

Code of practice for use of masonry —

Part 1: Structural use of unreinforced masonry

Committees responsible for this British Standard

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Autoclaved Aerated Concrete Products Association
Brick Development Association
British Ceramic Research Ltd.
British Masonry Society
British Precast Concrete Federation Ltd.
Calcium Silicate Brick Association
Concrete Block Association
Department of the Environment (Building Research Establishment)
Department of the Environment (Construction Directorate)
Department of the Environment (Property Services Agency)
Institution of Civil Engineers
Institution of Structural Engineers
National House Building Council
Royal Institute of British Architects

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Foreword

This Part of BS 5628 has been prepared under the direction of Technical Committee B/525, Building and Civil Engineering Structures. It supersedes BS 5628-1:1978, which is withdrawn.

This edition of BS 5628-1 introduces technical changes, but it does not reflect a full review or revision of the standard which will be undertaken in due course.

This Part uses limit state philosophy, in accordance with practice in other codes. The 1948, 1964 and 1970 editions of CP 111 were in permissible stress terms, and a section on reinforced masonry walls was included. Reinforced masonry has been excluded from this Part of BS 5628, as the subject is dealt with in Part 2. Plain concrete walls are covered in BS 8110.

The use of limit state enables the degree of risk to be varied by the choice of different partial safety factors. It has been recognized in this Part that masonry is built to differing standards of workmanship and, therefore, the partial safety factors have reflected this.

In view of the widespread demand for guidance on the design of walls to resist lateral loading, a section on this subject was incorporated in the 1978 edition. This was based on a large volume of research work. This new edition includes a comprehensive method of design for proposed cantilever walls for certain types of single storey buildings under wind loading.

It has become necessary, in structural design, to ensure explicitly that a building will not collapse catastrophically as the result of misuse or accident. The recommendations dealing with this requirement reflect the available theoretical and research studies on the behaviour of elements and structures under extreme conditions. Whilst some aspects of the work require further study, the guidance given represents a balanced combination of facts and engineering judgement.

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

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

Summary of pages

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Section 1. General

1 Scope

This Part of BS 5628 gives recommendations for the structural design of unreinforced masonry constructed of brick masonry, block masonry, masonry of square dressed natural stone, and random rubble masonry.

The thickness of a wall determined from strength considerations may not always be sufficient to satisfy requirements for other properties of the wall such as resistance to fire, thermal insulation, sound insulation or resistance to damp penetration and reference should be made to BS 5628-3, as appropriate.

It has been assumed in the drafting of this code that the design of masonry is entrusted to chartered structural or civil engineers or other appropriately qualified persons, for whose guidance it has been prepared, and that the execution of the work is carried out under the direction of appropriately qualified supervisors.

2 References

The titles of the standards publications referred to in this code are listed on page 70.

3 Definitions

For the purposes of this Part of BS 5628 the following definitions apply.

3.1

actual dimension

either the work size of the unit or, where applicable for solid walls, the sum of the work size of the units together with the work size of the joints between them

3.2

category 1 building

a building having four storeys (including basement storeys), or less

3.3

category 2 building

a building having five storeys (including basement storeys), or more

3.4

characteristic load

ideally, where the load acts unfavourably, the load which has a probability of not more than 5 % of being exceeded or, where the load acts favourably, the load which has a probability of at least 95 % of being exceeded. In practice, the load obtained from the appropriate British Standard

3.5

characteristic strength of masonry

the value of the strength of masonry below which the probability of test results falling is not more than 5 %

3.6

compressive strength of structural units

for the normal category of manufacturing control, the strength of a sample tested according to the appropriate British Standard

NOTE When manufacturing control is within the special category as defined in 27.2.1.2, compressive strength is taken as the acceptance limit, therein defined.

3.7

column

an isolated vertical loadbearing member whose width is not more than four times its thickness

3.8

design load

the characteristic load multiplied by a partial safety factor for loads

3.9

design strength

the characteristic strength divided by a partial safety factor for material strength

3.10**effective height or length**

the height or length of a wall, pier or column assumed for calculating the slenderness ratio

3.11**effective thickness**

the thickness of a wall, pier or column assumed for calculating the slenderness ratio

3.12**laterally loaded wall panels**

walls subjected mainly to loads normal to the face of the wall

3.13**lateral support**

the support, in relation to a wall or pier, which will restrict movement in the direction of the thickness of the wall or, in relation to a column, which will restrict movement in the direction of its thickness or width. Lateral supports may be horizontal or vertical

3.14**loadbearing walls**

walls primarily designed to carry an imposed vertical load in addition to their own weight

3.15**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 mortar or grout. Masonry may be reinforced or unreinforced

3.16**orthogonal ratio**

the ratio of the flexural strength of masonry when failure is parallel to the bed joints to that when failure is perpendicular to the bed joints

3.17**pier**

a member which forms an integral part of a wall, in the form of a thickened section placed at intervals along the wall

3.18**protected member**

a structural member capable of resisting a specified pressure

NOTE See Section 5.

3.19**slenderness ratio**

the ratio of the effective height or length to the effective thickness

3.20**structural units**

bricks or blocks or square dressed natural stone

3.21 Types of wall**3.21.1****single-leaf wall**

a wall of bricks or blocks laid to overlap in one or more directions and set solidly in mortar

3.21.2**double-leaf (collar-jointed) wall**

two parallel single-leaf walls, with a space between not exceeding 25 mm, filled solidly with mortar and so tied together as to result in common action under load

3.21.3**cavity wall**

two parallel single-leaf walls, usually at least 50 mm apart, and effectively tied together with wall ties, the space between being left as a continuous cavity or filled with non-loadbearing material

3.21.4**grouted cavity wall**

two parallel single-leaf walls, spaced at least 50 mm apart, effectively tied together with wall ties and with the intervening cavity filled with fine aggregate concrete (grout), which may be reinforced, so as to result in common action under load

3.21.5**faced wall**

a wall in which the facing and backing are so bonded as to result in common action under load

3.21.6**veneered wall**

a wall having a facing which is attached to the backing, but not so bonded as to result in common action under load

3.22**wallette**

a small masonry panel constructed for test purposes

4 Symbols

The following symbols are used in this code.

A	horizontal cross-sectional area
B	width of a bearing under a concentrated load
b	width of column
E_u	worst credible earth or water lateral load (see clause 21)
e_a	additional eccentricity due to deflection in walls
e_x	eccentricity at top of a wall
e_t	total design eccentricity in the mid-height region of a wall
e_m	the larger of e_x or e_t
F_k	characteristic load
F_m	average of the maximum loads carried by two test panels
F_t	tie force
f_k	characteristic compressive strength of masonry
f_{kx}	characteristic flexural strength (tension) of masonry
f_v	characteristic shear strength of masonry
f_y	characteristic tensile strength of flat metal section (shear connector)
G_k	characteristic dead load
g_A	design vertical load per unit area
g_d	design vertical dead load per unit area
h	clear height of wall or column between lateral supports
h_a	clear height of wall between concrete surfaces or other construction capable of providing adequate resistance to rotation across the full thickness of a wall
h_L	clear height of wall to point of application of a lateral load
h_{ef}	effective height or length of wall or column
k	multiplication factor for lateral strength of axially loaded walls

K	stiffness coefficient
L	length
L_a	a span in accidental damage calculation
N_s	number of storeys in a building
n	axial load per unit length of wall, available to resist an arch thrust
n_w	design vertical load per unit length of wall
p_{lim}	acceptance limit for compressive strength of units
p_o	specified compressive strength of units
p_u	mean compressive strength of units
Q_k	characteristic imposed load
q_{lat}	design lateral strength per unit area
r	width of flat metal section (shear connector)
t	overall thickness of a wall or column
t_{ef}	effective thickness of a wall or column
t_p	thickness of a pier
t_1	thickness of leaf 1 of a cavity wall
t_2	thickness of leaf 2 of a cavity wall
u	thickness of flat metal section (shear connector)
v_h	design shear stress
W_k	characteristic wind load
y_u	deflection of test wall in the mid-height region
Z	section modulus
α	bending moment coefficient for laterally loaded panels
β	capacity reduction factor for walls allowing for effects of slenderness and eccentricity
γ_f	partial safety factor for load
γ_m	partial safety factor for material
γ_{mv}	partial safety factor for material in shear
μ	orthogonal ratio
ψ_m	reduction factor for strength of mortar
ψ_u	unit reduction factor

5 Alternative materials and methods of design and construction

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

Where materials or methods are used that are not referred to by this code or any other British Standard, they should be proven by test, and the test assembly should be representative, as to materials, workmanship and details, of the design and construction for which approval is desired, and should be built under conditions truly representative of the conditions in the actual building construction. Details of the testing procedures to determine the characteristic compressive strength and characteristic flexural strength of masonry are set out in **A.2** and **A.3** respectively.

Section 2. Materials, components and workmanship

6 General

The materials, components and workmanship used in the construction of loadbearing walls should comply with the appropriate clause in BS 5628-3.

7 Structural units

The following structural units should comply with the appropriate clauses in the relevant British Standard:

Calcium silicate (sandlime and flintlime) bricks	BS 187
Clay bricks	BS 3921
Dimensions of bricks of special shapes and sizes	BS 4729
Stone masonry	BS 5628-3
Precast concrete masonry units	BS 6073-1
Reconstructed stone masonry units	BS 6457
Clay and calcium silicate modular bricks	BS 6649

Materials that have been previously used should not be re-used in masonry construction unless they have been thoroughly cleaned and conform to the code recommendations for similar new materials.

8 Laying of structural units

8.1 General

Structural units will normally be laid on their bed faces. In circumstances where units are used under load in another aspect, laid on stretcher or on end, the strength of the units should be determined for this aspect in accordance with the appropriate clauses of BS 187, BS 6073-1 and BS 3921.

8.2 Bricks with frogs

Bricks should normally be laid on a full bed mortar¹⁾ with the frog or larger frog uppermost, which should be filled with mortar as the work proceeds.

8.3 Perforated bricks

Perforated bricks and bricks defined as solid according to BS 187 and BS 3921, but having perforations passing through them, should be laid on a full width bed of mortar¹⁾. The bedding mortar for divided joint units should be laid by means of a mortar tray in accordance with the brickmaker's recommendations. The perforations should only be filled with mortar as required in BS 5628-3 or when specified by the designer.

8.4 Hollow and cellular blocks

8.4.1 *Hollow clay blocks*

Hollow clay blocks may have horizontal or vertical perforations. The blocks should be laid on a full bed of mortar¹⁾, except those with vertical perforations which are designed to be laid with a divided bed joint in accordance with the manufacturer's recommendations.

8.4.2 *Hollow and cellular concrete blocks*

Hollow and cellular concrete blocks complying with the requirements of BS 6073-1 are normally laid on a full bed of mortar¹⁾. Occasionally such blocks are laid with the bed joint separated into two parallel strips.

9 Rate of laying

The maximum height that should normally be built in a day is 1.5 m.

10 Forming of chases and holes

Chasing of completed walls or the formation of holes should be carried out only when approved by the designer and then in accordance with BS 5628-3.

¹⁾ When bed joints are raked out for pointing allowance should be made in design for the resulting loss of strength.

11 Pallet slips

Timber pallet slips or other material for fixings should not be built into walls without the approval of the designer.

12 Damp proof courses

Damp proof courses should comply with the requirements of one of the British Standards, as appropriate, specified in clause 4.7 of BS 5628-3:2001. In addition the recommendations of 5.6 of BS 8215 should be taken into account.

Designers should pay particular attention to the characteristics of the materials chosen for damp proof courses. Materials which squeeze out are undesirable in highly stressed walls, and the effect of sliding at the damp proof course 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 damp proof course.

Methods of test for damp proof courses are described in DD 86-1 and DD 86-2.

13 Wall ties

Wall ties should comply with BS 1243 or meet the recommendations of DD 140-2 (see also 36.2).

In situations of severe exposure, or where required by building regulations, suitable stainless steel or non-ferrous ties should be used.

14 Cements

Cement should comply with the requirements of one of the following British Standards: BS 12, BS 146, BS 4027 and BS 5224.

The use of high alumina cement is not permitted.

15 Mortars

15.1 General

The mixing and use of mortars should be in accordance with the recommendations given in BS 5628-3. The proportion 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.

15.2 Ready-mixed mortars

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

Wet ready-mixed retarded cement : lime : sand mixes should be used only with the written permission of the designer.

16 Colouring agents

Pigments should comply with the requirements of BS 1014 and should not exceed 10 % by mass of the cement in the mortar. Care should be taken to ensure that the pigment is evenly distributed throughout the mortar and that the strength of the mortar remains adequate. Carbon black should be limited to 3 % by mass of the cement.

17 Plasticizers

Plasticizers should comply with the requirements of BS 4887 and should be used only with the written permission of the designer.

If plasticizers are used, it is important to ensure that the manufacturer's instructions about quantity and mixing time are carefully followed.

18 Frost inhibitors

The use of calcium chloride or frost inhibitors based on calcium chloride is not permitted in mortars.

Table 1 — Requirements for mortar

		Mortar designation	Type of mortar (proportion by volume)			Mean compressive strength at 28 days	
			Cement : lime : sand	Masonry cement : sand	Cement : sand with plasticizer	Preliminary (laboratory) tests	Site tests
↑ Increasing strength ↓ Increasing ability to accommodate movement, e.g. due to settlement, temperature and moisture changes	(i)	1 : 0 to ¼ : 3	—	—	N/mm ²	N/mm ²	
	(ii)	1 : ½ : 4 to 4½	1 : 2½ to 3½	1 : 3 to 4	16.0	11.0	
	(iii)	1 : 1 : 5 to 6	1 : 4 to 5	1 : 5 to 6	6.5	4.5	
	(iv)	1 : 2 : 8 to 9	1 : 5½ to 6½	1 : 7 to 8	3.6	2.5	
Direction of change in properties is shown by the arrows		Increasing resistance to frost attack during construction → Improvement in bond and consequent resistance to rain penetration ←					

Section 3. Design: objectives and general recommendations

19 Basis of design

The design of loadbearing masonry members should be undertaken primarily to ensure an adequate margin of safety against the ultimate limit state being reached. Generally, this is achieved by ensuring that the design strength of a member is greater than or equal to the design load. However, for some design situations, for example freestanding walls with no allowable flexural strength or axially loaded walls subject to lateral loads, the fundamental relationship which governs the design will be independent of the material strength and the partial safety factors associated with it.

The assessment of the characteristic compressive strength may be based either on the results of laboratory tests carried out on representative wall panels, as outlined in A.2, or on the information given in clause 23.

The factor γ_m makes allowance for the variation in the quality of the materials and for the possible difference between the strength of masonry constructed under site conditions and that of specimens built in the laboratory for the purpose of establishing its physical properties.

The partial safety factors for loads (γ_f), used in this code for the ultimate limit state, are based on those adopted in BS 8110.

γ_f is introduced to take account of:

- a) possible unusual increases in load beyond those considered in deriving the characteristic load;
- b) inaccurate assessment of effects of loading, and unforeseen stress redistribution within the structure;
- c) the variations in dimensional accuracy achieved in construction.

The structural design should also ensure that there is an adequate margin of safety against a serviceability limit state being reached. In the case of the serviceability limit state of cracking due to axially applied service loads, an adequate margin may be assumed to exist when the design satisfies the ultimate limit state.

The risk of adverse effects on the structure, including non-loadbearing elements such as partitions, arising from expansion or contraction due to temperature and moisture changes, creep, settlement or deformation of flexural members, should be assessed. Where necessary, suitable details should be employed to maintain an adequate margin of safety against a limit state being reached.

20 Stability

20.1 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 details are not made by the same designer.

To ensure a robust and stable design it will be necessary to consider the layout of structure on plan, returns at the ends of walls, interaction between intersecting walls and the interaction between masonry walls and the other parts of the structure.

The design recommendations in Section 4 assume that all the lateral forces acting on the whole structure are resisted by walls in planes parallel to these forces, or by suitable bracing.

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

- a) buildings should be designed to be capable of resisting a uniformly distributed horizontal load equal to 1.5 % of the total characteristic dead load (i.e. $0.015G_k$) above any level [see clause 22b) and clause 22c)];
- b) connections of the type indicated in Appendix C should be provided as appropriate at floors and roofs.

20.2 Earth retaining and foundation structures

The overall dimensions and stability of earth retaining and foundation structures (e.g. the area of pad footings, etc.) should be determined by appropriate geotechnical procedures, which are not considered in this code. However, in order to establish section sizes and strengths 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 partial safety factor for loads, (γ_f) should be applied to all earth and water loads unless they derive directly from loads which have already been factored in alternative ways to those described in clause 21 and clause 22, 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.

20.3 Accidental forces

In addition to designing the structure to support loads arising from normal use, there should be a reasonable probability that it will not collapse catastrophically under the effect of misuse or accident. No structure can 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, chemical plant, etc.), 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, retaining earth banks, etc. should be considered.

20.4 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 walls during construction.

21 Loads

Ideally, the characteristic load on a structure should be determined statistically.

Since it is not yet possible to determine 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 6399-1 and BS 6399-3.
- b) *Characteristic imposed load.* The characteristic imposed load Q_k should be taken as the imposed load as defined in and calculated in accordance with BS 6399-2.
- c) *Characteristic wind load.* The characteristic wind load W_k should be taken as the wind load calculated in accordance with BS 6399-2.

For the purposes of this standard, worst credible earth and water lateral loads, E_u , should be obtained in accordance with BS 8002 (see also clause 22).

22 Design loads: partial safety factor, γ_f

When using the design relationship for the ultimate limit state given in sections 4 and 5, the design load should be taken as the sum of the products of the component characteristic loads multiplied by the appropriate partial safety factor, as shown below. Where alternative values are shown, that producing the more severe conditions should be selected.

- a) *Dead and imposed load*

design dead load	= $0.9G_k$ or $1.4G_k$
design imposed load	= $1.6Q_k$
design worst credible earth and water lateral load	= $1.2E_u$
- b) *Dead and wind load*

design dead load	= $0.9G_k$ or $1.4G_k$
design wind load	= $1.4W_k$
design worst credible earth and water lateral load	= $1.2E_u$

In the particular case of freestanding walls and laterally loaded wall panels, whose removal would in no way affect the stability of the remaining structure, γ_f applied on the wind load may be taken as 1.2.

c) *Dead, imposed and wind load*

design dead load	= $1.2G_k$
design imposed load	= $1.2Q_k$
design wind load	= $1.2W_k$
design worst credible earth and water lateral load	= $1.2E_u$

d) *Accidental damage* (see 37)

design dead load	= $0.95G_k$ or $1.05G_k$
design imposed load	= $0.35Q_k$ except that, in the case of buildings used predominantly for storage, or where the imposed load is of a permanent nature, $1.05Q_k$ should be used
design wind load	= $0.35W_k$

For all these cases:

G_k is the characteristic dead load;

Q_k is the characteristic imposed load;

W_k is the characteristic wind load;

E_u is the worst credible earth and water lateral load (see clause 21); and the numerical values are the appropriate γ_f factors.

Where other than worst credible earth and water lateral loads are used, such as nominal lateral loads determined in accordance with Civil Engineering Code of Practice No.2 1951, the appropriate safety factor γ_f for design worst credible earth and water lateral load determination is 1.4.

In design, each of the load combinations a) to d) should be considered and that giving the most severe conditions should be adopted.

In certain circumstances, other values of γ_f may be appropriate, e.g. in farm buildings. Reference should be made to the relevant British Standards, e.g. BS 5502-22.

23 Characteristic compressive strength of masonry, f_k

23.1 Normal masonry

The characteristic compressive strength, f_k , of any masonry may be determined by tests on wall specimens, following the procedures laid down in A.2.

For normally bonded masonry, defined in terms of the shape and compressive strength of the structural units and the designation of the mortar (see Table 1), the values given in Table 2 inclusive may be taken to be the characteristic compressive strength, f_k , of walls constructed under laboratory conditions tested at an age of 28 days under axial compression in such a manner that the effects of slenderness may be neglected. Linear interpolation within the tables is permitted, facilitated by the graphs [Figure 1a), Figure 1b), Figure 1c) and Figure 1d)].

Table 2a) applies to masonry built with standard format bricks complying with the requirements of BS 187, BS 6073-1 or BS 3921.

Table 2b) applies to masonry built with structural units with a ratio of height to least horizontal dimension of 0.6.

Table 2c) applies to structural units, other than solid concrete blocks, with a ratio of height to least horizontal dimension of between 2.0 and 4.0, and makes due allowance for the enhancement in strength resulting from the unit shape.

Table 2d) applies to 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 makes due allowance for the enhancement in strength resulting from the unit shape.

23.1.1 Walls or columns of small plan area

Where the horizontal cross-sectional area of a loaded wall or column is less than 0.2 m², the characteristic compressive strength should be multiplied by the factor:

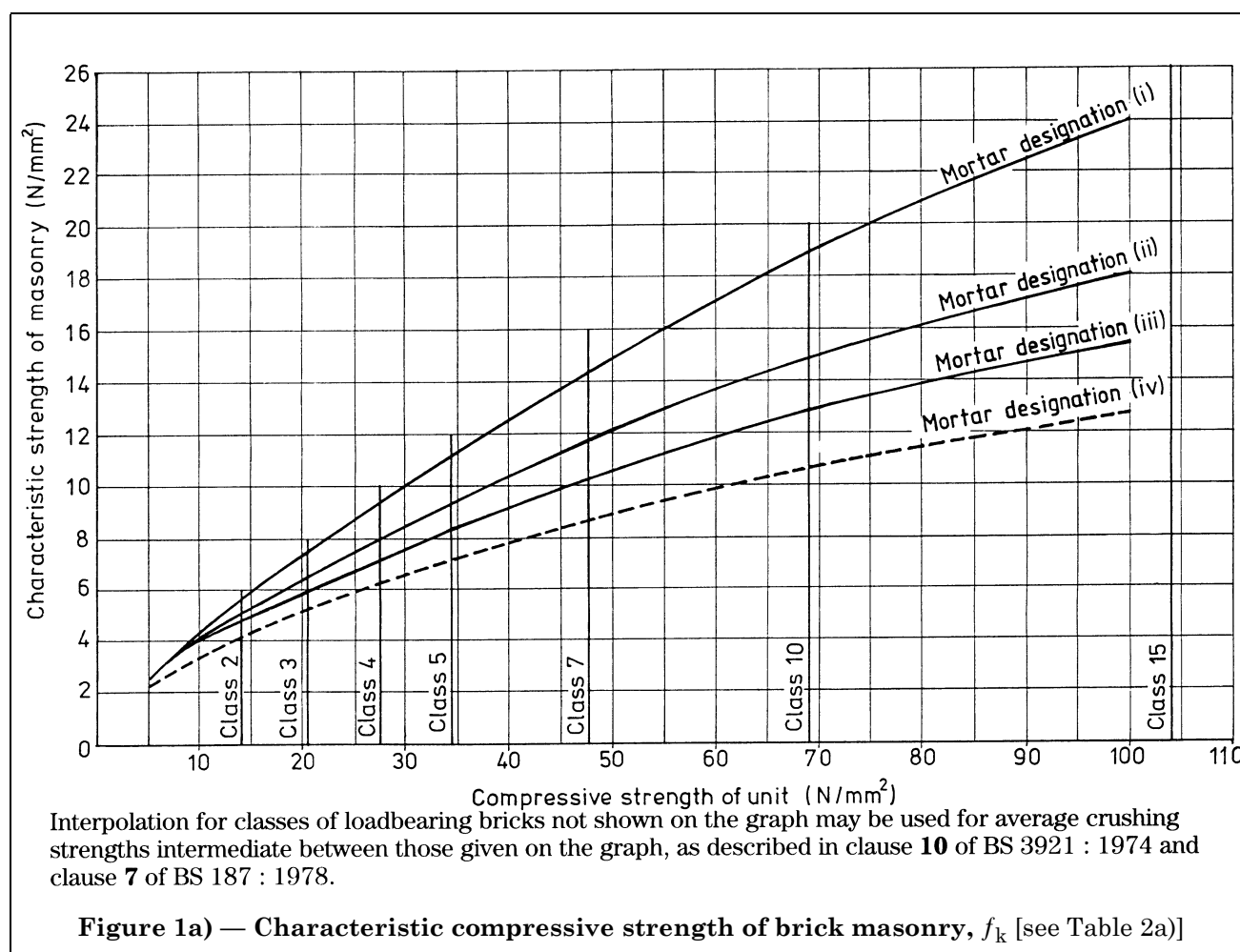
$$(0.70 + 1.5A)$$

where

A is the horizontal loaded cross-sectional area of the wall or column (m²).

23.1.2 Narrow brick walls

When brick walls are constructed so that the thickness of the wall or loaded inner leaf of a cavity wall is equal to the width of a standard format brick, the values of f_k obtained from Table 2a) may be multiplied by 1.15.



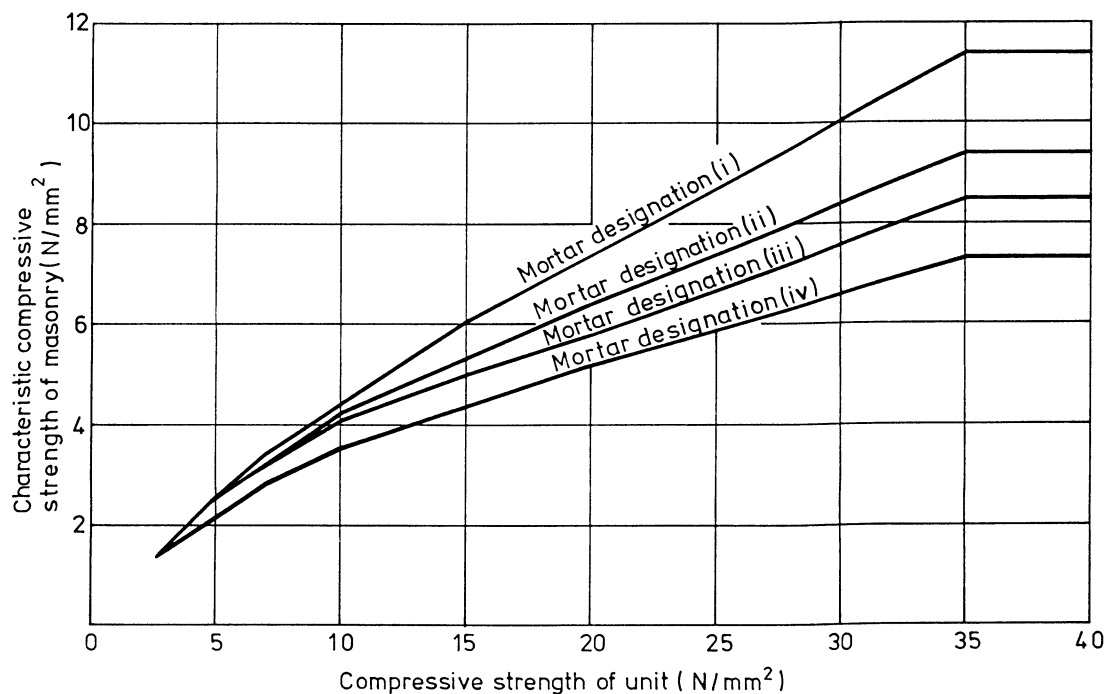


Figure 1b) — Characteristic compressive strength, f_k , of block masonry constructed with blocks having a ratio of height to least horizontal dimension of 0.6 [see Table 2b)]

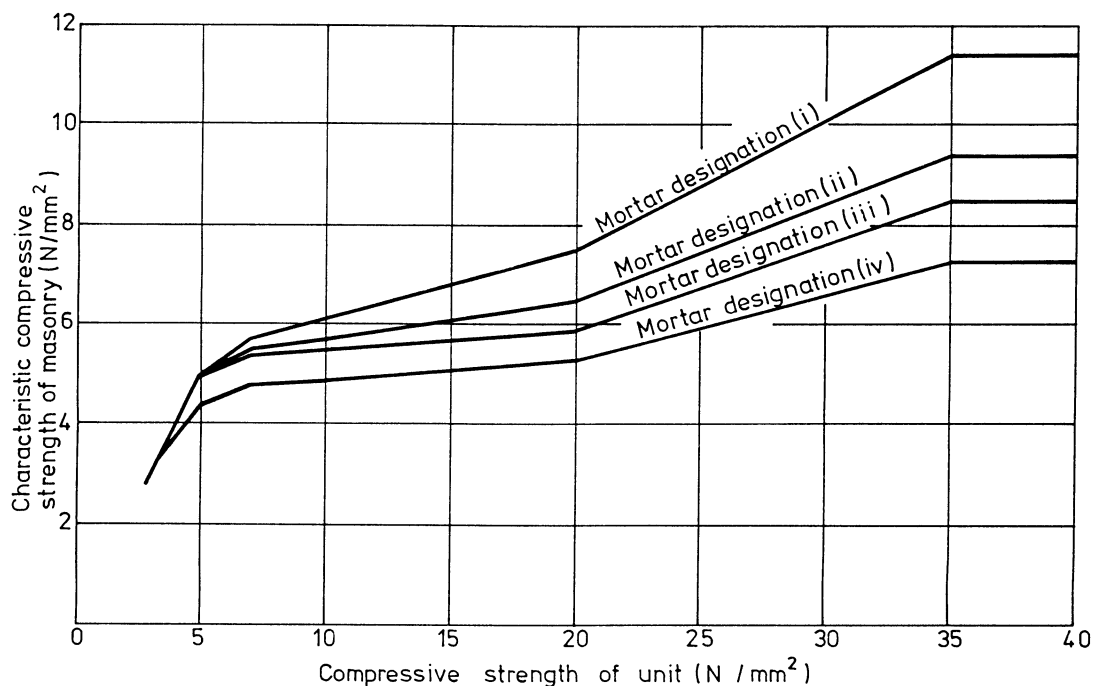


Figure 1c) — Characteristic compressive strength, f_k , of block masonry constructed with hollow blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0 [see Table 2c)]

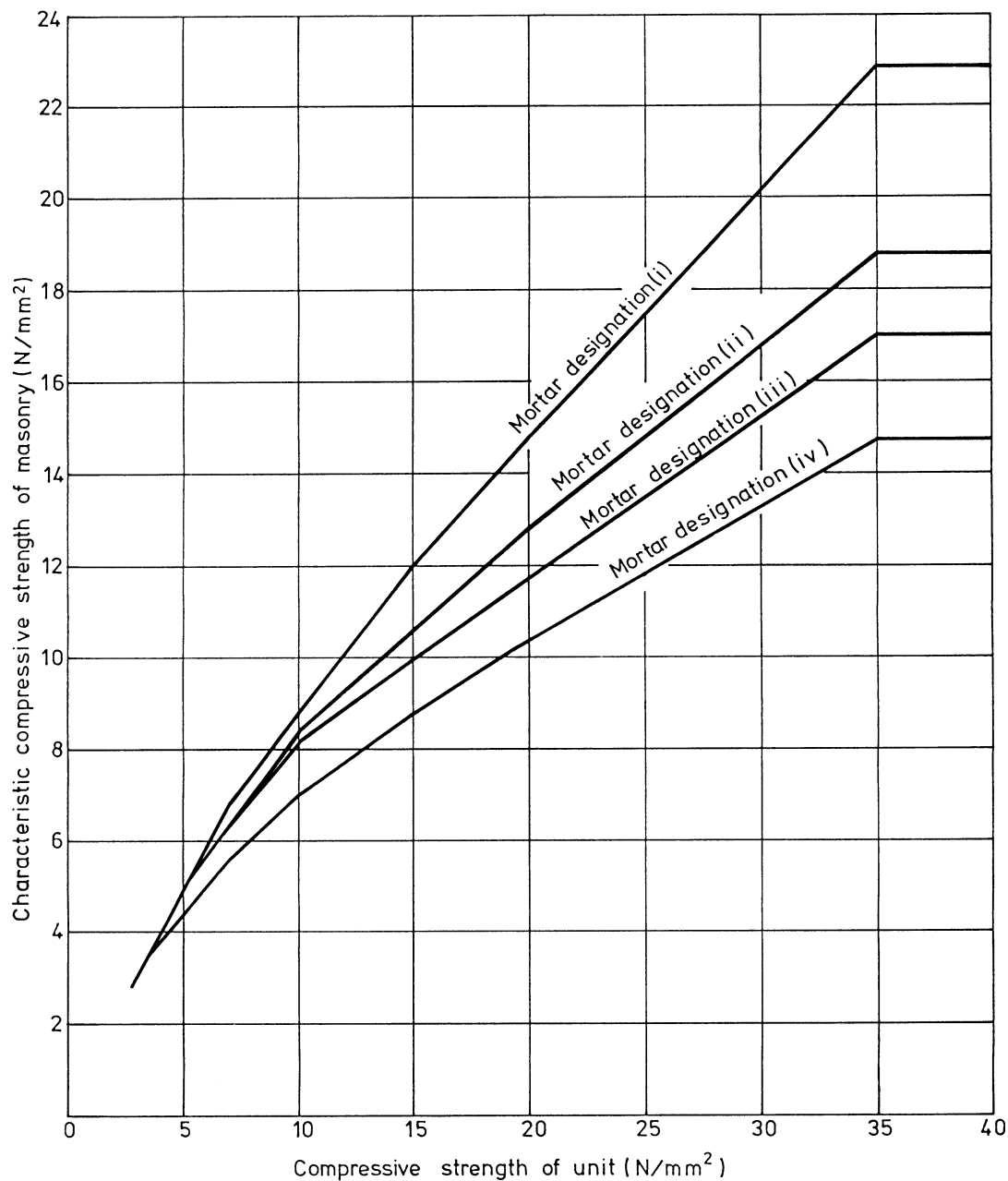


Figure 1d) — Characteristic compressive strength, f_k , of block masonry constructed from solid concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0 [see Table 2d)]

Table 2 — Characteristic compressive strength of masonry, f_k , in N/mm²

a) Constructed with standard format bricks									
Mortar designation	Compressive strength of unit (N/mm ²)								
	5	10	15	20	27.5	35	50	70	100
(i)	2.5	4.4	6.0	7.4	9.2	11.4	15.0	19.2	24.0
(ii)	2.5	4.2	5.3	6.4	7.9	9.4	12.2	15.1	18.2
(iii)	2.5	4.1	5.0	5.8	7.1	8.5	10.6	13.1	15.5
(iv)	2.2	3.5	4.4	5.2	6.2	7.3	9.0	10.8	12.7
b) Constructed with blocks having a ratio of height to least horizontal dimension of 0.6									
Mortar designation	Compressive strength of unit (N/mm ²)								
	2.8	3.5	5.0	7.0	10	15	20	35 or greater	
(i)	1.4	1.7	2.5	3.4	4.4	6.0	7.4	11.4	
(ii)	1.4	1.7	2.5	3.2	4.2	5.3	6.4	9.4	
(iii)	1.4	1.7	2.5	3.2	4.1	5.0	5.8	8.5	
(iv)	1.4	1.7	2.2	2.8	3.5	4.4	5.2	7.3	
c) Constructed with hollow blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0									
Mortar designation	Compressive strength of unit (N/mm ²)								
	2.8	3.5	5.0	7.0	10	15	20	35 or greater	
(i)	2.8	3.5	5.0	5.7	6.1	6.8	7.5	11.4	
(ii)	2.8	3.5	5.0	5.5	5.7	6.1	6.5	9.4	
(iii)	2.8	3.5	5.0	5.4	5.5	5.7	5.9	8.5	
(iv)	2.8	3.5	4.4	4.8	4.9	5.1	5.3	7.3	
d) Constructed from solid concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.0									
Mortar designation	Compressive strength of unit (N/mm ²)								
	2.8	3.5	5.0	7.0	10	15	20	35 or greater	
(i)	2.8	3.5	5.0	6.8	8.8	12.0	14.8	22.8	
(ii)	2.8	3.5	5.0	6.4	8.4	10.6	12.8	18.8	
(iii)	2.8	3.5	5.0	6.4	8.2	10.0	11.6	17.0	
(iv)	2.8	3.5	4.4	5.6	7.0	8.8	10.4	14.6	

23.1.3 Walls constructed in modular bricks

For 90 mm wide × 90 mm high modular bricks complying with the requirements of BS 6073-1 or as detailed in DD 34 or DD 59, the values of f_k in Table 2a) may be multiplied by the following factors:

- a) masonry thickness equal to width of brick: 1.25;
- b) other thicknesses: 1.10.

23.1.4 Walls constructed of wide bricks

When walls are constructed with bricks having a ratio of height to least horizontal dimension of less than 0.6, the value of f_k should have been obtained from wall tests carried out in accordance with A.2.

23.1.5 Hollow block walls

When walls are built of hollow blocks having a ratio of height to least horizontal dimension of between 0.6 and 2.0, the value of f_k should be obtained by interpolation between the values given in Table 2b) and Table 2c).

23.1.6 Solid concrete block walls

When walls are 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, the value of f_k should be obtained by interpolation between the values given in Table 2b) and Table 2d).

23.1.7 Walls of hollow concrete blocks filled with in-situ concrete

When walls are built with hollow concrete blocks and the vertical cavities are completely filled with in-situ concrete, the characteristic compressive strength of the masonry should be obtained as if the blocks were solid (see 23.1.6), provided that:

- a) the compressive strength of the blocks is assessed on their net area;
- b) the 28-day cube strength of the concrete infilling is not less than the compressive strength of the blocks derived from a) above.

23.1.8 Natural stone masonry

Natural stone masonry should be designed on the basis of solid concrete blocks of an equivalent compressive strength. Where masonry is constructed from large, carefully shaped pieces with relatively thin joints, its loadbearing capacity is more closely related to the intrinsic strength of the stone than is the case where small structural units are used. Design stresses in excess of those obtained from this code may be allowed in such massive stone masonry, provided that the designer is satisfied that the properties of the stone warrant an increase.

23.1.9 Random rubble masonry

The characteristic strength of random rubble masonry may be taken as 75 % of the corresponding strength of natural stone masonry built with similar materials. In the case of rubble masonry built with lime mortar, the characteristic strength may be taken as one-half of that for masonry in mortar designation (iv).

23.2 Structural units laid other than on the normal bed face

Where structural units are laid other than on the normal bed face, the compressive strength of the unit as determined for that direction (see clause 8) should be adopted when using Table 2.

23.3 Perforated bricks and hollow blocks

The compressive strength of perforated bricks and hollow blocks is determined by dividing the ultimate load by the gross plan area of the unit, as if it were solid. This compressive strength should therefore be used in obtaining the value of f_k from Table 2a), Table 2b) and Table 2c). Hollow concrete blocks are sometimes laid with mortar on the two outer strips of block (shell bedding), in which case the value of f_k should be obtained as usual from Table 2b) and Table 2c), but the design strength of the wall should be reduced by the ratio of the bedded area to the net area of block.

24 Characteristic flexural strength of masonry, f_{kx}

24.1 General

The characteristic flexural strength, f_{kx} , should be used only in the design of masonry in bending. In general, no direct tension should be allowed in masonry. However, at the designer's discretion half the values in Table 3 may be allowed in direct tension when suction forces arising from wind loads on roof structures are transmitted to masonry walls, or when the probable effects of misuse or accidental damage (see Section 5) are being considered. In no circumstances may the combined flexural and direct tensile stresses exceed the values given in Table 3.

Flexural tension should be relied on at a damp proof course only if the damp proof course consists of a material which has been proved by tests (see DD 86-1) to permit the joint to transmit tension or if it is of bricks complying with the requirements of BS 743.

24.2 Flexural strength

The characteristic flexural strength values given in Table 3 may be used for the categories of brick, block and mortar shown or, alternatively, tests may be carried out in accordance with A.3.

Linear interpolation between entries in Table 3 is permitted for:

- a) concrete block walls of thickness between 100 mm and 250 mm;
- b) concrete blocks of compressive strength between 2.8 N/mm² and 7.0 N/mm² in a wall of given thickness.

25 Characteristic shear strength of masonry, f_v

The characteristic shear strength of masonry, f_v , in the horizontal direction of the horizontal plane (see Figure 2) may be taken as $0.35 + 0.6g_A$ N/mm² with a maximum of 1.75 N/mm² for walls built in mortar designations (i) and (ii) or $0.15 + 0.6g_A$ N/mm² with a maximum of 1.4 N/mm² for walls built in mortar designations (iii) and (iv):

where

g_A is the design vertical load per unit area of wall cross section due to the vertical loads calculated from the appropriate loading condition specified in clause 22.

The characteristic shear strength f_v of bonded masonry in the vertical direction of the vertical plane (see Figure 2) may be taken as:

a) for brick:

0.7 N/mm² [for mortar designations (i) and (ii)];

0.5 N/mm² [for mortar designations (iii) and (iv)];

b) for dense aggregate solid concrete block with a minimum strength of 7 N/mm²:

0.35 N/mm² [for mortar designations (i), (ii) and (iii)].

26 Coefficient of friction

The coefficient of friction between clean concrete and masonry faces may be taken as 0.6.

27 Partial safety factors for material strength, γ_m

27.1 General

The value of γ_m to be used in the application of the design procedures given in Section 4 and Section 5 should be related to the quality control exercised.

27.2 Quality control

The value of γ_m adopted should be commensurate with the degree of control exercised both during the manufacture of the structural units and in the site supervision, and also with the quality of the mortar used during construction. Two levels of control are recognized in each case, as detailed in 27.2.1 and 27.2.2.

27.2.1 Manufacturing control

27.2.1.1 Normal category

Normal category should be assumed when the supplier is able to meet the requirements for compressive strength in the appropriate British Standard, but does not meet the requirements for the special category detailed in 27.2.1.2.

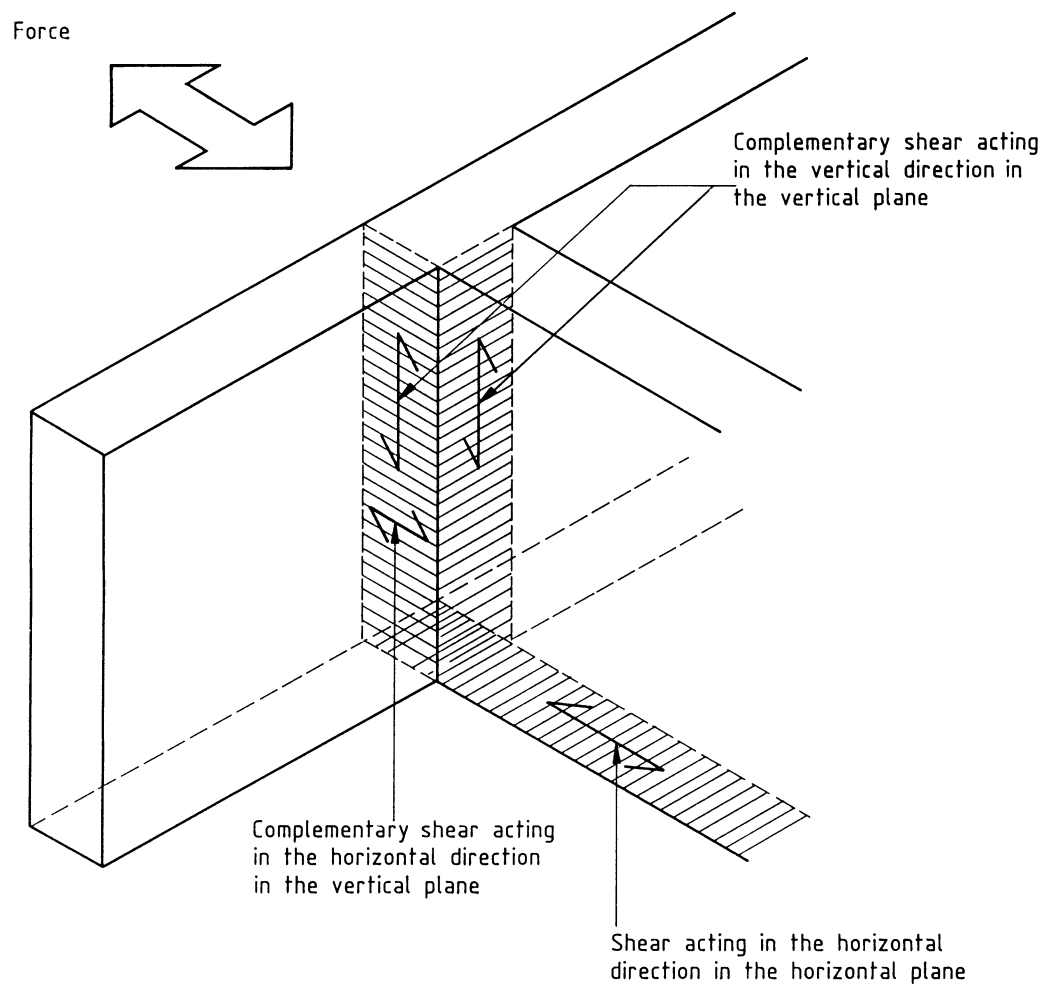


Figure 2 — Shear forces acting in the horizontal and vertical planes