

Code of practice for the use of masonry —

Part 1: Structural use of unreinforced masonry

ICS 91.080.30

Committees responsible for this British Standard

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British Precast Concrete Federation

CERAM Research Ltd.

Concrete Block Association

Construction Federation

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Mortar Industry Association Ltd.

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Foreword

This part of BS 5628 has been prepared under the direction of Subcommittee B/525/6, Use of masonry. It supersedes BS 5628-1:1992, which will be withdrawn on 31 March 2006.

The start and finish of text introduced or altered by Corrigendum No. 1 is indicated by tags **[C1]** **[C1]**.

BS 5628 is published in the following parts:

- Part 1: *Structural use of unreinforced masonry*;
- Part 2: *Structural use of reinforced and prestressed masonry*;
- Part 3: *Materials and components, design and workmanship*.

This edition of BS 5628-1 is a revision of the standard necessary to accommodate the publication of BS EN 771, BS EN 845 and BS EN 998 (see Clause 2), and the consequent withdrawal of the standards that they superseded.

Where materials, components and methods of design and construction are not covered by this or any other British Standard, this does not discourage their use. The designer may need to be satisfied by reference to the appropriate manufacturers' literature and test certificates, if any, issued by competent, independent authorities to ensure that the materials and methods to be employed provide a level of performance at least equal to that recommended in this standard.

As a code of practice, this part of BS 5628 takes the form of guidance and recommendations. It should not be quoted as though it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

This standard was drafted on the assumption that the execution of its recommendations is entrusted to appropriately qualified and competent people.

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

This document comprises a front cover, an inside front cover, pages i to iii, a blank page, pages 1 to 73 and a back cover.

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Section 1. General

1 Scope

This Part of BS 5628 gives recommendations for the structural design of unreinforced masonry units of bricks, blocks, manufactured stone, square dressed natural stone, and random rubble masonry.

NOTE 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 or BS 5390, 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 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 3892-1, *Pulverized-fuel ash — Specification for pulverized-fuel ash for use with Portland cement.*

BS 4027, *Specification for sulfate-resisting Portland cement.*

BS 4729, *Specification for dimensions of bricks of special shapes and sizes.*

BS 5224, *Specification for masonry cement.*

BS 5628, *Code of practice for the use of masonry — Part 2: Structural use of reinforced and prestressed masonry.*

BS 5628:2005, *Code of practice for the use of masonry — Part 3: Materials and components, design and workmanship.*

BS 6399-1, *Design loading for buildings — Part 1: Code of practice for dead and imposed loads.*

BS 6399-2, *Design loading for buildings — Part 2: Code of practice for wind loads.*

BS 6399-3, *Design loading for buildings — Part 3: Code of practice for imposed roof loads.*

BS 6699, *Specification for ground granulated blastfurnace slag for use with Portland cement.*

BS 7979, *Specification for limestone fines for use with Portland cement.*

BS 8000, *Workmanship on building sites — Part 3: Code of practice for masonry.*

BS 8002, *Code of practice for earth retaining structures.*

BS 8103, *Structural design of low-rise buildings — Part 1: Code of practice for stability, site investigation, foundations and ground floor slabs for housing.*

BS 8215:1998, *Code of practice for design and installation of damp-proof courses in masonry construction.*

BS EN 450-1, *Fly ash for concrete — Definition, specifications and conformity criteria.*

BS EN 197, *Cement — Part 1: Composition, specifications and conformity criteria for common cements.*

BS EN 771-1, *Specification for masonry units — Clay masonry units.*

BS EN 771-2, *Specification for masonry units — Calcium silicate masonry units.*

BS EN 771-3, *Specification for masonry units — Aggregate concrete masonry units.*

BS EN 771-4, *Specification for masonry units — Autoclaved aerated concrete masonry units.*

BS EN 771-5, *Specification for masonry units — Manufactured stone masonry units.*

BS EN 771-6, *Specification for masonry units — Natural stone masonry units.*

BS EN 772-1, *Methods of test for masonry units — Determination of compressive strength.*

BS EN 772-7, *Methods of test for masonry units — Determination of water absorption of clay masonry damp proof course units by boiling in water.*

BS EN 845, *Specification for ancillary components for masonry — Part 1: Ties, tension straps, hangers and brackets.*

BS EN 934, *Admixtures for concrete, mortar and grout — Part 3: Admixtures for masonry mortar. Definitions, requirements, conformity, marking and labelling.*

BS EN 998, *Specification for mortar for masonry — Part 2: Masonry mortar.*

BS EN 1015, *Methods of test for mortar for masonry — Part 2: Bulk sampling of mortars and preparation of test mortars.*

BS EN 1015, *Methods of test for mortar for masonry — Part 11: Determination of flexural and compressive strength of hardened mortar.*

BS EN 1052, *Methods of test for masonry — Part 1: Determination of compressive strength.*

BS EN 1052, *Methods of test for masonry — Part 2: Determination of flexural strength.*

BS EN 1052, *Methods of test for masonry — Part 3: Determination of initial shear strength.*

BS EN 1052, *Methods of test for masonry — Part 4: Determination of shear strength including damp proof course.*

BS EN 12878, *Pigments for the colouring of building materials based on cement and/or lime. Specifications and methods of test.*

DD 86, *Damp proof courses — Part 1: Methods of test for flexural bond strength and short term shear strength.*

DD 86, *Damp proof courses — Part 2: Method of test for creep deformation.*

3 Definitions

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

3.1

actual dimension

<either> work size of the unit

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

3.2

building classes

3.2.1

building class 1

- houses not exceeding four storeys;
- agricultural buildings;
- buildings into which people rarely go, provided no part of the building is closer to another building, or area where people do go, than a distance 1.5 times the building height.

3.2.2

building class 2A

- five-storey single occupancy houses;
- hotels not exceeding four storeys;
- flats, apartments and other residential buildings not exceeding four storeys;
- offices not exceeding four storeys;
- industrial buildings not exceeding three storeys;
- retaining premises not exceeding three storeys of less than 2 000 m² floor area in each storey;
- single-storey educational buildings;
- all buildings not exceeding two storeys to which members of the public are admitted and which contain floor areas not exceeding 2 000 m² at each storey.

3.2.3**building class 2B**

- hotels, flats, apartments and other residential buildings greater than four storeys but not exceeding 15 storeys;
- educational buildings greater than one storey but not exceeding 15 storeys;
- retailing premises greater than three storeys but not exceeding 15 storeys;
- hospitals not exceeding three storeys;
- offices greater than four storeys but not exceeding 15 storeys;
- all buildings to which members of the public are admitted which contain floor areas exceeding 2 000 m² but less than 5 000 m² at each storey;
- car parking not exceeding six storeys.

3.2.4**building class 3**

- all buildings defined above as class 2A and 2B that exceed the limits on area and/or number of storeys;
- grandstands accommodating more than 5 000 spectators;
- buildings containing hazardous substances and/or processes.

3.3**Category I masonry unit**

unit with a declared compressive strength, with a probability of failure to reach it not exceeding 5 %

NOTE This probability may be determined via the mean or characteristic value.

3.4**Category II masonry unit**

unit not intended to conform to the level of confidence of Category I units

3.5**characteristic load**

<ideally, where the load acts unfavourably> load which has a probability of not more than 5 % of being exceeded;

or,

<where the load acts favourably> load which has a probability of at least 95 % of being exceeded

NOTE In practice, the value of a characteristic load is obtained from the appropriate British Standard.

3.6**characteristic strength of masonry**

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

3.7**compressive strength of masonry units (other than manufactured stone)**

mean (not normalized) strength of a sample of masonry units tested in accordance with the test method prescribed in BS EN 772-1

3.8**column**

isolated vertical loadbearing member the width of which is not more than four times its thickness

3.9**design load**

characteristic load multiplied by a partial safety factor for loads

3.10**design strength**

characteristic strength divided by a partial safety factor for material strength

3.11**effective height or length**

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

3.12

effective thickness

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

3.13

key element

structural member capable of resisting a specified load

3.14

laterally loaded wall panels

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

3.15

lateral support

<in relation to a wall or pier> support that will restrict movement in the direction of the thickness of the wall

3.16

lateral support

<in relation to a column> support that will restrict movement in the direction of its thickness or width

NOTE Lateral supports may be horizontal or vertical.

3.17

loadbearing wall

wall primarily designed to carry an imposed vertical load in addition to its own weight

3.18

masonry

assemblage of masonry units, either laid in-situ or constructed in prefabricated panels, in which the masonry units are bonded and solidly put together with mortar or grout

NOTE Masonry may be reinforced or unreinforced.

3.19

orthogonal ratio

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

3.20

pier

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

3.21

slenderness ratio

ratio of the effective height or length to the effective thickness

3.22

masonry units

bricks or blocks of clay, calcium silicate, aggregate concrete, autoclaved aerated concrete, manufactured stone and natural stone

3.23

types of masonry mortar

3.23.1

designed masonry mortar

mortar, the composition and manufacturing method of which is chosen by the producer in order to achieve specified properties (performance concept)

3.23.2

prescribed masonry mortar

mortar made in pre-determined proportions, the properties of which are determined by the stated proportion of the constituents (recipe concept)

3.23.3***factory made masonry mortar***

mortar batched and mixed in a factory

NOTE It may be “dry mortar” which is ready mixed only requiring the addition of water, or “wet mortar” which is supplied ready for use.

3.23.4***semi-finished masonry mortar***

mortar defined in 3.23.5 or 3.23.6

3.23.5***pre-batched masonry mortar***

mortar, the constituents of which are wholly batched in a factory, supplied to the building site and mixed there according to the manufacturer's specification and conditions

3.23.6***premixed lime-sand masonry mortar***

mortar, the constituents of which are wholly batched and mixed in a plant, and supplied to the building site where further constituents specified or provided by the factory (e.g. cement and water) are added

3.23.7***thin layer masonry mortar***

designed mortar with a maximum aggregate size less than or equal to a prescribed figure

NOTE It is usually used in joints between 1 mm and 3 mm thick.

3.24**types of wall****3.24.1*****single leaf wall***

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

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

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

3.24.3***cavity wall***

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

3.24.4***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

3.24.5***faced wall***

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

3.24.6***veneered wall***

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

3.25**wallette**

small masonry panel constructed for test purposes

4 Symbols

For the purposes of this part of BS 5628, the following symbols apply:

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 17)
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_{yt}	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	span in accidental 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

5 Alternative materials and methods of design and construction

Where materials and methods are used that are not referred to in this British Standard, their use is not discouraged, provided that the materials conform to the requirements of the appropriate British Standards or other documents, 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 British Standard.

Where materials or methods are used that are not referred to by this 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, the characteristic shear strength and characteristic flexural strength of masonry are set out in BS EN 1052-1, BS EN 1052-3 and BS EN 1052-2 respectively.

Section 2. Materials, components and workmanship

6 General

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

7 Masonry units

The following masonry units should conform to the appropriate clauses in the relevant British Standard:

clay masonry units	BS EN 771-1
calcium silicate masonry units	BS EN 771-2
aggregate concrete masonry units	BS EN 771-3
autoclaved aerated concrete masonry units	BS EN 771-4
manufactured stone masonry units	BS EN 771-5
natural stone masonry units	BS EN 771-6
bricks of special shapes and sizes	BS 4729

Materials that have been previously used should only be re-used in masonry construction after they have been thoroughly cleaned and conform to the code recommendations for similar new materials.

8 Laying of masonry units

8.1 General

Masonry units will normally be laid on their bed faces, but some concrete block walls will be built by laying blocks flat; tables for compressive strength are given for this circumstance. In other cases 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 BS 5628-2, Annex D or the test method prescribed in BS EN 772-1.

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

8.2 Bricks with frogs

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

8.3 Hollow and cellular blocks

8.3.1 *Hollow clay blocks*

Hollow clay blocks conforming to BS EN 771-1 may have horizontal or vertical formed voids. The blocks should be laid on a full bed of mortar, except those with vertical perforations which are designed to be laid with shell bedding in accordance with the manufacturer's recommendations.

8.3.2 *Hollow and cellular concrete blocks*

Hollow and cellular concrete blocks conforming to BS EN 771-3 may be laid on a full bed of mortar. Occasionally such blocks are laid with shell bedding.

9 Rate of laying

The maximum height that should normally be built in a day is 1.5 m except when thin layer mortar is used.

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.

11 Damp proof courses

Damp proof courses should conform to the requirements of one of the British Standards, as appropriate, specified in BS 5628-3:2005, Clause 4.7.

Designers should pay particular attention to the characteristics of the materials chosen for damp proof courses. Materials that 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 prescribed in DD 86-1 and -2 and BS EN 1052-4.

12 Wall ties, tension straps, joist hangers and brackets

Wall ties, tension straps, joist hangers and brackets should conform to BS EN 845-1 and should be used in accordance with the recommendations made in BS 5628-3.

13 Cements

The following cements, or combination of cements, are suitable for use in mortars:

Cements:

Portland cement	BS EN 197-1 Notation CEM I
Limestone cement	BS EN 197-1 Notation CEM II/A-L and CEM II/A-LL
Sulfate-resisting Portland cement	BS 4027
Portland-slag cement	BS EN 197-1 Notation CEM or II/A-S or II/B-S
Portland-fly ash cement	BS EN 197-1 Notation CEM II/A-V or II/B-V
[C ₁] Masonry cement (inorganic filler, other than lime)	BS EN 413-1, Class MC 12.5 [C ₁]
[C ₁] Masonry cement (lime)	BS EN 413-1 Notation CEM I (not less than 65 % by mass) and lime [C ₁]

Combinations of cements:

- Combinations produced in the mortar mixer from Portland cement CEM I conforming to BS EN 197-1 and ground granulated blastfurnace slag conforming to BS 6699 where the proportions and properties conform to CEM II/A-S or CEM II/B-S of BS EN 197-1:2000, except Clause 9 of that standard.
- Combinations produced in the mortar mixer from Portland cement CEM I conforming to BS EN 197-1 and limestone fines conforming to BS 7979 where the proportions and properties conform to CEM II/A-L or CEM II/A-LL of BS EN 197-1:2000, except Clause 9 of that standard.
- Combinations produced in the mortar mixer from Portland cement CEM I conforming to BS EN 197-1 and pulverized fuel ash conforming to BS 3892-1, or to BS EN 450-1, where the proportions and properties conform to CEM II/A-V or CEM II/B-V of BS EN 197-1:2000, except Clause 9 of that standard.

The use of high alumina cement is not permitted.

14 Masonry mortars

14.1 General

The use of mortars should be in accordance with the recommendations given in BS 5628-3. For site made mortars, the mixing of the mortar should be in accordance with BS 5628-3. For factory made, semi-finished factory made and pre-batched masonry mortars, BS EN 998-2 applies.

Mortars should be designed or prescribed. For designed mortars, the compressive strength of the mortar provides the control of the hardened mortar quality. When samples are taken from a designed mortar in accordance with BS EN 1015-2, and tested in accordance with BS EN 1015-11, the compressive strength of the mortar should not be less than the declared compressive strength. Table 1 shows the relationship of compressive strength classes to strength.

14.2 Semi-finished factory made and pre-batched mortars

Semi-finished factory made and pre-batched mortars should conform to the requirements of BS EN 998-2. For designed mortars, the manufacturer should declare the strength that he is offering; for prescribed mortars, the provisions given in 14.1 apply.

Where pre-mixed lime-sand mortars are used, the specified addition of cement on site should be gauged.

14.3 Colouring agents

Pigments should conform to the requirements of BS EN 12878 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.

14.4 Plasticizers

Plasticizers should conform to the requirements of BS EN 934-3.

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

14.5 Frost inhibitors

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

Table 1 — Masonry mortars

	Mortar designation	Compressive strength class	Prescribed mortars (proportion of materials by volume) (see notes 1 and 2)				Compressive strength at 28 days N/mm ²
			cement ^a , lime: sand with or without air entrainment	cement ^a , sand with or without air entrainment	masonry cement ^b : sand	masonry cement ^c : sand	
Increasing ability to accommodate movement, e.g. due to settlement, temperature and moisture changes ↓ →	(i)	M12	1 : 0 to ¼ : 3	—	—	—	12
	(ii)	M6	1 : ½ : 4 to 4½	1 : 3 to 4	1 : 2½ to 3½	1 : 3	6
	(iii)	M4	1 : 1 : 5 to 6	1 : 5 to 6	1 : 4 to 5	1 : 3½ to 4	4
	(iv)	M2	1 : 2 : 8 to 9	1 : 7 to 8	1 : 5½ to 6½	1 : 4½	2
^a Cement, or combination of cements, in accordance with Clause 13, except masonry cements ^b Masonry cement in accordance with Clause 13, (inorganic filler other than lime) ^c Masonry cement in accordance with Clause 13, (lime)							
NOTE 1. 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 2. When the sand portion is given as, for example, 5 to 6, the lower figure should be used with sands containing a higher proportion of fines whilst the higher figure should be used with sands containing a lower proportion of fines.							

Section 3. Design: objectives and general recommendations

15 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 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 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.

16 Stability

16.1 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 four 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. $0.015 G_k$) above any level (see 18b) and c));
- b) connections of the type indicated in Annex C should be provided as appropriate at floors and roofs.

16.2 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 British Standard. However, in order to establish section sizes and strengths that 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 Clauses 17 and 18, 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.

16.3 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.

16.4 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.

17 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.
- 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 6399-1 and BS 6399-3.
- 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 18).

18 Design loads: partial safety factor, γ_f

When using the design relationship for the ultimate limit state given in Sections 3 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
 - i) design dead load = $0.9 G_k$ or $1.4 G_k$
 - ii) design imposed load = $1.6 Q_k$
 - iii) design worst credible earth and water lateral load = $1.2 E_u$
- b) Dead and wind load
 - i) design dead load = $0.9 G_k$ or $1.4 G_k$
 - ii) design wind load = $1.4 W_k$
 - iii) design worst credible earth and water lateral load = $1.2 E_u$

In the particular case of freestanding walls and laterally loaded wall panels, the removal of which 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
 - i) design dead load = $1.2 G_k$
 - ii) design imposed load = $1.2 Q_k$
 - iii) design wind load = $1.2 W_k$
 - iv) design worst credible earth and water lateral load = $1.2 E_u$
- d) Accidental damage (see Clause 33)
 - i) design dead load = $0.95 G_k$ or $1.05 G_k$
 - ii) design imposed load = $0.35 Q_k$ except that, in the case of buildings used predominantly for storage, or where the imposed load is of a permanent nature, $1.05 Q_k$ should be used
 - iii) design wind load = $0.35 W_k$

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 lateral load (see Clause 17)
- 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 the *Civil Engineering Code of Practice No. 2* [3], the appropriate safety factor γ_f for the 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.

19 Characteristic compressive strength of masonry, f_k

19.1 Normal masonry

19.1.1 *General*

The characteristic compressive strength, f_k , of any masonry may be determined by tests on specimens, in accordance with BS EN 1052-1.

For normally bonded masonry (other than manufactured stone) defined in terms of the shape and compressive strength of the masonry units and the classification of the mortar (see Table 1), the values given in Table 2 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.

Table 2a) applies to masonry built with standard format bricks of clay or calcium silicate, conforming to the requirements of BS EN 771-1 or -2, and having no more than 25 % formed voids (perforations) or 20 % frogs.

Table 2b) applies to masonry built with autoclaved aerated concrete blocks having a ratio of height to least horizontal dimension of 0.6.

Table 2c) applies to masonry built with aggregate concrete blocks and having a ratio of height to least horizontal dimension of 0.6.

Table 2d) applies to masonry built with aggregate concrete blocks having not more than 25 % of formed voids and a ratio of height to least horizontal dimension of between 2.0 and 4.5.

Table 2e) applies to masonry built with autoclaved aerated concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.5.

Table 2f) applies to masonry built with aggregate concrete blocks having more than 25 % but less than 60 % of formed voids and a ratio of height to least horizontal dimension of between 2.0 and 4.5.

Table 2g) applies to masonry built with solid aggregate concrete blocks having a block height/wall thickness ratio of between 1.0 and 1.2 as a collar jointed wall.

Table 2h) applies to masonry built with solid aggregate concrete blocks laid flat having an as laid height/wall thickness ratio of between 0.4 and less than 0.6

The characteristic compressive strength of masonry bonded with thin layer mortar may be taken as the values given for mortar strength class M 12 (mortar designation (i)) in Table 2.

19.1.2 *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 (in m²).

19.1.3 *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.

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

<i>a) — Constructed with standard format bricks of clay and calcium silicate having no more than 25% of formed voids, or 20% frogs</i>											
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a										
	5	10	15	20	30	40	50	75	100	125	150
M12 / (i)	2.5	4.0	5.3	6.4	8.3	10.0	11.6	15.2	18.3	21.2	23.9
M6 / (ii)	2.5	3.8	4.8	5.6	7.1	8.4	9.5	12.0	14.2	16.1	17.9
M4 / (iii)	2.5	3.4	4.3	5.0	6.3	7.4	8.4	10.5	12.3	14.0	15.4
M2 / (iv)	2.2	2.8	3.6	4.1	5.1	6.1	7.1	9.0	10.5	11.6	12.7
<i>b) — Constructed with autoclaved aerated concrete blocks having a ratio of height to least horizontal dimension of 0.6</i>											
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a										
	2.9	3.6	5.2	7.3	10.4						
M12 / (i)	1.4	1.7	2.5	3.4	4.4						
M6 / (ii)	1.4	1.7	2.5	3.2	4.2						
M4 / (iii)	1.4	1.7	2.5	3.2	4.1						
M2 / (iv)	1.4	1.7	2.5	2.8	3.5						
<i>c) — Constructed with aggregate concrete blocks having a ratio of height to least horizontal dimension of 0.6</i>											
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a										
	2.9	3.6	5.2	7.3	10.4	17.5	22.5	30	40 or greater		
M12 / (i)	1.4	1.7	2.5	3.4	4.4	6.3	7.5	9.5	11.2		
M6 / (ii)	1.4	1.7	2.5	3.2	4.2	5.5	6.5	7.9	9.3		
M4 / (iii)	1.4	1.7	2.5	3.2	4.1	5.1	6.0	7.2	8.2		
M2 / (iv)	1.4	1.7	2.2	2.8	3.5	4.6	5.3	6.2	7.1		
<i>d) — Constructed with aggregate concrete blocks having not more than 25% of formed voids and a ratio of height to least horizontal dimension of between 2.0 and 4.5</i>											
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a										
	2.9	3.6	5.2	7.3	10.4	17.5	22.5	30	40 or greater		
M12 / (i)	2.8	3.5	5.0	6.8	8.8	12.5	15.0	18.7	22.1		
M6 / (ii)	2.8	3.5	5.0	6.4	8.4	11.1	13.0	15.9	18.7		
M4 / (iii)	2.8	3.5	5.0	6.4	8.2	10.1	12.0	14.5	16.8		
M2 / (iv)	2.8	3.5	4.4	5.6	7.0	9.1	10.5	12.5	14.5		
<i>e) — Constructed with autoclaved aerated concrete blocks having a ratio of height to least horizontal dimension of between 2.0 and 4.5</i>											
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a										
	2.9	3.6	5.2	7.3	10.4						
M12 / (i)	2.8	3.5	5.0	6.8	8.8						
M6 / (ii)	2.8	3.5	5.0	6.4	8.4						
M4 / (iii)	2.8	3.5	5.0	6.4	8.2						
M2 / (iv)	2.8	3.5	4.4	5.6	7.0						

^a Measured in normal direction of test for units.

^a Measured in normal direction of test for units.

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

f) — Constructed with aggregate concrete blocks having more than 25% but less than 60% of formed voids and a ratio of height to least horizontal dimension of between 2.0 and 4.5									
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a								
	2.9	3.6	5.2	7.3	10.4	17.5	22.5	30	40 or greater
M12 / (i)	2.8	3.5	5.0	6.6	8.1	11.2	13.1	16.0	19.4
M6 / (ii)	2.8	3.5	5.0	6.4	7.5	9.9	11.6	14.0	16.7
M4 / (iii)	2.8	3.5	5.0	6.1	7.1	9.0	10.2	12.0	14.0
M2 / (iv)	2.8	3.5	4.4	5.8	6.7	8.0	8.9	10.2	11.5
g) — Constructed with aggregate concrete blocks having not more than 25% formed voids and having a block height/wall thickness ratio of between 1.0 and 1.2 as a collar jointed wall									
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a								
	2.9	3.6	5.2	7.3	10.4	17.5	22.5	30	40 or greater
M12 / (i)	2.8	3.4	4.4	5.5	7.0	9.7	11.6	14.2	16.5
M6 / (ii)	2.5	2.8	3.5	4.5	5.7	7.9	9.4	11.6	13.5
M4 / (iii)	2.3	2.4	3.1	4.0	5.1	7.0	8.3	10.3	12.0
M2 / (iv)	2.2	2.3	2.5	3.2	4.1	5.7	6.8	8.2	9.5
h) — Constructed with solid aggregate concrete blocks laid flat having an as laid height/wall thickness ratio of between 0.4 and 0.6									
Mortar strength Class/Designation	Compressive strength of unit (N/mm ²) ^a								
	2.9	3.6	5.2	7.3	10.4	17.5	22.5	30	40 or greater
M12 / (i)	2.8	3.5	4.5	5.6	7.2	9.7	11.3	13.5	15.4
M6 / (ii)	2.5	2.9	3.7	4.6	5.9	7.9	9.1	10.8	12.3
M4 / (iii)	2.3	2.5	3.2	4.1	5.2	7.0	8.1	9.6	11.1
M2 / (iv)	2.2	2.1	2.6	3.3	4.3	5.7	6.6	7.8	9.0

^a Measured in normal direction of test for units.

19.1.4 Walls constructed with bricks having more than 25% and less than 55% of formed voids

The characteristic compressive strength of masonry of walls constructed with bricks of clay or calcium silicate that have more than 25% and less than 55% of formed voids (perforations), may be taken from the values given in Table 2a) multiplied by 0.8, provided that the compressive strength of the units does not exceed 55 N/mm².

19.1.5 Walls constructed in modular bricks

For 90 mm wide × 90 mm high modular bricks conforming to the requirements of BS EN 771-1, -2 and -3, the values of f_k given in Table 2a) and Table 2c) as relevant may be multiplied by the following factors:

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

19.1.6 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 be obtained from tests carried out in accordance with BS EN 1052-1.

19.1.7 Hollow concrete block walls

When walls are built of blocks having more than 25% and less than 60% of formed voids and 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 2c) and those in Table 2f).

19.1.8 Concrete block walls having not more than 25% formed voids

When walls are built of C_{17} aggregate C_{17} concrete blocks having not more than 25% of formed voids and 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 2c) and those in C_{17} Table 2d) C_{17} .

19.1.9 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 had not more than 25% formed voids (see 19.1.8), 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.

19.1.10 Natural stone masonry

The characteristic compressive strength of stone masonry with bed joints 10 mm thick or less, and in mortar designation (iii) or stronger, may be taken as 0.35 times the mean compressive strength of the natural stone masonry units or representative cubes when prepared in accordance with BS EN 771-6 and tested in accordance with BS EN 772-1. Where the strength is derived from cubes, consideration should be given to the direction of any bedding planes, see BS EN 771-6.

19.1.11 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 strength class M2 (designation (iv)).

19.2 Masonry units laid other than on the normal bed face

Where masonry units, excluding aggregate concrete blocks, 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. When aggregate concrete blocks are laid on their stretcher face, that is laid flat, Table 2h) should be used in conjunction with the declared compressive strength of the unit when tested in the normal direction.

19.3 Perforated bricks and hollow blocks

The compressive strength of bricks and blocks having formed voids in them (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) to Table 2f). 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 interpolation between Table 2c) and Table 2f), but the design strength of the wall should be reduced by the ratio of the bedded area to the net area of block.

20 Characteristic flexural strength of masonry, f_{kx}

20.1 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, direct tension up to half the values given in Table 3 for the plane of failure parallel to the bed joints may be allowed 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 that has been proved by tests (see DD 86-1) to permit the joint to transmit tension, or if it is constructed with bricks conforming to the requirements of BS EN 771-1 for damp proof course bricks.