
British Standard Code of practice for
Use of masonry

**Part 2. Structural use of reinforced
and prestressed masonry**

Code de bonne pratique pour la maçonnerie
Partie 2. Usage structurel de la maçonnerie renforcée et précontrainte

Leitfaden für Mauerwerk im Hochbau
Teil 2. Bewehrtes und vorgespanntes Mauerwerk

Foreword

This Part of BS 5628 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee. Part 1, published in 1978, gives recommendations for the structural design of unreinforced masonry. Together with Part 1, this Part supersedes CP 111 : 1970, which is therefore withdrawn. BS 5628 : Part 3 is a revision of CP 121 : Part 1 and gives recommendations for detail design and workmanship of brick and block masonry.

The recommendations in this code are based on existing experience and practice in the UK and overseas and on the results of recent research. However, compared with reinforced masonry, there are relatively few examples of prestressed masonry at present in this country.

Appendix A of this code gives interim recommendations for the design of masonry incorporating bed joint reinforcement for enhancement of lateral load resistance, pending further research.

It has been assumed in the drafting of this code that the design of reinforced and prestressed masonry is entrusted to appropriately qualified and experienced persons, and the execution of the work is carried out under the direction of appropriately qualified supervisors.

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

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Section one. General

1 Scope

This Part of BS 5628 gives recommendations for the structural design of reinforced and prestressed masonry constructed of brick or block masonry or masonry of square dressed natural stone.

NOTE 1. The partial safety factors given in this code are based on the assumption that the special category of construction control (see 40.1) will be specified by the designer. If this is considered to be impracticable, higher partial safety factors should be used.

NOTE 2. The dimensions of a member determined from strength considerations may not always be sufficient to satisfy requirements for other properties of the member such as resistance to fire and thermal insulation, and reference should be made to other appropriate standards.

NOTE 3. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 5628 the definitions given in BS 5628 : Part 1 apply together with the following.

2.1 masonry. An assemblage of structural units, either laid in situ or constructed in prefabricated panels, in which the structural units are bonded and solidly put together with concrete and/or mortar so as to act compositely.

2.2 Types of masonry

2.2.1 reinforced masonry. Masonry in which steel reinforcement is incorporated to enhance resistance to tensile, compressive or shear forces.

2.2.2 prestressed masonry. Masonry in which pre-tensioned or post-tensioned steel is incorporated to enhance resistance to tensile or shear forces.

2.3 Types of reinforced masonry

2.3.1 grouted-cavity masonry. Two parallel single-leaf walls spaced at least 50 mm apart, effectively tied together with wall ties. The intervening cavity contains steel reinforcement and is filled with infill concrete so as to result in common action with the masonry under load.

2.3.2 pocket-type masonry. Masonry reinforced primarily to resist lateral loading where the main reinforcement is concentrated in vertical pockets formed in the tension face of the masonry and is surrounded by in situ concrete (see figure 7(a)).

2.3.3 Quetta bond masonry. Masonry at least one and a half units thick in which vertical pockets containing reinforcement and mortar or concrete infill occur at intervals along its length.

2.3.4 reinforced hollow blockwork. Hollow blockwork that may be reinforced horizontally or vertically and subsequently wholly or partly filled with concrete (see figure 7(b)).

2.4 effective depth. The depth from the compression face to the centroid of the longitudinal tensile reinforcement in members in bending.

2.5 prestressing tendon. Steel wire, strand or bar pre-tensioned or post-tensioned to prestress masonry.

2.6 shear span. Ratio of maximum design bending moment to maximum design shear force.

3 Symbols

The following symbols are used in this code:

A_m	cross-sectional area of masonry (in mm^2)
A_s	cross-sectional area of primary reinforcing steel (in mm^2)
A_{s1}	area of compression reinforcement in the most compressed face (in mm^2)
A_{s2}	area of reinforcement in the least compressed face (in mm^2)
A_{sv}	cross-sectional area of reinforcing steel resisting shear forces (in mm^2)
a	shear span (in mm)
a_v	distance from face of support to the nearest edge of a principal load (in mm)
b	width of section (in mm)
b_c	width of compression face midway between restraints (in mm)
b_t	width of section at level of the tension reinforcement (in mm)
c	lever arm factor
d	effective depth (in mm) (see 2.4)
d_c	depth of masonry in compression (in mm)
d_1	the depth from the surface to the reinforcement in the more highly compressed face (in mm)
d_2	the depth of the centroid of the reinforcement from the least compressed face (in mm)
E_c	modulus of elasticity of concrete (in kN/mm^2)
E_m	modulus of elasticity of masonry (in kN/mm^2)
E_n	nominal earth or water load (in N) (see clause 18)
E_s	modulus of elasticity of steel (in kN/mm^2)
e_x	resultant eccentricity in plane of bending (in mm)
F_{bst}	tensile bursting force (in N)
f_b	characteristic anchorage bond strength between mortar or concrete infill and steel (in N/mm^2)
f_{ci}	strength of concrete at transfer (in N/mm^2)
f_k	characteristic compressive strength of masonry (in N/mm^2)
f_{kx}	characteristic flexural strength (tension) of masonry (in N/mm^2)
f_{pb}	stress in tendon at the design moment of resistance of the section (in N/mm^2)
f_{pe}	effective prestress in tendon after all losses have occurred (in N/mm^2)
f_{pu}	characteristic tensile strength of prestressing tendons (in N/mm^2)
f_s	stress in the reinforcement (in N/mm^2)
f_{s1}	stress in the reinforcement in the most compressed face (in N/mm^2)

f_{s2}	stress in the reinforcement in the least compressed face (in N/mm^2)	t	overall thickness of a wall or column (in mm)
f_v	characteristic shear strength of masonry (in N/mm^2)	t_{ef}	effective thickness of a wall or column (in mm)
f_v	characteristic tensile strength of reinforcing steel (in N/mm^2)	t_f	thickness of a flange in a pocket-type wall (in mm)
G_k	characteristic dead load (in N)	V	shear force due to design loads (in N)
g_B	design load per unit area due to loads acting at right angles to the bed joints (in N/mm^2)	v	shear stress due to design loads (in N/mm^2)
h	clear distance between lateral supports (in mm)	W_k	characteristic wind load (in N)
h_{ef}	effective height of wall or column (in mm)	Z	section modulus (in mm^4)
K_t	coefficient to allow for type of prestressing tendon	z	lever arm (in mm)
L	length of the wall (in mm)	α	coefficient (see table 12)
l_t	transmission length (in mm)	γ_f	partial safety factor for load
M	bending moment due to design load (in $\text{N}\cdot\text{mm}$)	γ_m	partial safety factor for material
M_a	increase in moment due to slenderness (in $\text{N}\cdot\text{mm}$)	γ_{mb}	partial safety factor for bond strength between mortar or concrete infill and steel
M_d	design moment of resistance (in $\text{N}\cdot\text{mm}$)	γ_{mm}	partial safety factor for compressive strength of masonry
M_x	design moment about the x axis (in $\text{N}\cdot\text{mm}$)	γ_{ms}	partial safety factor for strength of steel
M_x'	effective uniaxial design moment about the x axis (in $\text{N}\cdot\text{mm}$)	γ_{mv}	partial safety factor for shear strength of masonry
M_y	design moment about the y axis (in $\text{N}\cdot\text{mm}$)	ρ	A_s/bd
M_y'	effective uniaxial design moment about the y axis (in $\text{N}\cdot\text{mm}$)	ϕ	nominal diameter of tendon
N	design axial load (in N)		
N_d	design axial load resistance (in N)		
N_{dz}	design axial load resistance of column, ignoring all bending (in N)		
ρ	overall section dimension in a direction perpendicular to the x axis (in mm)		
Q	moment of resistance factor (in N/mm^2)		
Q_k	characteristic imposed load (in N)		
q	overall section dimension in a direction perpendicular to the y axis (in mm)		
s_v	spacing of shear reinforcement along member (in mm)		

4 Alternative materials and methods of design and construction

Where materials and methods are used that are not referred to in this code, their use is acceptable, provided that the materials comply with the appropriate British Standards and that the methods of design and construction are such as to ensure strength and durability at least equal to that recommended in this code.

Alternatively, the materials or methods may be proven by test when the test assembly should be representative, as to materials, workmanship and details, of the intended design and construction, and should be built under conditions representative of the conditions in the actual building construction.

Section two. Materials and components

5 General

Unless otherwise stated, the materials and components used in the construction of loadbearing walls should comply with the appropriate clause of BS 5628 : Part 3 or BS 5390.

6 Structural units

Bricks and blocks intended for use in reinforced and prestressed masonry should be selected from the types listed below and should comply with the relevant British Standard.

Calcium silicate (sandlime and flintlime) bricks	BS 187
Clay bricks and blocks	BS 3921
Precast concrete masonry units	BS 6073 : Part 1
Reconstructed stone masonry units	BS 6457
Stone masonry	BS 5390

Selection of units should follow the recommendations contained in BS 5628 : Part 3 or BS 5390, as appropriate, in respect of durability and other considerations.

The tables and graphs in this Part of BS 5628 cover masonry units of compressive strength 7 N/mm^2 * or more. However, this should not be taken to preclude the use of masonry units of lower strength for certain applications.

Masonry units that have been previously used should not be reused in reinforced and prestressed masonry unless they have been thoroughly cleaned and follow the recommendations of this code for similar new materials.

7 Steel

7.1 Reinforcing steel

Reinforcing steel, including bed joint reinforcement, should comply with the relevant British Standard.

Hot rolled steel bars	BS 4449
Cold worked steel bars	BS 4461
Hard drawn low carbon steel wire	BS 4482
Steel fabric	BS 4483
Austenitic stainless steel (bar, wire or fabric)	BS 970 : Part 1 grades 304S15, 316S31 or 316S33, excluding free machining specifications.

Reinforcement may be galvanized after manufacture in accordance with BS 729 or clad with a layer of austenitic stainless steel of nominal thickness not less than 1 mm.

7.2 Prestressing steel

Prestressing wire, strands and bars should comply with BS 4486 or BS 5896.

8 Damp-proof courses

Damp-proof courses (d.p.cs) should comply with one of the British Standards, as appropriate, specified in clause 10 of BS 5628 : Part 3 : 1985.

Designers should pay particular attention to the characteristics of the materials chosen for d.p.cs. Materials which squeeze out are undesirable in highly stressed walls, and the effect of sliding at the d.p.c. should be considered especially in relation to lateral loading. In general, advice on the resistance to compression, tension, sliding and shear should be sought from the manufacturers of the d.p.c.

9 Wall ties

Wall ties for low-lift grouted-cavity construction (see 39.2.2) should be the vertical-twist type complying with the requirements of BS 1243 except for those for length.

The number and strength of wall ties for high-lift grouted cavity walls should be sufficient to resist the bursting forces which occur during the cavity filling and compaction operations. Details of a suitable tie are given in appendix B. Protection against corrosion should follow the recommendations of 32.2.7.

10 Cements

Cement should comply with BS 12, BS 146 or BS 4027. Masonry cement or high alumina cement should never be used.

11 Aggregate

Aggregate for mortar should follow the recommendations of 6.3 of BS 5628 : Part 3 : 1985.

Aggregate for concrete should follow the recommendations of 6.1.3 of BS 8110 : Part 1 : 1985.

12 Mortars

12.1 General

The mixing and use of mortars should follow the recommendations of BS 5628 : Part 3 or BS 5390, as appropriate. The proportions of the materials and mean compressive strengths required are given in table 1. When testing is required, it should be in accordance with A.1 of BS 5628 : Part 1 : 1978.

* Based on gross area for solid concrete blocks and net area for hollow concrete blocks (see C.2 of BS 6073 : Part 2 : 1981) and on the area of bed face for clay, calcium silicate and concrete bricks.

Table 1. Requirements for mortar				
Mortar designation (see note 1)	Type of mortar (proportions by volume) (see note 2)		Mean compressive strength at 28 days	
	Cement : lime : sand	Cement : sand with plasticizer (see 15.1)	Preliminary (laboratory) tests	Site tests
(i)	1 : 0 to ¼ : 3	—	N/mm ² 16.0	N/mm ² 11.0
(ii)	1 : ½ : 4 to 4½ (see note 3)	1 : 3 to 4 (see note 3)	6.5	4.5

NOTE 1. Designation (iii) mortar (see table 1 of BS 5628 : Part 1 : 1978) may be used in walls incorporating bed joint reinforcement to enhance lateral load resistance (see appendix A).

NOTE 2. Proportioning by mass will give more accurate batching than proportioning by volume, provided that the bulk densities of the materials are checked on site.

NOTE 3. In general, the lower proportion of sand applies to grade G of BS 1200 whilst the higher proportion applies to grade S of BS 1200.

12.2 Ready-mixed mortars

Ready-mixed lime:sand for mortar should comply with BS 4721. The appropriate addition of cement should be gauged on site.

Ready-to-use retarded cement:lime:sand mortars should comply with BS 4721 and be used only with the written permission of the designer.

13 Concrete infill and grout

13.1 Concrete infill for reinforced masonry should consist of the following proportions by volume of dry materials.

1 : 0 to ¼ : 3 : 2 cement : lime : sand :
10 mm maximum size aggregate.

Alternatively, a prescribed or designed mix of grade 25 as described in BS 5328 may be used.

Concrete infill for pre-tensioned prestressed masonry should be a prescribed or designed mix of minimum grade 40 as described in BS 5328.

Concrete infill for post-tensioned prestressed masonry should be a prescribed or designed mix of minimum grade 25 as described in BS 5328.

The maximum size of aggregate should not exceed the cover to any reinforcement less 5 mm.

13.2 The slump of all mixes should be appropriate to the size and configuration of the space to be filled but should be between 75 mm and 175 mm for unplasticized mixes. In order to ensure that complete filling and compaction is achieved, designers should consider the workability of the infill concrete in relation to the height of pour. For small sections, plasticizers or superplasticizers may be necessary.

13.3 Where tendons are used in narrow ducts which cannot be filled using the appropriate infill concrete described in 13.1, the ducts may be filled with a neat cement grout or

a sand:cement grout with a minimum cube strength of 17 N/mm² at 7 days. Sand for grout should pass a 1.18 mm sieve complying with BS 410.

14 Colouring agents for mortar

Colouring agents should comply with BS 1014 and their content by mass should not exceed 10 % (m/m) of the cement in the mortar, the agent should be evenly distributed throughout the mortar. Carbon black should be limited to 3 % (m/m) of the cement.

Consideration should be given to the strength and durability of mortars incorporating colouring agents.

15 Admixtures

15.1 General

For the purposes of this code an admixture is taken to be as defined in BS 4887 or BS 5075 : Part 1, including super plasticizers for infill concrete and mortar plasticizers.

Calcium chloride should never be used. Other admixtures should be used only with the written permission of the designer. If admixtures are used, it is important to ensure that the manufacturer's instructions about quality and mixing times are carefully followed.

Admixtures should comply with the relevant British Standard.

Concrete admixtures	BS 5075 : Part 1
Accelerating admixtures, retarding admixtures and water reducing admixtures	
Air-entraining admixtures	BS 5075 : Part 2
Mortar plasticizers	BS 4887

Where there is no appropriate British Standard, the suitability and effectiveness of an admixture should be at the discretion of the designer.

If two or more admixtures are to be used simultaneously in the same mix, data should be sought to assess their interaction and to ensure their compatibility. The behaviour of admixtures with composite and supersulphated cements may differ from their behaviour with Portland cement and data should be obtained on the performance of the intended mixture of materials before use.

The effect of admixtures on durability of concrete or mortar should be carefully assessed, with particular reference to whether they will combine with the ingredients to form harmful compounds or increase the risk of corrosion of the reinforcement.

The chloride ion content by mass of admixtures should not exceed 2 % (*m/m*) of the admixtures or 0.03 % (*m/m*) of the cement.

15.2 Chlorides

15.2.1 Chlorides in sands. The chloride ion content by mass of dry building sand should not exceed 0.15 % (*m/m*) of the cement.

15.2.2 Chlorides in mixes. The total chloride content of concrete and mortar mixes arising from aggregates and any other sources should not exceed the limits given in table 2.

Table 2. Chloride content of mixes	
Type or use of concrete or mortar	Maximum total chloride content by mass of cement
Prestressed concrete; heat-cured concrete containing embedded metal	% (<i>m/m</i>) 0.1
Concrete or mortar made with cement complying with BS 4027	0.2
Concrete or mortar containing embedded metal and made with cement complying with BS 12 or BS 146	0.4

Section three. Design objectives and general recommendations

16 Basis of design

16.1 Limit state design

16.1.1 The design of reinforced and prestressed masonry should provide an adequate margin of safety against the ultimate limit state. This is achieved by ensuring that the design strength is greater than or equal to the design load.

The design should be such that serviceability limit state criteria are met. Consideration should be given to the limit states of deflection and cracking and others where appropriate, e.g. fatigue.

16.1.2 Designers should consider whether the proportion of concrete infill in a given cross section is such that the recommendations of BS 8110 : Part 1 would be more appropriate than the recommendations of this code.

16.2 Limit states

16.2.1 Ultimate limit state. The strength of the structure should be sufficient to withstand the design loads, taking due account of the possibility of overturning or buckling. The design loads and the design strengths of materials should be those recommended in clauses 18 and 19 respectively, modified by the partial safety factors appropriate to the ultimate limit state given in clause 20.

16.2.2 Serviceability limit states

16.2.2.1 Deflection. The deflection of the structure or any part of it should not adversely affect the performance of the structure or any applied finishes, particularly in respect of weather resistance.

The design should be such that deflections are not excessive, with regard to the requirements of the particular structure, taking account of the following recommendations.

(a) The final deflection (including the effects of temperature, creep and shrinkage) of all elements should not, in general, exceed $\text{length}/125$ for cantilevers or $\text{span}/250$ for all other elements.

(b) Consideration should be given to the effect on partitions and finishes of that part of the deflection of the structure taking place after their construction. A limiting deflection of $\text{span}/500$ or 20 mm, whichever is the lesser, is suggested.

(c) If finishes are to be applied to prestressed masonry members, the total upward deflection, before the application of finishes, should not exceed $\text{span}/300$ unless uniformity of camber between adjacent units can be ensured.

In any calculation of deflections (see appendix C) the design loads and the design properties of materials should be those recommended for the serviceability limit state in clauses 18 to 20. For reinforcement, stresses lower than the characteristic strengths given in table 4 may need to be used to reduce deflection or control cracking.

16.2.2.2 Cracking. Fine cracking or opening up of joints may occur in reinforced masonry structures. However, cracking should not be such as to affect adversely the

appearance or durability of the structure. The effects of temperature, creep, shrinkage and moisture movement will require the provision of movement joints (see clause 20 of BS 5628 : Part 3 : 1985) or other precautions.

17 Stability

17.1 General considerations

The designer responsible for the overall stability of the structure should ensure the compatibility of the design and details of parts and components. There should be no doubt of this responsibility for overall stability when some or all of the design and detailing is carried out by more than one designer.

To ensure a robust and stable design it will be necessary to consider the layout of the structure on plan, the interaction of the masonry elements and their interaction with other parts of the structure.

As well as the above general considerations, attention should be given to the following recommendations.

(a) Buildings should be designed so that at any level they are capable of resisting a uniformly distributed horizontal load equal to 1.5 % of the total characteristic dead load above that level. This force may be apportioned between the structural elements according to their stiffness.

(b) Robust connections should be provided between elements of the structure, particularly at floors and roofs. For guidance, see appendix C of BS 5628 : Part 1 : 1978.

(c) Consideration should be given to connections between elements of different materials to ensure that any differences in their structural behaviour do not adversely affect the stability of the elements.

When bed joints are to be raked out for pointing, the designer should allow for the resulting loss of strength.

Care should be taken in the use of d.p.c. materials that might reduce the bending and shear strengths of the masonry. Recommended test methods are given in DD 86 : Part 1.

17.2 Earth-retaining and foundation structures

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 the partial safety factor for load, γ_f , comparable to those applied to other forms of loading.

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

17.3 Accidental forces

In addition to designing the structure to support loads arising from normal use, the designer should consider the effect of misuse or accident. No structure can necessarily be expected to be resistant to the excessive loads or forces that could arise due to an extreme cause, but it should not be damaged to an extent disproportionate to the original cause.

Furthermore, owing to the nature of a particular occupancy or use of a structure, e.g. flour mill or chemical plant, it may be necessary in the design concept or a design appraisal to consider the effect of a particular hazard and to ensure that, in the event of an accident, there is an acceptable probability of the structure remaining after the event, even if in a damaged condition.

Where there is the possibility of vehicles running into and damaging or removing vital loadbearing members of the structure in the ground floor, the provision of bollards, walls, etc. should be considered.

Buildings of five storeys and above (category 2 buildings as defined in BS 5628 : Part 1) should be designed following the additional recommendations of clause 37 of BS 5628 : Part 1 : 1978, except that mortar designation (iii) is recommended only for plain masonry containing bed joint reinforcement designed in accordance with appendix A.

17.4 During construction

The designer should consider whether special precautions or temporary propping are necessary to ensure the overall stability of the structure or of individual elements during construction.

18 Loads

Ideally, the characteristic load on a structure should be determined statistically. Since it is not yet possible to express loads in this way the following should be used as characteristic loads.

(a) *Characteristic dead load.* The characteristic dead load, G_k , is the weight of the structure complete with finishes, fixtures and partitions and should be taken as equal to the dead load as defined in, and calculated in accordance with, BS 6399 : Part 1.

(b) *Characteristic imposed load.* The characteristic imposed load, Q_k , should be taken as equal to the imposed load as defined in, and calculated in accordance with, BS 6399 : Part 1 or other appropriate codes of practice.

(c) *Characteristic wind load.* The characteristic wind load, W_k , should be taken as equal to the wind load as defined in, and calculated in accordance with, CP 3 : Chapter V : Part 2.

For the purposes of this code nominal earth loads, E_n , should be obtained in accordance with current practice, e.g. as described in Civil Engineering Code of Practice No. 2, 1951*. (See also 20.2.1.)

19 Structural properties and analysis

19.1 Structural properties

19.1.1 Characteristic compressive strength of masonry, f_k

19.1.1.1 General. The characteristic compressive strength of masonry, f_k , used in the design of a member should be that appropriate to the direction of the compressive force in the member.

19.1.1.2 Direct determination of the characteristic compressive strength of brick masonry, f_k The characteristic compressive strength of brick masonry may be obtained from tests as described in appendix D.

19.1.1.3 Value of f_k where the compressive force is perpendicular to the bed face of the unit. Where no specific tests are carried out (see 19.1.1.2) the value of f_k for a given masonry defined in terms of the compressive strength of the structural units and the mortar designation may be taken to be the characteristic compressive strength of masonry constructed with units laid in the normal way under laboratory conditions and tested at an age of 28 days under axial compression in such a manner that the effects of slenderness may be neglected (see table 3 and figure 1).

The value of f_k should be taken from the appropriate section of the table or figure, using the following guidelines.

(a) Table 3(A) and figure 1(a) apply to masonry built with bricks or other structural units with a ratio of height to least horizontal dimension of 0.6.

NOTE. This table is intended to cover normal size bricks which have an aspect ratio ≈ 0.63 .

(b) Table 3(B) and figure 1(b) apply to masonry built with solid concrete blocks with a ratio of height to least horizontal dimension of 1.0 and they make due allowance for the enhancement in strength resulting from the unit shape.

(c) Table 3(C) and figure 1(c) apply to masonry built with solid concrete blocks, i.e. those without cavities, with a ratio of height to least horizontal dimension of between 2.0 and 4.0, and they make due allowance for the enhancement in strength resulting from the unit shape.

(d) Table 3(D) and figure 1(d) apply to masonry built with structural units, other than solid concrete blocks, with a ratio of height to least horizontal dimension of between 2.0 and 4.0 and they make due allowance for the enhancement in strength resulting from the unit shape.

(e) When masonry is built of hollow blocks having a ratio of height to least horizontal dimension between 0.6 and 2.0, the value of f_k should be obtained by interpolation between the values given in tables 3(a) and 3(d).

(f) When masonry is built of solid concrete blocks, i.e. those without any cavities, having a ratio of height to least horizontal dimension of between 0.6 and 2.0,

* Available from the Institution of Structural Engineers, 11 Upper Belgrave Street, London SW1X 8BH

the value of f_k should be obtained by interpolation between the values given in table 3(A) and 3(C). To assist the designer, table 3(B) gives values of f_k for solid concrete blocks having a ratio of height to least horizontal dimension of 1.0.

(g) When masonry is built with hollow concrete blocks and the vertical cavities are filled completely with in situ concrete, the value of f_k should be obtained as if the blocks were solid (see (f)) provided that:

(1) the compressive strength of the blocks is assessed on their net area as defined in appendix C of BS 6073 : Part 2 : 1981;

(2) the characteristic concrete cube strength of the infill is not less than the compressive strength of the blocks derived from (1) and in no case less than the appropriate minimum strength given in clause 13.

Where the infill concrete is less strong than the concrete in the block, the characteristic compressive strength of the masonry should be obtained as if the blocks were solid and of compressive strength equal to the cube strength of the infill concrete.

(h) When masonry is built with square dressed natural stone, the value of f_k should be obtained as if the units were solid concrete blocks of an equivalent compressive strength.

Linear interpolation within the tables is permitted.

19.1.1.4 *Value of f_k where the compressive force is parallel to the bed face of the unit.* The value of f_k for masonry in which the compressive forces act parallel to the bed faces may be taken as:

(a) for masonry units without holes, frogged bricks where the frogs are filled and filled hollow blocks, the strength obtained from the appropriate item of 19.1.1.3;

(b) for cellular bricks and bricks with perforations, the characteristic compressive strength, f_k , determined in accordance with 19.1.1.2 or, where no test data are available, one-third of the strength obtained from the appropriate item of 19.1.1.3;

(c) for unfilled hollow and cellular blocks, the characteristic compressive strength, f_k , given in table 3, using the strength of the block determined in the direction parallel to the bed face of the unit.

19.1.1.5 *Value of f_k for units of unusual format or for unusual bonding patterns.* The value of f_k for masonry constructed with units of unusual formats, or with an unusual bonding pattern, may be taken as:

(a) for brick masonry, the values determined by test in accordance with 19.1.1.2, provided that the value of f_k is not taken to be greater than the appropriate value given in table 3.

(b) for block masonry, the value given in table 3, using the strength of the block determined in the appropriate aspect.

19.1.2 *Characteristic compressive strength of masonry in bending.* For a given masonry defined in terms of the compressive strength of the structural units and mortar designation, the value of f_k derived from 19.1.1 may be taken to be the characteristic compressive strength of masonry in bending.

19.1.3 *Characteristic shear strength of masonry, f_v*

19.1.3.1 *Shear in bending (reinforced masonry)*

19.1.3.1.1 For sections in which the reinforcement is placed in bed or vertical joints, including Quetta bond and other sections where the reinforcement is wholly surrounded with mortar designation (i) or (ii) (see table 1), the characteristic shear strength, f_v , may be taken as 0.35 N/mm^2 .

For simply supported beams or cantilevers where the ratio of the shear span (see 2.6) to the effective depth is less than 2, f_v may be increased by a factor:

$$2d/a_v$$

where

d is the effective depth;

a_v is the distance from the face of the support to the nearest edge of a principal load;

provided that f_v is not taken to be greater than 0.7 N/mm^2 .

At sections in certain laterally loaded walls there may be substantial compressive stresses from vertical loads. In such cases the shear may be adequately resisted by the plain masonry (see clause 25 of BS 5628 : Part 1 : 1978).

19.1.3.1.2 For reinforced sections in which the main reinforcement is placed within pockets, cores or cavities filled with concrete infill as defined in 13.1, the characteristic shear strength of the masonry, f_v , may be obtained from the following equation:

$$f_v = 0.35 + 17.5 \rho$$

where

$$\rho = A_s/bd$$

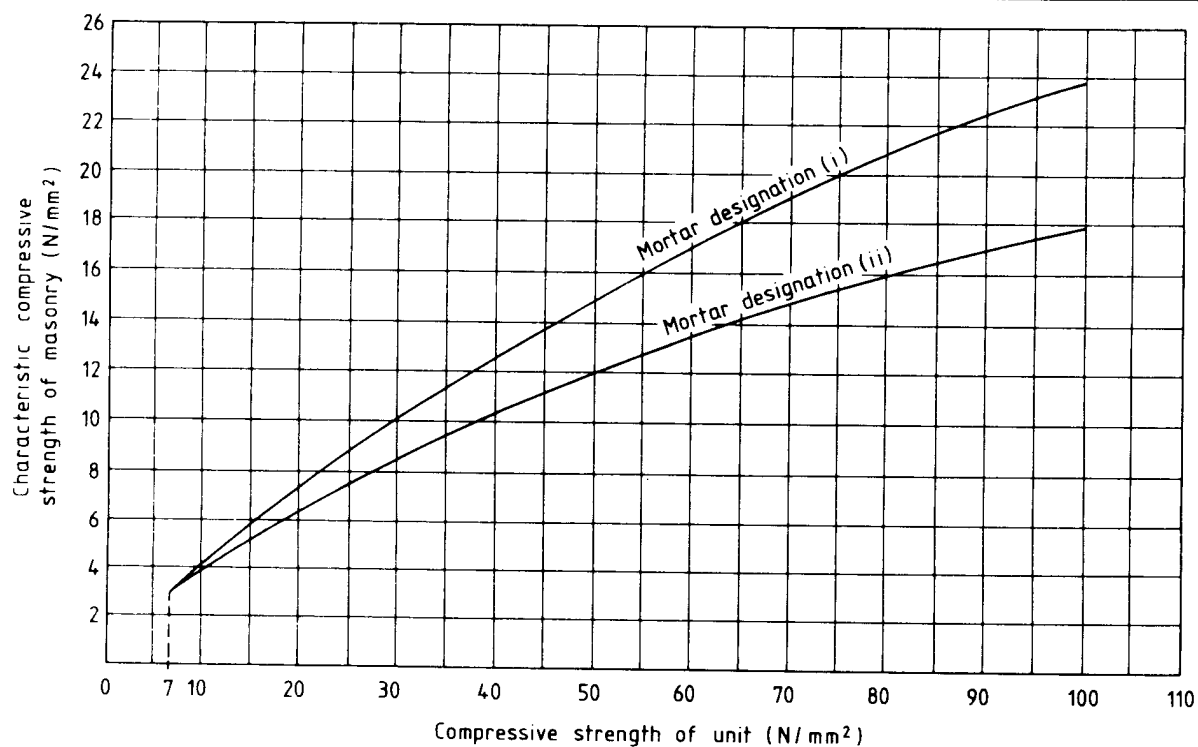
A_s is the cross-sectional area of primary reinforcing steel;

b is the width of section;

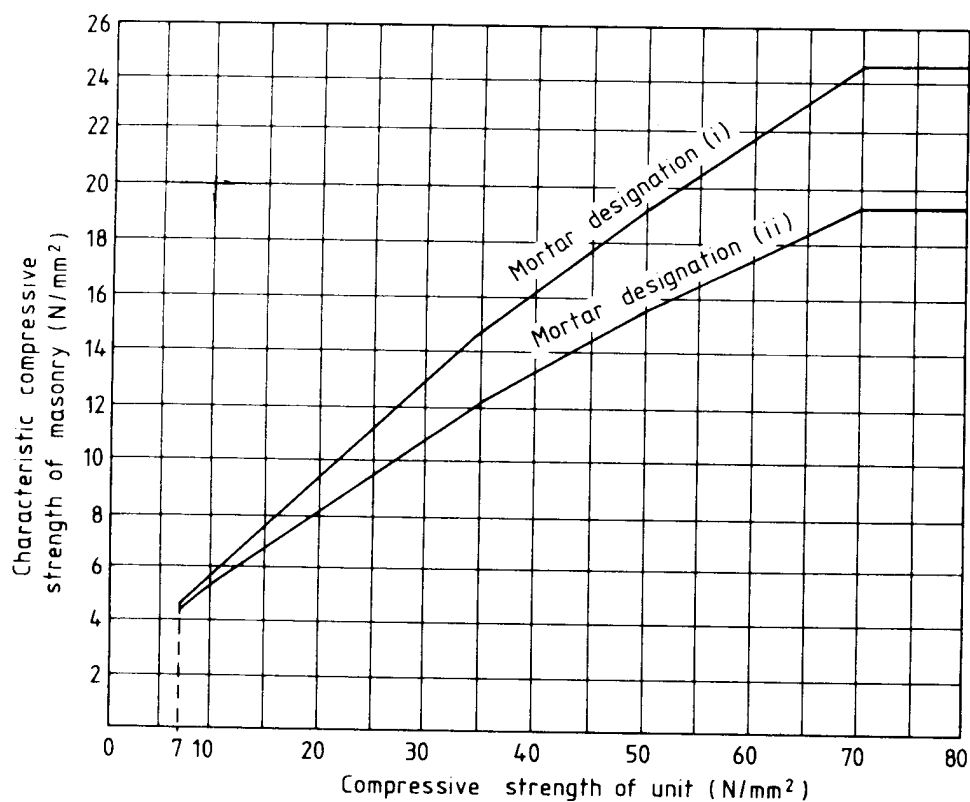
d is the effective depth (see 2.4);

provided that f_v is not taken to be greater than 0.7 N/mm^2 .

For simply supported reinforced beams or cantilever retaining walls where the ratio of the shear span, a , (see 2.6) to the effective depth, d , is six or less, f_v may be increased by a factor $\{2.5 - 0.25 (a/d)\}$ provided that f_v is not taken to be greater than 1.75 N/mm^2 .

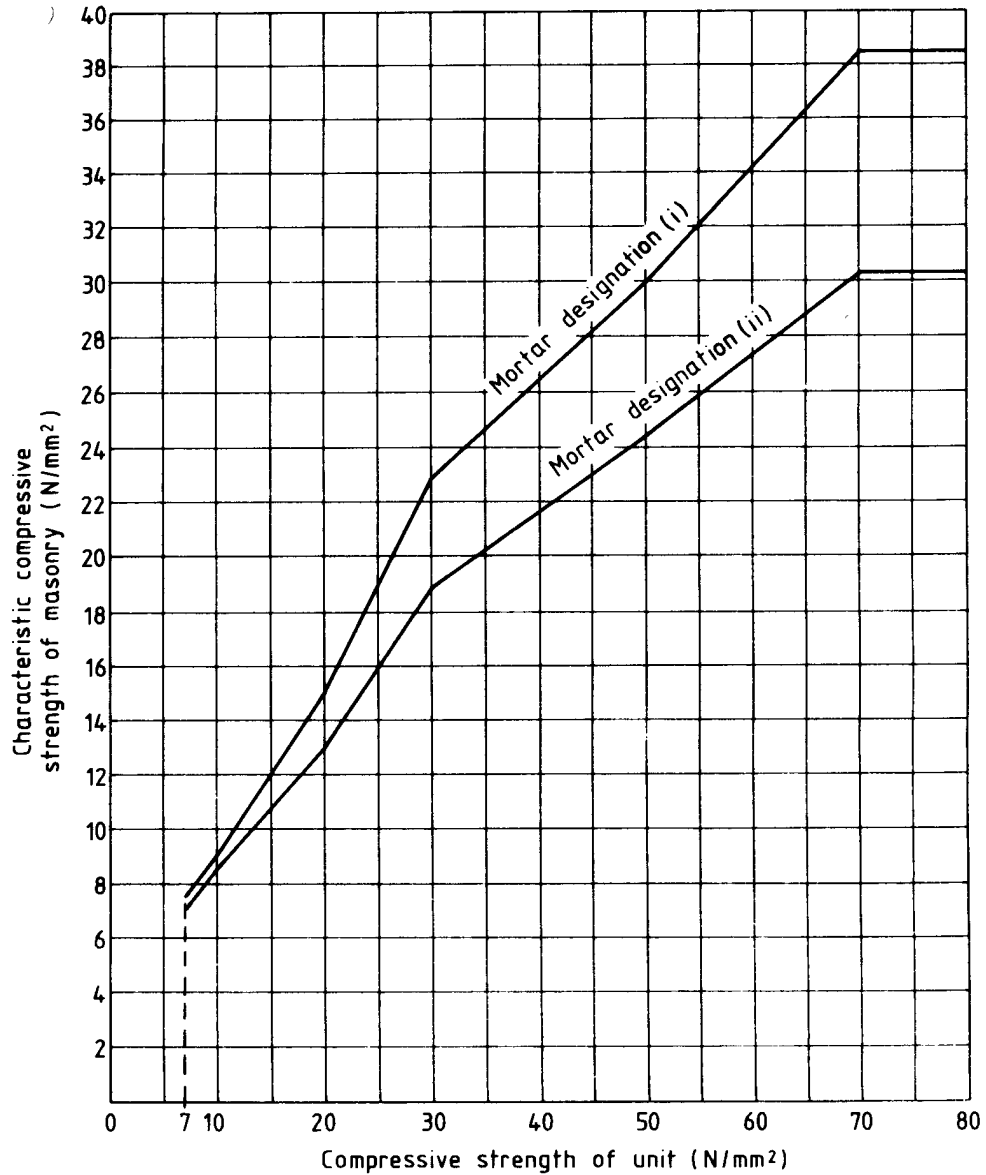


(a) Masonry constructed with bricks or other units having a ratio of height to least horizontal dimension of 0.6 (see table 3(A))



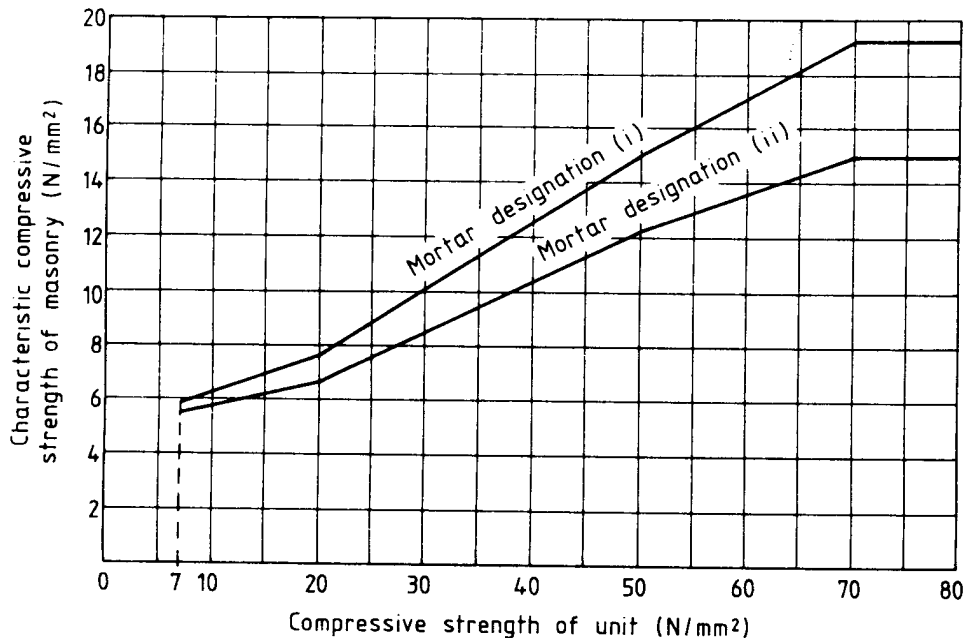
(b) Block masonry constructed with solid blocks having a ratio of height to least horizontal dimension of 1.0 (see table 3(B))

Figure 1. Characteristic compressive strength, f_k , of masonry



(c) Block masonry constructed with solid blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0 (see table 3(C))

Figure 1. (continued)



(d) Block masonry constructed with structural units other than solid concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0 (see table 3(D))

Figure 1. (concluded)

19.1.3.2 Racking shear in reinforced masonry shear walls. When designing reinforced masonry shear walls the characteristic shear strength of masonry, f_v , may be taken to be:

$$0.35 + 0.6g_B, \text{ with a maximum of } 1.75 \text{ N/mm}^2$$

where

g_B is the design load per unit area normal to the bed joint due to the loads calculated for the appropriate loading condition detailed in clause 20.

Alternatively, for reinforced sections in which the main reinforcement is placed within pockets, cores or cavities filled with concrete infill as defined in 13.1, the characteristic shear strength of masonry, f_v , may be taken to be 0.7 N/mm^2 provided that the ratio of height to length of the wall does not exceed 1.5.

Designers should consider the effect of damp-proof courses on shear strength of masonry (see 17.1).

19.1.3.3 Shear in prestressed sections. For prestressed sections with bonded or unbonded tendons the characteristic shear strength of masonry, f_v , may be obtained from the following formula:

$$f_v = 0.35 + 0.6 g_B$$

where

g_B is the design load per unit area due to the loads acting at right angles to the bed joints, including prestressing loads (in N/mm^2).

NOTE. In elements prestressed parallel to the bed joints $g_B = 0$, giving $f_v = 0.35 \text{ N/mm}^2$.

For simply supported prestressed beams or cantilever retaining walls where the ratio of the shear span, a , to the effective depth, d , is six or less, f_v may be increased by a factor $\{2.5 - 0.25 (a/d)\}$.

In all cases f_v should not be taken to be greater than 1.75 N/mm^2 .

Table 3. Characteristic compressive strength, f_k , of masonry									
(A) Constructed with bricks or other units having a ratio of height to least horizontal dimension of 0.6									
Mortar designation	Characteristic compressive strength of masonry, f_k (N/mm ²)								
	Compressive strength of unit (N/mm ²)								
	7	10	15	20	27.5	35	50	70	100
(i)	3.4	4.4	6.0	7.4	9.2	11.4	15.0	19.2	24.0
(ii)	3.2	4.2	5.3	6.4	7.9	9.4	12.2	15.1	18.2
(B) Constructed with solid concrete blocks having a ratio of height to least horizontal dimension of 1.0									
	Compressive strength of unit (N/mm ²)								
	7	10	15	20	35	50	70 or greater		
(i)	4.4	5.7	7.7	9.5	14.7	19.3	24.7		
(ii)	4.1	5.4	6.8	8.2	12.1	15.7	19.4		
(C) Constructed with solid concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0									
	Compressive strength of unit (N/mm ²)								
	7	10	15	20	35	50	70 or greater		
(i)	6.8	8.8	12.0	14.8	22.8	30.0	38.4		
(ii)	6.4	8.4	10.6	12.8	18.8	24.4	30.2		
(D) Constructed with structural units other than solid concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0									
	Compressive strength of unit (N/mm ²)								
	7	10	15	20	35	50	70 or greater		
(i)	5.7	6.1	6.8	7.5	11.4	15.0	19.2		
(ii)	5.5	5.7	6.1	6.5	9.4	12.2	15.1		