

Eurocode 6 — Design of masonry structures —

Part 1-1: General rules for reinforced and unreinforced masonry structures

ICS 91.010.30; 91.080.30

National foreword

This British Standard is the UK implementation of EN 1996-1-1:2005+A1:2012, incorporating corrigendum July 2009. It supersedes BS EN 1996-1-1:2005, which is withdrawn.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum July 2009 is indicated in the text by AC AC.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable BS EN 1996-1-1:2005+A1:2012 to be used in the UK the latest version of the NA to this Standard containing these NDPs should also be used. At the time of publication, it is NA to BS EN 1996-1-1:2005+A1:2012.

The UK participation in its preparation was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/6, Use of masonry.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

The publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Eurocode 6 : Calcul des ouvrages en maçonnerie - Partie
1-1: Règles générales pour ouvrages en maçonnerie armée
et non armée

Eurocode 6 - Bemessung und Konstruktion von
Mauerwerksbauten - Teil 1-1: Allgemeine Regeln für
bewehrtes und unbewehrtes Mauerwerk

This European Standard was approved by CEN on 23 June 2005 and includes Amendment 1 approved by CEN on 6 July 2012.

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Foreword

This document (EN 1996-1-1:2005+A1:2012) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2013, and conflicting national standards shall be withdrawn at the latest by May 2013.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document includes Corrigendum 1 issued by CEN on 29 July 2009 and Amendment 1 approved by CEN on 6 July 2012.

This document supersedes  EN 1996-1-1:2005 .

The start and finish of text introduced or altered by amendment is indicated in the text by tags  .

The modifications of the related CEN Corrigendum have been implemented at the appropriate places in the text and are indicated by the tags  .

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Background to the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on Article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980's.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement¹⁾ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European

1) Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

Standard (EN). This links de facto the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990, *Eurocode: Basis of structural design*

EN 1991, *Eurocode 1: Actions on structures*

EN 1992, *Eurocode 2: Design of concrete structures*

EN 1993, *Eurocode 3: Design of steel structures*

EN 1994, *Eurocode 4: Design of composite steel and concrete structures*

EN 1995, *Eurocode 5: Design of timber structures*

EN 1996, *Eurocode 6: Design of masonry structures*

EN 1997, *Eurocode 7: Geotechnical design*

EN 1998, *Eurocode 8: Design of structures for earthquake resistance*

EN 1999, *Eurocode 9: Design of aluminium structures*

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes:

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 — Mechanical resistance and stability — and Essential Requirement N°2 — Safety in case of fire;
- as a basis for specifying contracts for construction works and related engineering services;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs).

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents²⁾ referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards³⁾. Therefore, technical aspects arising from the Eurocodes work need to be

2) According to Article 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

3) According to Article 12 of the CPD the interpretative documents shall :

adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National Annex (informative).

The National Annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i. e.:

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- country specific data (geographical, climatic etc), e.g. snow map,
- the procedure to be used where alternative procedures are given in the Eurocode

and it may also contain:

- decisions on the application of informative annexes,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works⁴⁾. Furthermore, all the information accompanying the CE Marking of the construction products, which refer to Eurocodes, shall clearly mention which Nationally Determined Parameters have been taken into account.

This European Standard is Part of EN 1996 which comprises the following Parts:

Part 1-1: *General rules for reinforced and unreinforced masonry*  structures 

NOTE This Part combines ENV 1996-1-1 and ENV 1996-1-3.

-
- a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
 - b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e. g. methods of calculation and of proof, technical rules for project design, etc. ;
 - c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals. The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.
- 4) see Article 3.3 and Article 12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

Part 1-2: *General rules - Structural fire design*

Part 2: *Design considerations, selection of materials and execution of masonry.*

Part 3: *Simplified calculation methods for unreinforced masonry structures*

EN 1996-1-1 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, EN 1996-1-1 is intended to be used, for direct application, together with ENs 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998 and 1999.

EN 1996-1-1 is intended for use by:

- committees drafting standards for structural design and related products, testing and execution standards;
- clients (e. g. for the formulation of their specific requirements on reliability levels and durability);
- designers and contractors;
- relevant authorities.

National Annex for EN 1996-1-1

This standard gives some symbols and some alternative methods for which a National value or choice needs to be given; notes under the relevant clauses indicate where national choices may have to be made. The National Standard implementing EN 1996-1-1 in a particular country should have a National Annex containing all Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in that country.

National choice is allowed in EN 1996-1-1 through clauses:

- 2.4.3(1)P Ultimate limit states;
- 2.4.4(1) Serviceability limit states;
- 3.2.2(1) Specification of masonry mortar;
- 3.6.1.2(1) Characteristic compressive strength of masonry other than shell bedded;
- 3.6.2(3), (4) and (6) Characteristic shear strength of masonry;
- $\boxed{A_1}$ 3.6.4(3) $\boxed{A_1}$ Characteristic flexural strength of masonry;
- 3.7.2(2) Modulus of elasticity;
- 3.7.4(2) Creep, moisture expansion or shrinkage and thermal expansion;
- 4.3.3(3) and (4) Reinforcing steel;
- 5.5.1.3(3) Effective thickness of masonry walls;
- 6.1.2.2(2) Slenderness ratio λ_c below which creep may be ignored;
- $\boxed{A_1}$ 6.2(2) Design value of the limiting shear resistance $\boxed{A_1}$;

- 8.1.2 (2) Minimum thickness of wall;
- 8.5.2.2(2) AC Cavity and veneer walls AC;
- 8.5.2.3(2) Double-leaf walls.
- 8.6.2 (1) Vertical chases and recesses;
- 8.6.3 (1) Horizontal and inclined chases.

Section 1 General

1.1 Scope

1.1.1 Scope of Eurocode 6

(1)P Eurocode 6 applies to the design of buildings and civil engineering works, or parts thereof, in unreinforced, reinforced, prestressed and confined masonry.

(2)P Eurocode 6 deals only with the requirements for resistance, serviceability and durability of structures. Other requirements, for example, concerning thermal or sound insulation, are not considered.

(3)P Execution is covered to the extent that is necessary to indicate the quality of the construction materials and products that should be used and the standard of workmanship on site needed to comply with the assumptions made in the design rules.

(4)P Eurocode 6 does not cover the special requirements of seismic design. Provisions related to such requirements are given in Eurocode 8 which complements, and is consistent with Eurocode 6.

(5)P Numerical values of the actions on buildings and civil engineering works to be taken into account in the design are not given in Eurocode 6. They are provided in Eurocode 1.

1.1.2 Scope of Part 1-1 of Eurocode 6

(1)P The basis for the design of buildings and civil engineering works in masonry is given in this Part 1-1 of Eurocode 6, which deals with unreinforced masonry and reinforced masonry where the reinforcement is added to provide ductility, strength or improve serviceability. The principles of the design of prestressed masonry and confined masonry are given, but application rules are not provided. This Part is not valid for masonry with a plan area of less than 0,04 m².

(2) For those types of structures not covered entirely, for new structural uses for established materials, for new materials, or where actions and other influences outside normal experience have to be resisted, the principles and application rules given in this EN may be applicable, but may need to be supplemented.

(3) Part 1-1 gives detailed rules which are mainly applicable to ordinary buildings. The applicability of these rules may be limited, for practical reasons or due to simplifications; any limits of applicability are given in the text where necessary.

(4)P The following subjects are dealt with in Part 1-1:

- section 1 : General;
- section 2 : Basis of design;
- section 3 : Materials;

- section 4 : Durability;
- section 5 : Structural analysis;
- section 6 : Ultimate Limit State;
- section 7 : Serviceability Limit State;
- section 8 : Detailing;
- section 9 : Execution;

(5)P Part 1-1 does not cover:

- resistance to fire (which is dealt with in EN 1996-1-2);
- particular aspects of special types of building (for example, dynamic effects on tall buildings);
- particular aspects of special types of civil engineering works (such as masonry bridges, dams, chimneys or liquid-retaining structures);
- particular aspects of special types of structures (such as arches or domes);
- masonry where gypsum, with or without cement, mortars are used;
- masonry where the units are not laid in a regular pattern of courses (rubble masonry);
- masonry reinforced with other materials than steel.

AC deleted text AC

1.2 Normative references

1.2.1 General

(1)P This European standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to, or revisions of, any of these publications apply to this European standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

1.2.2 Reference standards

The following standards are referenced in this EN 1996-1-1:

- EN 206-1, *Concrete — Part 1: Specification, performance, production and conformity*
- EN 771-1, *Specification for masonry units — Part 1: Clay masonry units*
- EN 771-2, *Specification for masonry units — Part 2: Calcium silicate masonry units*
- EN 771-3, *Specification for masonry units — Part 3: Aggregate concrete masonry units (Dense and light-weight aggregates)*
- EN 771-4, *Specification for masonry units — Part 4: Autoclaved aerated concrete masonry units*

- EN 771-5, *Specification for masonry units — Part 5: Manufactured stone masonry units*
- EN 771-6, *Specification for masonry units — Part 6: Natural stone masonry units*
- EN 772-1, *Methods of test for masonry units — Part 1: Determination of compressive strength*
- EN 845-1, *Specification for ancillary components for masonry — Part 1: Ties, tension straps, hangers and brackets*
- EN 845-2, *Specification for ancillary components for masonry — Part 2: Lintels*
- EN 845-3, *Specification for ancillary components for masonry — Part 3: Bed joint reinforcement of steel meshwork*
- EN 846-2, *Methods of test for ancillary components for masonry — Part 2: Determination of bond strength of prefabricated bed joint reinforcement in mortar joints*
- EN 998-1, *Specification for mortar for masonry — Part 1: Rendering and plastering mortar*
- EN 998-2, *Specification for mortar for masonry — Part 2: Masonry mortar*
- EN 1015-11, *Methods of test for mortar for masonry — Part 11: Determination of flexural and compressive strength of hardened mortar*
- EN 1052-1, *Methods of test for masonry — Part 1: Determination of compressive strength*
- EN 1052-2, *Methods of test for masonry — Part 2: Determination of flexural strength*
- EN 1052-3, *Methods of test for masonry — Part 3: Determination of initial shear strength*
- EN 1052-4, *Methods of test for masonry — Part 4: Determination of shear strength including damp proof course*
- EN 1052-5, *Methods of test for masonry — Part 5: Determination of bond strength by bond wrench method*
- EN 1990, *Basis of structural design*
- EN 1991, *Actions on structures*
- EN 1992, *Design of concrete structures*
- EN 1993, *Design of steel structures*
- EN 1994, *Design of composite steel and concrete structures*
- EN 1995, *Design of timber structures*
- EN 1996-2, *Design, selection of materials and execution of masonry*
- EN 1997, *Geotechnical design*
- EN 1999, *Design of aluminium structures*
- EN 10080, *Steel for the reinforcement of concrete — Weldable reinforcing steel*
- prEN 10138, *Prestressing steels*

—  prEN 10348, *Steel for the reinforcement of concrete — Galvanized reinforcing steel* 

1.3 Assumptions

(1)P The assumptions given in EN 1990:2002, 1.3, apply to this EN 1996-1-1.

1.4 Distinction between principles and application rules

(1)P The rules in EN 1990:2002, 1.4, apply to this EN 1996-1-1.

1.5 Terms and Definitions

1.5.1 General

(1) The terms and definitions given in EN 1990:2002, 1.5, apply to this EN 1996-1-1.

(2) The terms and definitions used in this EN 1996-1-1 are given the meanings contained in 1.5.2 to 1.5.11, inclusive.

1.5.2 Terms relating to masonry

1.5.2.1

masonry

assemblage of masonry units laid in a specified pattern and joined together with mortar

1.5.2.2

unreinforced masonry

masonry not containing sufficient reinforcement so as to be considered as reinforced masonry

1.5.2.3

reinforced masonry

masonry in which bars or mesh are embedded in mortar or concrete so that all the materials act together in resisting action effects

1.5.2.4

prestressed masonry

masonry in which internal compressive stresses have been intentionally induced by tensioned reinforcement

1.5.2.5

confined masonry

masonry provided with reinforced concrete or reinforced masonry confining elements in the vertical and horizontal direction

1.5.2.6

masonry bond

disposition of units in masonry in a regular pattern to achieve common action

1.5.3 Terms relating to strength of masonry

1.5.3.1

characteristic strength of masonry

value of the strength of masonry having a prescribed probability of 5% of not being attained in a hypothetically unlimited test series. This value generally corresponds to a specified fractile of the assumed statistical distribution of the particular property of the material or product in a test series. A nominal value is used as the characteristic value in some circumstances

1.5.3.2

compressive strength of masonry

strength of masonry in compression without the effects of platen restraint, slenderness or eccentricity of loading

1.5.3.3

shear strength of masonry

f_{A1} strength of masonry in shear f_{A1}

1.5.3.4

flexural strength of masonry

strength of masonry in bending

1.5.3.5

anchorage bond strength

bond strength, per unit surface area, between reinforcement and concrete or mortar, when the reinforcement is subjected to tensile or compressive forces

1.5.3.6

adhesion

effect of mortar developing a tensile and shear resistance at the contact surface of masonry units

1.5.4 Terms relating to masonry units

1.5.4.1

masonry unit

preformed component, intended for use in masonry construction

1.5.4.2

groups 1, 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

1.5.4.3

bed face

top or bottom surface of a masonry unit when laid as intended

1.5.4.4

frog

depression, formed during manufacture, in one or both bed faces of a masonry unit

1.5.4.5

hole

formed void which may or may not pass completely through a masonry unit

1.5.4.6

griphole

formed void in a masonry unit to enable it to be more readily grasped and lifted with one or both hands or by machine

1.5.4.7

web

solid material between the holes in a masonry unit

1.5.4.8

shell

peripheral material between a hole and the face of a masonry unit

1.5.4.9

gross area

area of a cross-section through the unit without reduction for the area of holes, voids and re-entrants

1.5.4.10

compressive strength of masonry units

mean compressive strength of a specified number of masonry units (see EN 771-1 to EN 771-6)

1.5.4.11

normalized compressive strength of masonry units

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 EN 771-1 to EN 771-6)

1.5.5 Terms relating to mortar

1.5.5.1

masonry mortar

mixture of one or more inorganic binders, aggregates and water, and sometimes additions and/or admixtures, for bedding, jointing and pointing of masonry

1.5.5.2

general purpose masonry mortar

masonry mortar without special characteristics

1.5.5.3

thin layer masonry mortar

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

NOTE see note in 3.6.1.2 (2)

1.5.5.4

lightweight masonry mortar

Ⓐ designed masonry mortar with a dry hardened density equal to or below 1 300 kg/m³ according to EN 998 2 Ⓐ

1.5.5.5

designed masonry mortar

mortar whose composition and manufacturing method is chosen in order to achieve specified properties (performance concept)

1.5.5.6

prescribed masonry mortar

mortar made in predetermined proportions, the properties of which are assumed from the stated proportions of the constituents (recipe concept)

1.5.5.7

factory made masonry mortar

mortar batched and mixed in a factory

1.5.5.8

semi-finished factory made masonry mortar

prebatched masonry mortar or a premixed lime and sand masonry mortar

1.5.5.9

prebatched masonry mortar

mortar whose constituents are wholly batched in a factory, supplied to the building site and mixed there according to the manufacturers' specification and conditions

1.5.5.10

premixed lime and sand masonry mortar

mortar whose constituents are wholly batched and mixed in a factory, supplied to the building site, where further constituents specified or provided by the factory are added (e. g. cement) and mixed with the lime and sand

1.5.5.11

site-made mortar

mortar composed of individual constituents batched and mixed on the building site

1.5.5.12

compressive strength of mortar

mean compressive strength of a specified number of mortar specimens after curing for 28 days

1.5.6 Terms relating to concrete infill

1.5.6.1

concrete infill

concrete used to fill pre-formed cavities or voids in masonry

1.5.7 Terms relating to reinforcement

1.5.7.1

reinforcing steel

steel reinforcement for use in masonry

1.5.7.2

bed joint reinforcement

reinforcing steel that is prefabricated for building into a bed joint

1.5.7.3

prestressing steel

steel wires, bars or strands for use in masonry

1.5.8 Terms relating to ancillary components

1.5.8.1

damp proof course

layer of sheeting, masonry units or other material used in masonry to resist the passage of water

1.5.8.2

wall tie

device for connecting one leaf of a cavity wall across a cavity to another leaf or to a framed structure or backing wall

1.5.8.3

strap

device for connecting masonry members to other adjacent components, such as floors and roofs

A1 1.5.8.4

composite lintel

lintel comprising a prefabricated part and a complementary element of in-situ masonry, above, acting together **A1**

1.5.9 Terms relating to mortar joints

1.5.9.1

bed joint

mortar layer between the bed faces of masonry units

1.5.9.2

perpend joint (head joint)

mortar joint perpendicular to the bed joint and to the face of wall

1.5.9.3

longitudinal joint

vertical mortar joint within the thickness of a wall, parallel to the face of the wall

1.5.9.4

thin layer joint

joint made with thin layer mortar

1.5.9.5

jointing

process of finishing a mortar joint as the work proceeds

1.5.9.6

pointing

process of filling and finishing mortar joints where the surface of the joint has been raked out or left open for pointing

1.5.10 Terms relating to wall types

1.5.10.1

load-bearing wall

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

1.5.10.2

single-leaf wall

wall without a cavity or continuous vertical joint in its plane

1.5.10.3

cavity wall

wall consisting of two parallel single-leaf walls, effectively tied together with wall ties or bed joint reinforcement. The space between the leaves is left as a continuous cavity or filled or partially filled with non-loadbearing thermal insulating material

NOTE A wall consisting of two leaves separated by a cavity, where one of the leaves is not contributing to the strength or stiffness of the other (possibly loadbearing) leaf, is to be regarded as a veneer wall.

1.5.10.4

double-leaf wall

wall consisting of two parallel leaves with the longitudinal joint between filled solidly with mortar and securely tied together with wall ties so as to result in common action under load

1.5.10.5

grouted cavity wall

wall consisting of two parallel leaves with the cavity filled with concrete or grout and securely tied together with wall ties or bed joint reinforcement so as to result in common action under load

1.5.10.6

faced wall

wall with facing units bonded to backing units so as to result in common action under load

1.5.10.7

shell bedded wall

wall in which the masonry units are bedded on two or more strips of mortar two of which are at the outside edges of the bed face of the units

1.5.10.8

veneer wall

wall used as a facing but not bonded or contributing to the strength of the backing wall or framed structure

1.5.10.9

shear wall

wall to resist lateral forces in its plane

1.5.10.10

stiffening wall

wall set perpendicular to another wall to give it support against lateral forces or to resist buckling and so to provide stability to the building

1.5.10.11

non-loadbearing wall

wall not considered to resist forces such that it can be removed without prejudicing the remaining integrity of the structure

1.5.11 Miscellaneous terms

1.5.11.1

chase

channel formed in masonry

1.5.11.2

recess

indentation formed in the face of a wall

1.5.11.3

grout

pourable mixture of cement, sand and water for filling small voids or spaces

1.5.11.4

movement joint

joint permitting free movement in the plane of the wall

1.5.11.5

built in length

length declared by the manufacturer of the prefabricated part needed to anchor the reinforcing bars according to EN 845-2 

1.6 Symbols

(1) Material-independent symbols are given in EN 1990, 1.6.

(2) Material-dependent symbols used in this EN 1996-1-1 are:

Latin letters

a_1 distance from the end of a wall to the nearest edge of a loaded area;

 *deleted text* 

 a_v maximum bending moment in the member divided by the maximum shear force in the member; 

A loaded horizontal gross cross-sectional area of a wall;

A_{ef}	effective area of bearing;
A_s	cross-sectional area of steel reinforcement;
A_{sw}	area of shear reinforcement;
b	width of a section;
b_c	width of the compression face midway between restraints;
b_{ef}	effective width of a flanged member;
$b_{ef,l}$	effective width of a $\boxed{\text{AC}}$ L-shaped $\boxed{\text{AC}}$ flanged member;
$b_{ef,t}$	effective thickness of a $\boxed{\text{AC}}$ T-shaped $\boxed{\text{AC}}$ flanged member;
c_{nom}	nominal concrete cover;
d	effective depth of a beam;
d_a	deflection of an arch under the design lateral load;
d_c	largest dimension of the cross section of a core in the direction of bending;
e_c	additional eccentricity;
e_{he}	eccentricity at the top or bottom of a wall, resulting from horizontal loads;
e_{hm}	eccentricity at the middle of a wall, resulting from horizontal loads;
e_i	eccentricity at the top or the bottom of a wall;
e_{init}	initial eccentricity;
e_k	eccentricity due to creep;
e_m	eccentricity due to loads;
e_{mk}	eccentricity at the middle of the wall;
E	short term secant modulus of elasticity of masonry;
$\boxed{\text{AC}} E_d$	design value of the load applied to a reinforced masonry member; $\boxed{\text{AC}}$
$E_{longterm}$	long term modulus of elasticity of masonry;
E_n	modulus of elasticity of member n;
f_b	normalised mean compressive strength of a masonry unit;
f_{bod}	design anchorage strength of reinforcing steel;
f_{bok}	characteristic anchorage strength;
f_{ck}	characteristic compressive strength of concrete infill;
f_{cvk}	characteristic shear strength of concrete infill;

f_d	design compressive strength of masonry in the direction being considered;
f_k	characteristic compressive strength of masonry;
f_m	compressive strength of masonry mortar;
f_{vd}	design shear strength of masonry;
f_{vk}	characteristic shear strength of masonry;
f_{vk0}	characteristic initial shear strength of masonry, under zero compressive stress;
$\boxed{A_1} f_{vk0i}$	characteristic initial shear strength at zero precompression at the interface of the top surface of the prefabricated part and the masonry built on it (the complementary element) $\boxed{A_1}$;
f_{vlt}	limit to the value of f_{vk} ;
f_{xd}	design flexural strength appropriate to the plane of bending;
f_{xd1}	design flexural strength of masonry having the plane of failure parallel to the bed joints;
$f_{xd1,app}$	apparent design flexural strength of masonry having the plane of failure parallel to the bed joints;
f_{xk1}	characteristic flexural strength of masonry having $\boxed{AC}$ the plane of failure $\boxed{AC}$ parallel to the bed joints;
f_{xd2}	design flexural strength of masonry having $\boxed{AC}$ the plane of failure $\boxed{AC}$ perpendicular to the bed joints;
$f_{xd2,app}$	apparent design flexural strength of masonry having the plane of failure perpendicular to the bed joints;
f_{xk2}	characteristic flexural strength of masonry having the plane of failure perpendicular to the bed joints;
f_{yd}	design strength of reinforcing steel;
f_{yk}	characteristic strength of reinforcing steel
F_d	design compressive or tensile resistance of a wall tie;
$\boxed{A_1} F_{tkl}$	characteristic tensile resistance of the prefabricated part of the composite lintel declared by the manufacturer in accordance with EN 845-2; $\boxed{A_1}$
g	total of the widths of mortar strips;
G	shear modulus of masonry;
h	clear height of a masonry wall;
h_i	clear height of masonry wall, i ;
h_{ef}	effective height of a wall;
h_{tot}	total height of a structure, from the top of the foundation, or a wall, or a core;

h_c	height of a wall to the level of the load;
I_j	second moment of area of member, j ;
k	ratio of the lateral load capacity of a vertically spanning wall to the lateral load capacity of the actual wall area, taking possible edge restraint into account;
k_m	ratio of slab stiffness to wall stiffness
k_r	rotational stiffness of a restraint;
K	constant used in the calculation of the compressive strength of masonry;
l	length of a wall (between other walls, between a wall and an opening, or between openings);
l_b	straight anchorage length;
l_c	length of the compressed part of a wall;
l_{cl}	clear length of an opening
l_{ef}	effective span of a masonry beam;
l_{efm}	effective length of a bearing at mid height of a wall;
l_r	clear distance between lateral restraints;
l_a	the length or the height of the wall between supports capable of resisting an arch thrust;
M_{ad}	additional design moment;
M_d	design bending moment at the bottom of a core;
M_i	end moment at node i ;
M_{id}	design value of the bending moment at the top or the bottom of the wall;
M_{md}	design value of the greatest moment at the middle of the height of the wall;
M_{Rd}	design value of the moment of resistance;
M_{Ed}	design value of the moment applied;
M_{Edu}	design value of the moment above a floor;
M_{Edf}	design value of the moment below a floor;
n	number of storeys;
n_i	stiffness factor of members;
n_t	number of wall ties or connectors per m^2 of wall;
n_{tmin}	minimum number of wall ties or connectors per m^2 of wall;
N	sum of the design vertical actions on a building;

N_{ad}	the maximum design arch thrust per unit length of wall;
N_{id}	design value of the vertical load at the top or bottom of a wall or column;
N_{md}	design value of the vertical load at the middle of the height of a wall or column;
N_{Rd}	design value of the vertical resistance of a masonry wall or column;
N_{Rdc}	design value of the vertical concentrated load resistance of a wall;
N_{Ed}	design value of the vertical load;
N_{Edf}	design value of the load out of a floor;
N_{Edu}	design value of the load above the floor;
AC deleted text AC	
N_{Edc}	design value of a concentrated vertical load;
$q_{lat,d}$	design lateral strength per unit area of wall;
Q_d	design value of the total vertical load, in the part of a building stabilised by a core;
r	arch rise;
R_e	yield AC strength AC of steel;
s	spacing of shear reinforcement;
AC deleted text AC	
t	thickness of a wall;
$t_{ch,v}$	maximum depth of a vertical chase or recess without calculation;
$t_{ch,h}$	maximum depth of a horizontal or inclined chase;
t_i	thickness of wall i ;
t_{min}	minimum thickness of a wall;
t_{ef}	effective thickness of a wall;
t_f	thickness of a flange;
t_{ri}	thickness of the rib, i ;
V_{Ed}	design value of a shear load;
V_{Rd}	design value of the shear resistance;
A1 V_{Rdlt}	design value of the limiting shear resistance; A1
w_i	uniformly distributed design load, i ;
W_{Ed}	design lateral load per unit area;

x	depth to the neutral axis;
z	lever arm;
Z	elastic section modulus of a unit height or length of the wall;

Greek letters

α	angle of shear reinforcement to the axis of the beam;
α_t	coefficient of thermal expansion of masonry ;
$\alpha_{1,2}$	bending moment coefficients;
β	enhancement factor for concentrated loads;
χ	magnification factor for the shear resistance of reinforced walls;
δ	factor used in the determination of the normalised mean compressive strength of masonry units;
$\varepsilon_{c\infty}$	final creep strain of masonry;
ε_{el}	elastic strain of masonry;
ε_{mu}	limiting compressive strain in masonry;
ε_{sy}	yield strain of reinforcement;
ϕ	effective diameter of the reinforcing steel;
ϕ_{∞}	final creep coefficient of masonry;
Φ	reduction factor;
Φ_{fl}	reduction factor, taking the influence of the flexural strength into account;
Φ_t	reduction factor at the top or bottom of the wall;
Φ_m	reduction factor within the middle height of the wall;
γ_M	partial factor for materials, including uncertainties about geometry and modelling;
η	factor for use in calculating the out-of-plane eccentricity of loading on walls;
λ_x	depth of the compressed zone in a beam, when using a rectangular stress block;
λ_c	value of the slenderness ratio up to which eccentricities due to creep can be neglected;
μ	orthogonal ratio of the flexural strengths of masonry;
ξ	magnification factor for the rotational stiffness of the restraint of the structural element being considered;

ρ_d	dry density;
ρ_n	reduction factor;
ρ_t	stiffness coefficient;
σ_d	design compressive stress ;
ν	angle of inclination to the vertical of the structure.

Section 2 Basis of design

2.1 Basic requirements

2.1.1 General

- (1)P The design of masonry structures shall be in accordance with the general rules given in EN 1990.
- (2)P Specific provisions for masonry structures are given in this section and shall be applied.
- (3) The basic requirements of EN 1990, Section 2, are deemed to be satisfied for masonry structures when the following are applied:
- limit state design in conjunction with the partial factor method described in EN 1990;
 - actions given in EN 1991;
 - combination rules given in EN 1990;
 - the principles and rules of application given in this EN 1996-1-1.

2.1.2 Reliability

- (1)P The reliability required for masonry structures will be obtained by carrying out design according to this EN 1996-1-1.

2.1.3 Design working life and durability

- (1) For the consideration of durability reference should be made to Section 4.

2.2 Principles of limit state design

- (1)P Limit states may concern only the masonry, or such other materials as are used for parts of the structure, for which reference shall be made to relevant Parts of EN 1992, EN 1993, EN 1994, EN 1995 and EN 1999.
- (2)P For masonry structures, the ultimate limit state and serviceability limit state shall be considered for all aspects of the structure including ancillary components in the masonry.
- (3)P For masonry structures, all relevant design solutions including relevant stages in the sequence of construction shall be considered.

2.3 Basic variables

2.3.1 Actions

(1)P Actions shall be obtained from the relevant Parts of EN 1991.

2.3.2 Design values of actions

(1)P Partial factors for actions γ_{AC} shall γ_{AC} be obtained from EN 1990.

(2) Partial factors for creep and shrinkage of concrete elements in masonry structures should be obtained from EN 1992-1-1.

(3) For serviceability limit states, imposed deformations should be introduced as estimated (mean) values.

2.3.3 Material and product properties

(1) Properties of materials and construction products and geometrical data to be used for design should be those specified in the relevant ENs, hENs or ETAs, unless otherwise indicated in this EN 1996-1-1.

2.4 Verification by the partial factor method

2.4.1 Design values of material properties

(1)P The design value for a material property is obtained by dividing its characteristic value by the relevant partial factor for materials, γ_M .

2.4.2 Combination of actions

(1)P Combination of actions shall be in accordance with the general rules given in EN 1990.

NOTE 1 In residential and office structures, it will usually be possible to simplify the load combinations given in EN 1990.

NOTE 2 In normal residential and office structures the imposed loads, as given in the EN 1991-1 series, may be treated as one fixed variable action (that is, equal loading on all spans, or zero, when appropriate) for which reduction factors are given in the EN 1991-1 series.

2.4.3 Ultimate limit states

(1)P The relevant values of the partial factor for materials γ_M shall be used for the ultimate limit state for ordinary and accidental situations. When analysing the structure for accidental actions, the probability of the accidental action being present shall be taken into account.

NOTE The numerical values to be ascribed to the symbol γ_M for use in a country may be found in its National Annex. Recommended values, given as classes that may be related to execution control (see also Annex A) according to national choice, are given in the table below.

Material		γ_M				
		Class				
		1	2	3	4	5
A	Masonry made with: Units of Category I, designed mortar ^a	1,5	1,7	2,0	2,2	2,5
B	Units of Category I, prescribed mortar ^b	1,7	2,0	2,2	2,5	2,7
C	Units of Category II, any mortar ^{a, b, e}	2,0	2,2	2,5	2,7	3,0
D	Anchorage of reinforcing steel	1,7	2,0	2,2	2,5	2,7
E	Reinforcing steel and prestressing steel	1,15				
F	Ancillary components ^{c, d}	1,7	2,0	2,2	2,5	2,7
G	Lintels according to EN 845-2	1,5 to 2,5				
^a Requirements for designed mortars are given in EN 998-2 and EN 1996-2.						
^b Requirements for prescribed mortars are given in EN 998-2 and EN 1996-2.						
^c Declared values are mean values.						
^d Damp proof courses are assumed to be covered by masonry γ_M .						
^e When the coefficient of variation for Category II units is not greater than 25 %.						

END OF NOTE

2.4.4 Serviceability limit states

(1) Where simplified rules are given in the relevant clauses dealing with serviceability limit states, detailed calculations using combinations of actions are not required. When needed, the partial factor for materials, for the serviceability limit state, is γ_M .

NOTE The value to be ascribed to the symbol γ_M for use in a country may be found in its National Annex. The recommended value for γ_M , for all material properties for serviceability limit states is 1.0.

2.5 Design assisted by testing

(1) Structural properties of masonry may be determined by testing.

NOTE Annex D (informative) of EN 1990 gives recommendations for design assisted by testing.

Section 3 Materials

3.1 Masonry Units

3.1.1 Types and grouping of masonry units

(1)P Masonry units shall comply with any of the following types:

- clay units in accordance with EN 771-1.
- calcium silicate units in accordance with EN 771-2.
- aggregate concrete units (dense and lightweight aggregate) in accordance with EN 771-3.
- autoclaved aerated concrete units in accordance with EN 771-4.
- manufactured stone units in accordance with EN 771-5.

dimensioned natural stone units in accordance with AC *deleted text* AC EN 771-6.

(2) Masonry units may be Category I or Category II.

NOTE The definitions of Category I and II units are given in EN 771-1 to 6.

(3) Masonry units should be grouped as Group 1, Group 2, Group 3 or Group 4, for the purposes of using the equations and other numerical values given in 3.6.1.2 (2), (3), (4), (5) and (6), and 3.6.1.3 and where grouping is referred to in other clauses.

NOTE Normally the manufacturer will state the grouping of his units.

(4) Autoclaved aerated concrete, manufactured stone and dimensioned natural stone units are considered to be Group 1. The geometrical requirements for grouping of clay, calcium silicate and aggregate concrete units are given in table 3.1.

Table 3.1 — Geometrical requirements for Grouping of Masonry Units

	Materials and limits for Masonry Units							
	Group 1 (all materials)		Group 2		Group 3		Group 4	
		Units	Vertical holes				Horizontal holes	
Volume of all holes (% of the gross volume)	≤ 25	clay	> 25; ≤ 55		≥ 25; ≤ 70		> 25; ≤ 70	
		calcium silicate	> 25; ≤ 55		not used		not used	
		concrete ^b	> 25; ≤ 60		> 25; ≤ 70		> 25; ≤ 50	
Volume of any hole (% of the gross volume)	≤ 12,5	clay	each of multiple holes ≤ 2 gripholes up to a total of 12,5		each of multiple holes ≤ 2 gripholes up to a total of 12,5		each of multiple holes ≤ 30	
		calcium silicate	each of multiple holes ≤ 15 gripholes up to a total of 30		not used		not used	
		concrete ^b	each of multiple holes ≤ 30 gripholes up to a total of 30		each of multiple holes ≤ 30 gripholes up to a total of 30		each of multiple holes ≤ 25	
Declared values of thickness of webs and shells (mm)	No requirement		web	shell	web	shell	web	shell
		clay	≥ 5	≥ 8	≥ 3	≥ 6	≥ 5	≥ 6
		calcium silicate	≥ 5	≥ 10	not used		not used	
		concrete ^b	≥ 15	≥ 18	≥ 15	≥ 15	≥ 20	≥ 20
Declared value of combined thickness ^a of webs and shells (% of the overall width)	No requirement	clay	≥ 16		≥ 12		≥ 12	
		calcium silicate	≥ 20		not used		not used	
		concrete ^b	≥ 18		≥ 15		≥ 45	

^a The combined thickness is the thickness of the webs and shells, measured horizontally in the relevant direction. The check is to be seen as a qualification test and need only be repeated in the case of principal changes to the design dimensions of units.

^b In the case of conical holes, or cellular holes, use the mean value of the thickness of the webs and the shells.

3.1.2 Properties of masonry units –compressive strength

(1)P The compressive strength of masonry units, to be used in design, shall be the normalised mean compressive strength, f_b .

NOTE In the EN 771 series of standards, the normalised mean compressive strength is either:

- declared by the manufacturer; or
- obtained by converting the compressive strength by using EN 772-1, Annex A (Conversion of the compressive strength of masonry units to the normalised mean compressive strength).

(2) When the manufacturer declares the normalised compressive strength of masonry units as a characteristic strength, this should be converted to the mean equivalent, using a factor based on the coefficient of variation of f_{AC} the compressive strength of f_{AC} the units.

3.2 Mortar

3.2.1 Types of masonry mortar

(1) Masonry mortars are defined as general purpose, thin layer or lightweight mortar according to their constituents.

(2) Masonry mortars are considered as designed or prescribed mortars according to the method of defining their composition.

(3) Masonry mortars may be factory made (pre-batched or pre-mixed), semi-finished factory made or site-made, according to the method of manufacture.

(4)P Factory made and semi-finished factory made masonry mortars shall be in accordance with EN 998-2. Site-made masonry mortar shall be in accordance with EN 1996-2. Pre-mixed lime and sand masonry mortar shall be in accordance with EN 998-2, and shall be used in accordance with EN 998-2.

3.2.2 Specification of masonry mortar

(1) Mortars should be classified by their compressive strength, expressed as the letter M followed by the compressive strength in N/mm^2 , for example, M5. Prescribed masonry mortars, additionally to the M number, will be described by their prescribed constituents, e. g. 1: 1: 5 cement: lime: sand by volume.

NOTE The National Annex of a country may ascribe acceptable equivalent mixes, described by the proportion of the constituents, to stated M values. Such acceptable equivalent mixes should be given in the National Annex.

(2) General purpose masonry mortars may be designed mortars in accordance with EN 998-2 or prescribed masonry mortars in accordance with EN 998-2.

(3) Thin layer and lightweight masonry mortars should be designed mortars in accordance with EN 998-2.

3.2.3 Properties of mortar

3.2.3.1 Compressive strength of masonry mortar

(1)P The compressive strength of masonry mortar, f_m , shall be determined in accordance with EN 1015-11.

f_{AC} deleted text f_{AC}

3.2.3.2 Adhesion between units and mortar

(1)P The adhesion between the mortar and the masonry units shall be adequate for the intended use.

NOTE 1 Adequate adhesion will depend on the type of mortar used and the units to which that mortar is applied.

NOTE 2 EN 1052-3 deals with the determination of the initial shear strength of masonry and f_{AC} deleted text f_{AC} EN 1052-5 f_{AC} deleted text f_{AC} , deals with the determination of flexural bond strength.

3.3 Concrete infill

3.3.1 General

(1)P Concrete used for infill shall be in accordance with EN 206.

(2) Concrete infill is specified by the characteristic compressive strength, f_{ck} , (concrete strength class), which relates to the cylinder/cube strength at 28 days, in accordance with EN 206.

3.3.2 Specification for concrete infill

(1) The strength class, as defined in EN 206-1, of concrete infill should not be less than C12/15.

(2) The concrete may be designed or prescribed and should contain just sufficient water to provide the specified strength and to give adequate workability.

(3)P The workability of concrete infill shall be such as to ensure that voids will be completely filled, when the concrete is placed in accordance with EN 1996-2.

(4) The slump class S3 to S5 or flow class F4 to F6, in accordance with EN 206-1, will be satisfactory for most cases. In holes, where the smallest dimension is less than 85 mm, $\boxed{AC}$ slump class S5 or flow class F6 $\boxed{AC}$ should be used. Where high slump concretes are to be used, measures need to be taken to reduce the resulting high shrinkage of the concrete.

(5) The maximum aggregate size of concrete infill should not exceed 20 mm. When concrete infill is to be used in voids whose least dimension is less than 100 mm or when the cover to the reinforcement is less than 25 mm, the maximum aggregate size should not exceed 10 mm.

3.3.3 Properties of concrete infill

(1)P The characteristic compressive strength and shear strength of concrete infill shall be determined from tests on concrete specimens.

NOTE Test results may be obtained from tests carried out for the project, or be available from a database.

(2) Where test data are not available the characteristic compressive strength, f_{ck} , and the characteristic shear strength, f_{cvk} , of concrete infill may be taken from table 3.2.

Table 3.2 — Characteristic strengths of concrete infill

Strength class of concrete	C12/15	C16/20	C20/25	C25/30, or stronger
f_{ck} (N/mm ²)	12	16	20	25
f_{cvk} (N/mm ²)	0,27	0,33	0,39	0,45

3.4 Reinforcing steel

3.4.1 General

(1)P Reinforcing carbon steel shall be specified in accordance with $\boxed{AC}$ EN 10080 $\boxed{AC}$. Stainless steel and specially coated bars shall be specified separately.

(2)P The requirements for the properties of the reinforcement are for the material as placed in the hardened masonry or concrete infill. Operations carried out on site or during manufacture, that might damage the properties of the material shall be avoided.

NOTE ~~AC~~ deleted text ~~AC~~ EN 10080 refers to a yield ~~AC~~ strength ~~AC~~ R_e , which includes the characteristic, minimum and maximum values based on the long-term quality of production. In contrast f_{yk} is the characteristic yield strength based on only that reinforcement required for the structure. There is no direct relationship between f_{yk} and the characteristic R_e . However the methods of evaluation and verification of yield strength given in ~~AC~~ deleted text ~~AC~~ EN 10080 provide a sufficient check for obtaining f_{yk} .

(3) Reinforcing steel may be carbon steel or austenitic stainless steel. Reinforcing steel may be plain or ribbed (high bond) and weldable.

(4) Detailed information on the properties of reinforcing steel is to be found in EN 1992-1-1.

3.4.2 Properties of reinforcing steel bars

(1)P The characteristic strength of reinforcing steel bars, f_{yk} , shall be in accordance with EN 1992-1-1, AnnexC.

(2) The coefficient of thermal expansion may be assumed to be $12 \times 10^{-6} \text{ K}^{-1}$.

NOTE The difference between this value and the value for the surrounding masonry or concrete may normally be neglected.

3.4.3 Properties of bed joint ~~AC~~ deleted text ~~AC~~ reinforcement

(1)P ~~A1~~ deleted text ~~A1~~ Bed joint reinforcement shall be in accordance with EN 845-3.

3.5 Prestressing steel

(1)P Prestressing steel shall be in accordance with EN 10138 or an appropriate European Technical Approval.

(2) The properties of prestressing steel should be obtained from EN 1992-1-1.

3.6 Mechanical properties of masonry

3.6.1 Characteristic compressive strength of masonry

3.6.1.1 General

(1)P The characteristic compressive strength of masonry, f_k , shall be determined from results of tests on masonry specimens.

NOTE Test results may be obtained from tests carried out for the project, or be available from a database.

3.6.1.2 Characteristic compressive strength of masonry other than shell bedded masonry

(1) The characteristic compressive strength of masonry should be determined from either:

(i) results of tests in accordance with EN 1052-1 which tests may be carried out for the project or be available from tests previously carried out e.g. a database; the results of the tests should be expressed as a table, or in terms of equation (3.1).

$$f_k = K f_b^\alpha f_m^\beta \quad (3.1)$$

where

- f_k is the characteristic compressive strength of the masonry, in N/mm²
- K AC is a constant and, where relevant, modified according to 3.6.1.2(3) and/or 3.6.1.2(6) AC
- α, β are constants
- f_b is the normalised mean compressive strength of the units, in the direction of the applied action effect, in N/mm²
- f_m is the compressive strength of the mortar, in N/mm²

Limitations on the use of equation (3.1) should be given in terms of f_b, f_m , the coefficient of variation of the test results, and the Grouping of the units.

or

(ii) from (2) and (3), below.

NOTE The decision on which of methods (i) and (ii) is to be used in a country may be found in its National Annex. If (i) is used, tabulated values or the constants to be used in equation (3.1) and the limitations, preferably referring to the grouping in Table 3.1, should be given in the National Annex.

(2) The relationship between the characteristic compressive strength of masonry, f_k , the normalised mean compressive strength of the units, f_b , and the mortar strength, f_m , may be obtained from:

- equation (3.2), for masonry made with general purpose mortar and lightweight mortar;
- equation (3.3), for masonry made with thin layer mortar, in bed joints of thickness 0,5 mm to 3 mm, and clay units of Group 1 and 4, calcium silicate, aggregate concrete and autoclaved aerated AC concrete AC units;
- equation (3.4), for masonry AC ~~deleted text~~ AC made with thin layer mortar, in bed joints of thickness 0,5 mm to 3 mm, and clay units of Group 2 and 3.

NOTE EN 998-2 gives no limit for the thickness of joints made of thin layer mortar; the limit on the thickness of bed joints of AC 0,5 mm AC to 3 mm is to ensure that the thin layer mortar has the enhanced properties assumed to exist to enable equations (3.3) and (3.4) to be valid. The mortar strength, f_m , does not need to be used with equation (3.3) and (3.4).

$$\text{AC } f_k = K f_b^{0,7} f_m^{0,3} \text{ AC} \quad (3.2)$$

$$f_k = K f_b^{0,85} \quad (3.3)$$

$$f_k = K f_b^{0,7} \quad (3.4)$$

where

- K is a constant according to table 3.3, and where relevant, modified according to 3.6.1.2(3) and or 3.6.1.2(6)

provided that the following requirements are satisfied:

- the masonry is detailed in accordance with section 8 of this EN 1996-1-1;

- all joints satisfy the requirements of 8.1.5 (1) and (3) so as to be considered as filled;
- f_b is not taken to be greater than 75 N/mm² when units are laid in general purpose mortar
- f_b is not taken to be greater than 50 N/mm² when units are laid in thin layer mortar;
- f_m is not taken to be greater than 20 N/mm² nor greater than $2f_b$ when units are laid in general purpose mortar;
- f_m is not taken to be greater than 10 N/mm² when units are laid in lightweight mortar;
- the thickness of the masonry is equal to the width or length of the unit, so that there is no mortar joint parallel to the face of the wall through all or any part of the length of the wall;
- the coefficient of variation of the strength of the masonry units is not more than 25 %.

(3) Where action effects are parallel to the direction of the bed joints, the characteristic compressive strength may also be determined from equations (3.2), (3.3) or (3.4), using the normalized compressive strength of the masonry unit, f_b , obtained from tests where the direction of application of the load to the test specimen is the same as the direction of the action effect in the masonry, but with the factor, δ , as given in EN 772-1, not taken to be greater than 1,0. For Group 2 and 3 units, K should then be multiplied by 0,5.

(4) For masonry made of general purpose mortar where Group 2 and Group 3 aggregate concrete units are used with the vertical cavities filled completely with concrete, the value of f_b should be obtained by considering the units to be Group 1 with a compressive strength corresponding to the compressive strength of the units or of the concrete infill, whichever is the lesser.

(5) When the perpend joints are unfilled, equations (3.2), (3.3) or (3.4) may be used, considering any horizontal actions that might be applied to, or be transmitted by, the masonry. See also 3.6.2(4).

(6) For masonry made with general purpose mortar where there is a mortar joint parallel to the face of the wall through all or any part of the length of the wall, the values of K can be obtained by multiplying the values given in table 3.3 by 0,8.

Table 3.3 — Values of K for use with general purpose, thin layer and lightweight mortars

Masonry Unit		General purpose mortar	Thin layer mortar (bed joint ≥ 0,5 mm and ≤ 3 mm)	Lightweight mortar of density	
				$600 \leq \rho_d$ ≤ 800 kg/m ³	$800 < \rho_d$ ≤ 1 300kg/m ³
Clay	Group 1	0,55	0,75	0,30	0,40
	Group 2	0,45	0,70	0,25	0,30
	Group 3	0,35	0,50	0,20	0,25
	Group 4	0,35	0,35	0,20	0,25
Calcium Silicate	Group 1	0,55	0,80	‡	‡
	Group 2	0,45	0,65	‡	‡
Aggregate Concrete	Group 1	0,55	0,80	0,45	0,45
	Group 2	0,45	0,65	0,45	0,45
	Group 3	0,40	0,50	‡	‡
	Group 4	0,35	‡	‡	‡
Autoclaved Aerated Concrete	Group 1	0,55	0,80	0,45	0,45
Manufactured Stone	Group 1	0,45	0,75	‡	‡
Dimensioned Natural Stone	Group 1	0,45	‡	‡	‡

‡ Combination of mortar/unit not normally used, so no value given.

3.6.1.3 Characteristic compressive strength of shell bedded masonry

(1) AC The characteristic compressive strength of shell bedded masonry may also be obtained from 3.6.1.2 using the normalised mean compressive strength of the units f_b that is obtained for normal bedding (thus not obtained from tests on units tested in accordance with EN 772-1 for shell bedded units), provided that: AC

- the width of each strip of mortar is 30 mm or greater;
- the thickness of the masonry is equal to the width or length of the masonry units so that there is no longitudinal mortar joint through all or part of the length of the wall;
- the ratio g/t is not less than 0,4;
- K is taken from 3.6.1.2 when $g/t = 1,0$ or K is taken as half of those values when $g/t = 0,4$, with intermediate values obtained by linear interpolation,

where

g is the total of the widths of the mortar strips;

t is the thickness of the wall.

(2) The characteristic compressive strength of shell bedded masonry AC ~~deleted text~~ AC may be obtained from 3.6.1.2, provided that the normalised mean compressive strength of the units, f_b , used in the equation is that obtained from tests on units tested in accordance with EN 772-1 for shell bedded units.