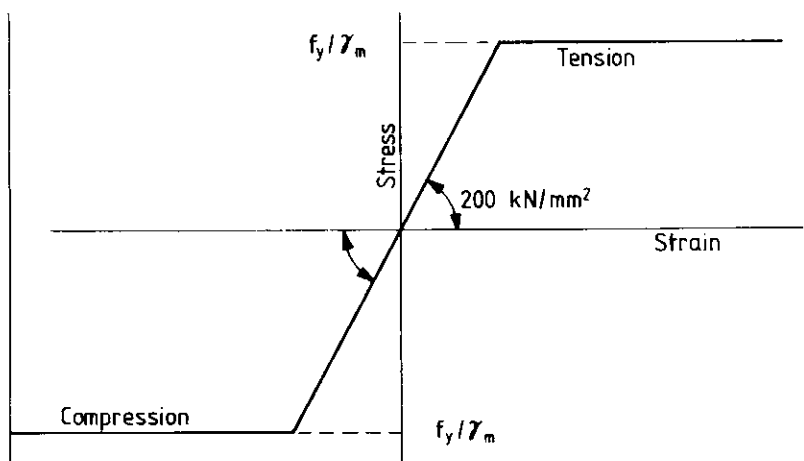
2.6.2 Prototype tests

A design may be deemed satisfactory if the analytical or empirical basis of the design has been justified by development testing of prototype units and structures relevant to the particular design under consideration.



NOTE 1. 0.67 takes account of the relation between the cube strength and the bending strength in a flexural member. It is simply a coefficient and *not* a partial safety factor.
NOTE 2. f_{cu} is in N/mm^2 .

Figure 2.1 Short term design stress-strain curve for normal-weight concrete



NOTE. f_y is in N/mm^2 .

Figure 2.2 Short term design stress-strain curve for reinforcement

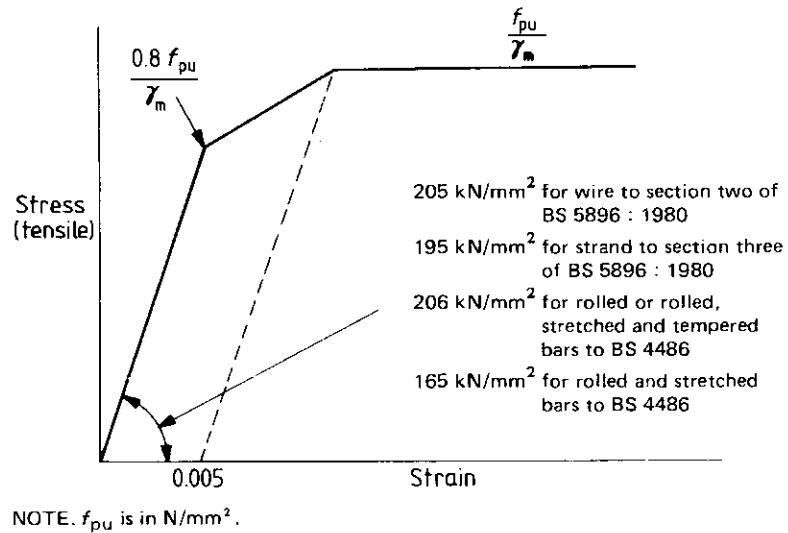


Figure 2.3 Short term design stress-strain curve for prestressing tendons