How to design masonry structures using Eurocode 6

1. Introduction to Eurocode 6

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Introduction

The introduction of European standards to UK construction is a significant event. The ten design standards, known as the Eurocodes, will affect all design and construction activities as current British standards for design are due to be withdrawn in March 2010.

This publication is part of a series of three guides entitled *How to design masonry structures using Eurocode 6*. The aim is to make the transition to Eurocode 6, *Design of masonry structures* as easy as possible by drawing together in one place key information and commentary required for the design of typical masonry elements.

The Concrete Centre and the Modern Masonry Alliance recognised that effective guidance is required to ensure that the UK design profession is able to use Eurocode 6 quickly, effectively, efficiently and with confidence. Therefore a steering group, with members from across the masonry industry (see back cover for a list of members), was established to oversee the development of these guides.

Guidance on Eurocode 6

The purpose of this series of guides is to introduce designers to the basic approach adopted in Eurocode 6. This is the first guide in the series of three and provides:

- A brief outline of the scope of Eurocode 6.
- An introduction to design, including fire resistance and movement.
- Assessment of actions and combination of actions using Eurocode*.
- How to specify mortar and masonry units.
- Glossary of Eurocode 6 terms.

The second guide in the series, *Vertical resistance*[1], explains how to design for vertical actions, whilst the third guide, *Lateral resistance*[2], covers the design of laterally loaded masonry panels. Further information on Eurocode 6 can be found at www.eurocode6.org.

Eurocode 6

Eurocode 6 comprises the following parts:

- Part 1–1, *General rules for reinforced and unreinforced masonry structures*[3].
- Part 1–2, *Structural fire design*[4].
- Part 2, *Design considerations, selection of materials and execution of masonry*[5].
- Part 3, *Simplified calculation methods for unreinforced masonry structures*[6].

Each part also has a National Annex (NA) which provides the Nationally Determined Parameters (NDPs) to be used in the application of Eurocode 6 in the UK. The UK NDPs have been used throughout this guide.

This series concentrates on Eurocode 6, Part 1–1 but includes material from Part 2 to explain the exposure and durability requirements. The scope and content of Part 1–2 and Part 3 are also briefly explained.

Eurocode 6 is intended to be used with Eurocode*: *Basis of structural design*[7], Eurocode 1: *Actions on structures*[8] and, where appropriate, the other Eurocodes and relevant European Standards. The guide *Introduction to Eurocodes*[9] provides more information on the Eurocode family.

Eurocode 6 has been developed to enable the designer to use the following types of masonry unit: clay, calcium silicate, aggregate concrete, autoclaved aerated concrete (aircrete), manufactured stone and natural stone. European standards for these materials have now been published by BSI and form part of an array of standards relating to masonry produced under the auspices of the European Committee for Standardisation (CEN), committee TC/125 (Masonry).

*BS EN 1990 is entitled 'Eurocode', but is often referred to as Eurocode 0.

Scope of Part 1–1 of Eurocode 6

Part 1–1 describes the principles and requirements for safety, serviceability and durability of masonry structures. It is based on the limit state concept used in conjunction with a partial factor method. For the design of new structures, BS EN 1996–1–1 is intended to be used together with the other relevant Eurocodes.

Scope of Part 1–2 of Eurocode 6

This part deals with the design of masonry structures for the accidental situation of fire exposure and identifies differences from, or supplements to, normal temperature design. Only passive methods of fire protection are considered and active methods are not covered. It addresses the need to avoid premature collapse of the structure and to limit the spread of fire.

Scope of Part 2 of Eurocode 6

This part gives the basic rules for the selection and execution of masonry to enable it to comply with the design assumptions of the other parts of Eurocode 6. It includes guidance on factors affecting performance and durability, storage and use of materials, site erection and protection, and the assessment of the appearance of masonry.

Scope of Part 3 of Eurocode 6

This part provides simplified calculation methods to facilitate the design of a range of common wall types under certain conditions of use. The methods are consistent with Part 1–1 but result in more conservative designs, and other methods are available in the UK; see 'Simplified calculation methods' on page 7. The simplified methods are not applicable to design for accidental situations, which should be designed for in accordance with Cl 5.2 of Part 1–1.

Supporting standards

There are European Standards that support Eurocode 6, and whilst they were developed within a common framework, it has not proved possible to standardise all the test methods used for the different materials. Words like brick and block have disappeared from the European vocabulary and they are all referred to as masonry units. Products should be specified by their performance requirements.

The Standards that support the use of masonry in Eurocode 6 were published by BSI and required, as an interim measure, the updating of all three parts of BS 5628[10] to accommodate the revised material standards and test methods. These revised versions of BS 5628 were published at the end of 2005. Two key factors that changed from previous UK practice are:

- The six new masonry unit standards introduced new methods for determining the compressive strength of masonry units[11].
- The method of determining characteristic compressive and shear strengths of masonry has changed.

Basis of design

Masonry structures are required to be designed in accordance with the general rules given in Eurocode, which requires that:

$E_d \leq R_d$

where

E_d = design value of the effect of actions
R_d = design value of the resistance

The basic requirements of Section 2 of Eurocode are deemed to be satisfied for masonry structures when the following are applicable:

- Limit state design in conjunction with the partial factor method described in Eurocode.
- Actions as given in Eurocode 1. (See 'Assessment of actions' below.)
- Combination rules as given in Eurocode.
- The principles and application rules given in Eurocode 6.

Thus using the partial factor method, the design value for a material property is obtained by dividing its characteristic value by the relevant partial factor for materials as follows:

$$R_d = \frac{R_k}{\gamma_M}$$

where

R_d = design value of resistance
R_k = characteristic value of the resistance
γ_M = partial factor for a material property

Partial factors for materials

The partial factors for use with masonry are given in table NA.1 of the National Annex to Eurocode 6, Part 1–1 and shown here as Table 1. Two levels of attestation of conformity are recognized, Category I and Category II and this will be declared by the manufacturer of the masonry units. There are also two classes of execution control that are recognized: 1 and 2.

Assessment of actions

The Eurocodes use the term action to refer to a set of forces, deformations or accelerations acting on the structure; this includes horizontal and vertical loads. The guide *How to design concrete structures using Eurocode 2: Introduction to Eurocodes*[9] gives guidance on determining the design value of actions and should ideally be consulted. However, a brief explanation on how to determine the partial factors for masonry design to Eurocode 6 is given below.

There are a number of combinations of actions that are described in Eurocode, but for masonry design (excluding retaining structures) the ultimate limit state, STR (STR represents an internal failure or excessive deformation of the structure or structural member) will normally be used. For plain masonry, Eurocode 6 indicates that,

Table 1
Value of partial factors, γ_M, for materials for ultimate limit states

Material	Class of execution control	
	1[a]	2[a]
Masonry		
When in a state of direct or flexural compression		
Unreinforced masonry made with:		
Units of category I	2.3[b]	2.7[b]
Units of category II	2.6[b]	3.0[b]
Reinforced masonry made with:		
Units of category I	2.0[b]	–[c]
Units of category II	2.3[b]	–[c]
When in a state of flexural tension		
Units of category I and II	2.3[b]	2.7[b]
When in a state of shear		
Unreinforced masonry made with:		
Units of category I and II	2.5[b]	2.5[b]
Reinforced masonry made with:		
Units of category I and II	2.0[b]	–[c]
Steel and other components		
Anchorage of reinforcing steel	1.5[d]	–[c]
Reinforcing steel and prestressing steel	1.15[d]	–[c]
Ancillary components – wall ties	3.5[b]	3.5[b]
Ancillary components – straps	1.5[e]	1.5[e]
Lintels in accordance with BS EN 845–2	See NA to BS EN 845–2[12]	See NA to BS EN 845–2[12]

Key

a Class 1 of execution control should be assumed whenever the work is carried out following the recommendations for workmanship in BS EN 1996–2, including appropriate supervision and inspection, and in addition:

- the specification, supervision and control ensure that the construction is compatible with the use of the appropriate partial factors given in BS EN 1996–1–1;
- the mortar conforms to BS EN 998–2, if it is factory made mortar, or if it is site mixed mortar, preliminary compression strength tests carried out on the mortar to be used, in accordance with BS EN 1015–2 and BS EN 1015–11, indicate conformity to the strength requirements given in BS EN 1996–1–1 and regular testing of the mortar used on site, in accordance with BS EN 1015–2 and BS EN 1015–11, shows that the strength requirements of BS EN 1996–1–1 are being maintained.

Class 2 of execution control should be assumed whenever the work is carried out following the recommendations for workmanship in BS EN 1996–2, including appropriate supervision.

b When considering the effects of misuse or accident these values may be halved.

c Class 2 of execution control is not considered appropriate for reinforced masonry and should not be used. However, masonry wall panels reinforced with bed joint reinforcement used:

- to enhance the lateral strength of the masonry panel,
- to limit or control shrinkage or expansion of the masonry,

can be considered to be unreinforced masonry for the purpose of class of execution control and the unreinforced masonry direct or flexural compression γ_M values are appropriate for use.

d When considering the effects of misuse or accident these values should be taken as 1.0.

e For horizontal restraint straps, unless otherwise specified, the declared ultimate load capacity depends on there being a design compressive stress in the masonry of at least 0.4 N/mm^2. When a lower stress due to design loads may be acting, for example when autoclaved aerated concrete or lightweight aggregate concrete masonry is used, the manufacturer's advice should be sought and a partial factor of 3 should be used. No value for misuse is given.

provided the ultimate limit state is satisfied, no checks for the serviceability limit states are required. This assumes compliance with the limiting dimensions and ratios specified in Eurocode 6.

There are three combinations that can be used for the STR limit state Expression (6.10), which is always conservative, or the most onerous of Expressions (6.10a) or (6.10b) (see Table 2). For laterally loaded masonry walls, where self-weight is usually beneficial, it will be sufficient to use Expression (6.10) only. For vertically loaded walls there will be some benefit in using Expression (6.10b), which, for members supporting one variable action (except storage loads) is the most economical of the three expressions, provided that the permanent actions are not greater than 4.5 times the variable actions.

In Table 2 ψ_0 is a factor that reduces the design value of an action when it acts in combination with another action (i.e. when it is an accompanying action). The value of ψ_0 can be obtained from Table 3. The UK NA to Eurocode values can be applied to Expression (6.10), and this is shown in Table 4, which also shows the factors to be used when wind loads act in combination with imposed loads. Note that wind loads and imposed loads are both considered to be variable actions.

Table 2
Design values of actions, ULS (Table A1.2 (B) of Eurocode)

Combination Expression reference	Permanent actions		Leading variable action	Accompanying variable action
	Unfavourable	Favourable		
Exp. (6.10)	$\gamma_{G,j,sup}\, G_{k,j,sup}$	$\gamma_{G,j,inf}\, G_{k,j,inf}$	$\gamma_{Q,1}\, Q_{k,1}$	$\gamma_{Q,i}\, \psi_{0,i}\, Q_{k,i}$
Exp. (6.10a)	$\gamma_{G,j,sup}\, G_{k,j,sup}$	$\gamma_{G,j,inf}\, G_{k,j,inf}$	$\gamma_{Q,1}\, \psi_{0,1}\, Q_{k,1}$	$\gamma_{Q,i}\, \psi_{0,i}\, Q_{k,i}$
Exp. (6.10b)	$\xi\gamma_{G,j,sup}\, G_{k,j,sup}$	$\gamma_{G,j,inf}\, G_{k,j,inf}$	$\gamma_{Q,1}\, Q_{k,1}$	$\gamma_{Q,i}\, \psi_{0,i}\, Q_{k,i}$

Notes

G_k = characteristic value of a permanent load
Q_k = characteristic value of the variable action
$\gamma_{G,sup}$ = partial factor for permanent action upper design value
$\gamma_{G,inf}$ = partial factor for permanent action lower design value
γ_Q = partial factor for variable actions
ψ_0 = factor for combination value of a variable action
ξ = reduction factor/distribution coefficient
Where a variable action is favourable Q_k should be taken as 0.

Table 3
Recommended combination values of variable actions (ψ_0) buildings (from UK National Annex to Eurocode)

Action	ψ_0
Imposed loads in buildings (see BS EN 1991–1–1)	
Category A: domestic, residential areas	0.7
Category B: office areas	0.7
Category C: congregation areas	0.7
Category D: shopping areas	0.7
Category E: storage areas	1.0
Category F: traffic area, vehicle weight < 30 kN	0.7
Category G: traffic area, 30 kN < vehicle weight < 160 kN	0.7
Category H: roofs [a]	0.7
Snow loads on buildings (see BS EN 1991–3)	
For sites located at altitude H > 1000 m above sea level	0.7
For sites located at altitude H < 1000 m above sea level	0.5
Wind loads on buildings (see BS EN 1991–1–5)	**0.6**

Key

a See also 1991–1–1: Cl 3.3.2

Imperfections

Eurocode 6 also recognizes that imperfections should be taken into account in design and requires that, at the ultimate limit state, the horizontal forces to be resisted at any level should be the sum of 1 and 2 below.

1. The horizontal load due to the vertical load being applied to a structure with the following notional inclination angle v to the vertical:

   $$v = \frac{1}{100\sqrt{h_{tot}}} \text{ radians}$$

   where

   h_{tot} = the total height of the structure in metres.

   Each vertical action therefore produces a horizontal action to which the same load factor and combination factor as the vertical load apply.

2. The wind load derived from Eurocode 1, Parts 1–4 multiplied by its partial factor and distributed across the elements resisting the load in proportion to their stiffness.

Mortar

The way in which mortar is specified has changed, as can be seen in Table 5. The primary method of designation for mortar is the strength grade. Thus an M12 mortar should have a minimum compressive strength of 12 N/mm^2 at 28 days. Eurocode 6 recognises three types of masonry mortar: general purpose, thin layer and lightweight mortar, and they may all be either designed or prescribed (see Glossary).

The use of mortars should be in accordance with the recommendations given in Eurocode 6, Part 2. For site made mortars, the mixing of the mortar should be in accordance with Part 2 (BS 5628–3[10] provides more detailed information). For factory made, semi-finished factory made and pre-batched masonry mortars, BS EN 998–2[13] applies.

For designed mortars, the compressive strength of the mortar provides the control of the hardened mortar quality, whereas prescribed mortars use set proportions. When samples are taken from a designed mortar in accordance with BS EN 1015–2[14], and tested in accordance with BS EN 1015–11[15], the compressive strength of the mortar should not be less than the declared compressive strength.

Table 4
Design values of actions derived for UK design, ultimate limit state

Combination expression reference	Permanent actions		Leading variable action (unfavourable)	Accompanying variable actions (unfavourable)
	Unfavourable	Favourable		
Combination of permanent actions and one variable action				
Exp. (6.10)	1.35 G_k [a]	1.0 G_k [a]	1.5 Q_k [b]	–
Exp. (6.10a)	1.35 G_k [a]	1.0 G_k [a]		1.5 $\psi_{0\text{-}1}$ [b] Q_k
Exp. (6.10b)	0.925 x 1.35 G_k [a]	1.0 G_k [a]	1.5 Q_k	
Combination of permanent actions, wind load ($Q_{k,W}$) and imposed load ($Q_{k,I}$)				
Exp. (6.10) Case 1	1.35 G_k [a]	1.0 G_k [a]	1.5 $Q_{k,W}$	1.05 [c] $Q_{k,I}$
Exp. (6.10) Case 2	1.35 G_k [a]	1.0 G_k [a]	1.5 $Q_{k,I}$	0.75 [d] $Q_{k,W}$

Key

a Where the variation in permanent action is not considered significant $G_{k,j,sup}$ and $G_{k,j,inf}$ may be taken as G_k

b Where a variable action is favourable Q_k should be taken as 0

c The value of ψ_0 has been taken as 0.7, for storage loads ψ_0 = 1.0 and a factor of 1.5 must be used

d The value of ψ_0 has been taken as 0.5

Durability of materials

Eurocode 6, Part 2 gives the basic rules for selection of mortar and masonry units for durability. Exposure conditions are defined in Cl 2.1.2(3) of Part 2, with further guidance given in Annexes A, B and C. The UK NA to Part 2 advises that Annexes B and C should not be used because the information is not as extensive as that given in BS 5628–3[10]. It is expected that Non-Contradictory Complementary Information (NCCI) will be given in a Published Document[16] based on table 12 of BS 5628–3; this advice is included in Table 6.

Structural fire design

Eurocode 6, Part 1–2 provides information on the passive fire resistance of masonry walls so that the designer can ensure that the loadbearing performance is maintained for the necessary period of time and that the fire is appropriately contained.

Designers will find that the tabulated data covers most situations but there is also the provision for testing and calculations. (Calculation methods are excluded by the UK NA to Part 1–2.) The tables cover loadbearing and non-loadbearing walls, single leaf, cavity and separating walls.

Table 5
Acceptable assumed equivalent mixes for prescribed masonry mortars

Compressive strength class [a]	Prescribed mortars (proportion of materials by volume) (see Note)				Mortar designation
	Cement [b]: lime: sand with or without air entrainment	Cement [b]: sand with or without air entrainment	Masonry cement [c]: sand	Masonry cement [d]: sand	
M12	1:0 to ¼: 3	1:3	Not suitable	Not suitable	(i)
M6	1:½: 4 to 4½	1:3 to 4	1:2½ to 3½	1:3	(ii)
M4	1:1: 5 to 6	1:5 to 6	1:4 to 5	1:3½ to 4	(iii)
M2	1:2: 8 to 9	1:7 to 8	1:5½ to 6½	1:4½	(iv)

Key

a The number following 'M' is the compressive strength at 28 days in N/mm^2

b Cement or combinations of cement in accordance with Cl. NA.2.3.2 of NA to BS EN 1996–1–1, except masonry cements

c Masonry cement in accordance with Cl. NA.2.3.2 of NA to BS EN 1996–1–1, (inorganic filler other than lime)

d Masonry cement in accordance with Cl. NA.2.3.2 of NA to BS EN 1996–1–1 (lime)

Note

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.

Table 6
Selection of masonry units and mortar for various exposure conditions

Masonry condition or situation	Quality of masonry units and appropriate mortar designations (i), (ii), (iii) and (iv)			
	Clay units	Calcium silicate units	Aggregate concrete bricks	Concrete blocks
A – Work below or near external ground level[a]				
A1 – Low risk of saturation	Without freezing: LD: F0 and S0 or HD: F0, F1 or F2 and S0, S1 or S2 in (i), (ii) or (iii) With freezing: HD: F1 or F2 and S0, S1 or S2 in (i), (ii) or (iii)	Without or with freezing: Compressive strength class 20 or above in (iii) or (iv)[b]	Without or with freezing: Compressive strength 16.5 N/mm^2 or above in (iii)	Without or with freezing: See note 4 for options, all in (iii) or (iv)[b]
A2 – High risk of saturation without freezing[c]	HD: F1 or F2, and S1 or S2 in (i) or (ii)[d]	Compressive strength class 20 or above in (ii) or (iii)	Compressive strength 16.5 N/mm^2 or above in (ii) or (iii)	As for A1 in (ii) or (iii)
A3 – High risk of saturation with freezing[c]	HD: F2 and S1 or S2 in (i) or (ii)[d]	Compressive strength class 20 or above in (ii) or (iii)	Compressive strength 22 N/mm^2 or above in (ii) or (iii)	As for A1 in (ii)
B – Masonry dpcs[a]				
B1 – In buildings	Dpc units, max. water absorption 4.5% in (i)[e]	Not suitable	Not suitable	Not suitable
B2 – In external works	Dpc units, max. water absorption 7.0% in (i)[e]	Not suitable	Not suitable	Not suitable
C – Unrendered external walls (other than chimneys, cappings, copings, parapets and sills)				
C1 – Low risk of saturation	HD: F1 or F2 and S1 or S2 in (i), (ii) or (iii)	Compressive strength class 20 or above in (iii) or (iv)[b]	Compressive strength 7.3 N/mm^2 or above in (iii)	Any in (iii) or (iv)[b]
C2 – High risk of saturation	HD: F2 and S1 or S2 in (i) or (ii)[d]	Compressive strength class 20 or above in (iii)	Compressive strength 18 N/mm^2 or above in (iii)	Any in (iii)
D – Rendered external walls (other than chimneys, cappings, copings, parapets, sills)				
Rendered external walls	HD: F1 or F2 and S1[f] or S2 in (i), (ii) or (iii)	Compressive strength class 20 or above in (iii) or (iv)[b]	Compressive strength 7.3 N/mm^2 or above in (iii)	Any in (iii) or (iv)[b]
E – Internal walls and inner leaves of cavity walls above dpc level				
Internal walls and inner leaves of cavity walls	LD: F0 and S0; or HD: F0, F1 or F2 and S0, S1 or S2 in (i), (ii), (iii) or (iv)[b]	Compressive strength class 20 or above in (iii) or (iv)[b]	Compressive strength 7.3 N/mm^2 or above in (iii) or (iv)b	Any in (iii) or (iv)[b]
F – Unrendered parapets (other than cappings and copings)				
F1 – Low risk of saturation	HD:F1 or F2 and S1 or S2 in (i), (ii) or (iii)	Compressive strength class 20 or above in (iii)	Compressive strength 22 N/mm^2 or above in (iii)	See note 4 for options, all in (iii)
F2 – High risk of saturation	HD: F2 and S1[f] or S2 in (i) or (ii)	Compressive strength class 20 or above in (iii)	Compressive strength 22 N/mm^2 or above in (iii)	As for F1 in (ii)
G – Rendered parapets (other than cappings and copings)				
Rendered parapets	HD: F1 or F2 and S2 in (i), (ii) or (iii); or HD: F1 or F2 and S1[f] in (i) or (ii)	Compressive strength class 20 or above in (iii)	Compressive strength 7.3 N/mm^2 or above in (iii)	Any in (iii)
H – Chimneys[f]				
H1 – Unrendered with low risk of saturation	HD: F1 or F2 and S1 or S2 in (i), (ii) or (iii)	Compressive strength class 20 or above in (iii)	Compressive strength 12 N/mm^2 or above in (iii)	Any in (iii)
H2 – Unrendered with high risk of saturation	HD: F2 and S1 or S2 in (i) or (ii)	Compressive strength class 20 or above in (iii)	Compressive strength 16.5 N/mm^2 or above in (iii)	See note 4 for options, all in (ii)
H3 – Rendered	HD: F1 or F2 and S2 in (i), (ii) or (iii); or HD: F1 or F2 and S1 in (i) or (ii)	Compressive strength class 20 or above in (iii)	Compressive strength 7.3 N/mm^2 or above in (iii)	Any in (iii)
I – Cappings, copings and sills[g]				
Cappings, copings and sills	HD: F2 and S1 or S2 in (i)	Compressive strength class 30 or above in (ii)	Compressive strength 33 N/mm^2 or above in (ii)	Options A, B or C of note 4, all in (ii)
J – Freestanding boundary and screen walls[h] (other than cappings and copings)				
J1 – With coping	HD: F1 or F2 and S1[f] in (i) or (ii): or HD: F1 or F2 and S2 in (i), (ii) or (iii)	Compressive strength class 20 or above in (iii)	Compressive strength 16.5 N/mm^2 or above in (iii)	Any in (iii)
J2 – With capping	HD: F2 and S1[f] or S2 in (i) or (ii)	Compressive strength class 20 or above in (iii)	Compressive strength 22 N/mm^2 or above in (iii)	See note 4 for options, all in (ii)
K – Earth-retaining walls (other than cappings and copings) (Not included in Eurocode 6)				
K1 – Waterproofing retaining face and coping	HD: F1 or F2 and S1[f] or S2 in (i) or (ii)	Compressive strength class 20 or above in (ii) or (iii)	Compressive strength 16.5 N/mm^2 or above in (ii)	See note 4 for options, all in (iii)
K2 – With coping or capping but no waterproofing on retaining face	HD: F2 and S1[f] or S2 in (i)	Compressive strength class 30 or above in (ii)	Compressive strength 33 N/mm^2 or above in (i) or (ii)	As for K1 but in (i) or (ii)
L – Drainage and sewage, e.g. inspection chambers, manholes[a] (Not included in Eurocode 6)				
L1 – Surface water	Engineering bricks or F1 or F2 and S1[f] or S2 in (i)	Compressive strength class 20 or above in (ii) or (iii) (Consult manufacturer)	Compressive strength 22 N/mm^2 or above in (iii)	Options A, B or C of note 4, all in (iii)

Table continues on page 6

Table 6 – Continued from page 5

Masonry condition or situation	Quality of masonry units and appropriate mortar designations (i), (ii), (iii) and (iv)			
	Clay units	Calcium silicate units	Aggregate concrete bricks	Concrete blocks
L2 – Foul drainage (continuous contact with masonry)	Engineering bricks or F1 or F2 and S1[f] or S2 in (i)	Compressive strength class 50 or above in (ii). (Consult manufacturer)	Compressive strength 48 N/mm^2 or above with cement ≥ 350 kg/m^3 in (i) or (ii)	Not suitable
L3 – Foul drainage (occasional contact with masonry)	Engineering bricks or F1 or F2 and S1[f] or S2 in (i)	Compressive strength class 20 or above in (ii) or (iii). (Consult manufacturer)	Compressive strength 48 N/mm^2 or above with cement ≥ 350 kg/m^3 in (i) or (ii)	Not suitable

Notes

1 For designations (i), (ii), (iii) and (iv) see Table 5.

2 LD - clay masonry unit with a low gross dry density for use in protected masonry.
HD - clay masonry unit for unprotected masonry as well as clay masonry unit with a high gross dry density for use in protected masonry.

3 Categories used for clay masonry for freeze/thaw are as follows:
F0 Passive exposure
F1 Moderate exposure
F2 Severe exposure.

Categories used for clay masonry for active salt content are as follows:
S0 No requirement for active salt content
S1 Limited active salt content (see BS EN 771–1, Cl. 5.3.9)
S2 Limited active salt content (see BS EN 771–1, Cl. 5.3.9).

4 Concrete block options:
A Of net density ≥ 1500 kg/m^3
B Made with dense aggregate conforming to BS EN 12620
C Having a compressive strength of 7.3 N/mm^2
D Most types of autoclaved aerated block (consult manufacturer).

Key

a In sulfate bearing ground conditions seek expert advice.

b Where designation (iv) mortar is used the masonry should be fully protected during execution.

c In conditions of highly mobile groundwater, consult the manufacturer on the selection of materials.

d Designation (ii) mortar should have sulfate resisting Portland cement when used with S1 clay units.

e Unlikely to be suitable for walls of other masonry units as differential movement can occur.

f Sulfate resisting Portland cement should be used in the mortar and the base coat of render if applicable.

g Use sulfate resisting Portland cement for chimney terminals. Dpcs for capping, copping and sills should be bedded in the same mortar as the masonry units.

h Drainage should be provided behind the wall. The potentials for contamination from the ground and ground water should be considered. Climatic exposure conditions can be severe.

Reinforced and prestressed masonry

Eurocode 6, Part 1–1 contains information relating to the design of reinforced masonry, but provides no application rules on the design of prestressed masonry. The clauses relating to reinforced masonry contain information similar to that provided in BS 5628–2[10]. However, Eurocode 6 does not provide the coherent design thread provided by BS 5628–2 and lacks developed procedures for enhancing the lateral load performance of masonry panels by using bed joint reinforcement.

It is therefore recommended that, pending the development of appropriate Non-Contradictory Complementary Information (NCCI) material, the design of reinforced and prestressed masonry may be more conveniently carried out using BS 5628–2.

Masonry movement

The potential for movement in completed masonry needs to be allowed for in design, and Eurocode 6, Part 2 makes recommendations for controlling differential movements; for example, the use of movement tolerant ties between the leaves of a cavity wall.

Movement joints need to be provided to deal with the effects of moisture, temperature and movement caused by other agents. The position of movement joints needs to be considered with care to ensure that the structural integrity of the wall is maintained. Factors affecting the location of joints include:

- The type and group of masonry unit.
- The geometry of the structure.
- The degree of restraint.
- The effect of loading, thermal and climatic conditions.
- Requirements for fire, sound and thermal performance.
- The presence of reinforcement.

Movement joints that pass through the full thickness of the wall should be provided. The maximum horizontal distance, l_m, between vertical movement joints for use for all walls in the UK (in the absence of other guidance from the manufacturer) is shown in Table 7.

Execution of masonry

Eurocode 6, Part 2 gives guidance on the execution of masonry including:

- Permissible deviations.
- Jointing and pointing.
- Storage, preparation and use of materials on site.
- Masonry protection during execution.

Further detail on the first two points is given in the following paragraphs.

Permissible deviations

The permissible deviations of the constructed masonry from the position in which it is intended to be built should form part of the design specification. The permissible deviations should not normally be greater than the values shown in Table 8 for structural imperfections.

Mortar pointing

Most masonry is constructed in such a way that the bedding mortar also forms the tooled surface of the finished mortar joint. If it is necessary to point the mortar joint the unhardened mortar should be raked out to a depth not less than 15 mm, but no more than 15% of the wall thickness.

Simplified calculation methods

Eurocode 6, Part 3 contains simplified calculation methods for unreinforced masonry structures. These methods are based on the principles contained in Part 1 and should not be confused with simple rules developed on the basis of experience. In general, these methods are more conservative than design based on Part 1 and have not, historically, been used in the UK, unlike some European countries. In the UK guidance on the Building Regulations[17–19] and BS 8103–2[20] provide a very effective and economic set of simple rules for low rise masonry and it is anticipated that these will continue to be the primary method of demonstrating compliance for many small buildings.

Table 7
Maximum horizontal distance between vertical movement joints in walls (in the absence of other guidance from the manufacturer)

Type of masonry	l_m (m)
Clay masonry – unreinforced	15[a]
Calcium silicate masonry	9 [b]
Aggregate concrete and manufactured stone masonry	9 [b]
Autoclaved aerated concrete masonry	9 [b]
Natural stone masonry	20 [c]

Key

a The value for clay masonry walls containing bed joint reinforcement may be greater than 15 m subject to expert advice.

b This value applies when the ratio, length to height of panel, is 3 to 1 or less. It should be reduced for long horizontal panels of masonry which lie outside this ratio.

c When using this figure, movement joints should be located at not more than 8 m from the corner.

Table 8
Permissible deviations for structural design purposes

Position	Maximum deviation
Verticality	
In any one storey	± 20 mm
In total height of building of three storeys or more	± 50 mm
Vertical alignment	± 20 mm
Straightness [a]	
In any one metre	± 10 mm
In 10 metres	± 50 mm
Thickness	
Of wall leaf [b]	± 5 mm or ± 5 % of the leaf thickness, whichever is the greater
Of overall cavity wall	± 10 mm

Key

a Deviation from straightness is measured from a straight reference line between any two points.

b Excluding leaves of single masonry unit width or length, where the dimensional tolerances of the masonry units govern the leaf thickness.

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Glossary of Eurocode 6 terminology

Term	Definition
Adhesion	The effect of mortar developing a tensile or shear resistance at the contact surface of masonry units.
Category I masonry unit	Units with a declared compressive strength with a probability of failure to reach it not exceeding 5%. This may be determined via the mean or characteristic value.
Category II masonry unit	Units not intended to comply with the level of confidence of Category 1 units.
Confined masonry	Masonry provided with reinforced concrete or reinforced masonry confining elements in the vertical and horizontal direction. (Not usually used in the UK.)
Designed masonry mortar	A mortar whose composition and manufacturing method is chosen in order to achieve specified properties (performance concept).
General purpose masonry mortar	Masonry mortar without special characteristics.
Griphole	A formed void in a masonry unit to enable it to be more readily grasped and lifted with one or both hands or by machine.
Groups 1, 1s, 2, 3 and 4 masonry units	Group designations for masonry units, according to the percentage, size and orientation of holes in the units when laid. Note: The group designation will normally be declared by the manufacturer. Historically only Groups 1, 1s and 2 units have been used in the UK. Group 1s is referred to in BS EN 1996–1–2.
Hole	A formed void which may or may not pass completely through a masonry unit.
Lightweight masonry mortar	Designed masonry mortar with a dry hardened density below a prescribed figure.
Normalized compressive strength of masonry units	The compressive strength of masonry units converted to the air dried compressive strength of an equivalent 100 mm wide x 100 mm high masonry unit (see BS EN 772[21]).
Orthogonal ratio, μ	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.
Prescribed masonry mortar	Mortar made in predetermined proportions, the properties of which are assumed from the stated proportions of the constituents (recipe concept).
Shell	The peripheral material between a hole and the face of a masonry unit.
Shell bedded wall	A wall in which the masonry units are bedded on two or more strips of mortar, two of which are at the outside edge of the bed face of the units.
Thin layer masonry mortar	Designed masonry mortar with a maximum aggregate size less than or equal to a prescribed figure.
Web	The solid material between the holes in a masonry unit.

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