DD ENV 1996-3:2001

Eurocode 6: Design of masonry structures —

Part 3: Simplified calculation methods and simple rules for masonry

(together with United Kingdom National Application Document)

ICS 91.010.30; 91.080.30

Committees responsible for this Draft for Development

The preparation of this Draft for Development was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/6, Use of masonry, upon which the following bodies were represented:

Association of Consulting Engineers

Autoclaved Aerated Concrete Products Association

Brick Development Association

British Ceramic Research Ltd.

British Masonry Society

British Precast Concrete Federation Ltd.

Construction Federation

Concrete Block Association

Department of the Environment, Transport and the Regions — represented by the Building Research Establishment

Department of the Environment, Transport and the Regions — Construction Research Directorate

Institution of Civil Engineers

Institution of Structural Engineers

National House Building Council

Royal Institute of British Architects

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Contents

National foreword

This Draft for Development was prepared by Subcommittee B/525/6, and is the English language version of ENV 1996-3:1999, *Eurocode 6: Design of masonry structures — Part 3: Simplified calculation methods and simple rules for masonry*, published by the European Committee for Standardization (CEN). This Draft for Development also includes the United Kingdom (UK) National Application Document (NAD) to be used with the ENV for the design of masonry structures to be constructed in the UK.

ENV 1996-3:1999 results from a programme of work sponsored by the European Commission to make available a common set of rules for the design of building and civil engineering works.

This publication is not to be regarded as a British Standard.

An ENV is made available for provisional application during a trial period of use of three years, but does not have the status of a European Standard. The aim is to use the experience gained period to modify the ENV so that it can be adopted as a European Standard. The publication of this ENV and its NAD should be considered to supersede any reference to a British Standard in previous DD ENV Eurocodes concerning the subject covered by these documents.

The values for certain parameters in the ENV Eurocodes may be set by individual CEN Members so as to meet the requirements of national regulations. These parameters are designated by □(boxed values in the ENV.

During the ENV period of validity, reference should be made to the supporting documents listed in the NAD. The purpose of the NAD is to provide essential information, particularly in relation to safety, to enable the ENV to be used for masonry structures constructed in the UK and the NAD takes precedence over corresponding provisions in the ENV.

Approved Document A to The Building Regulations 1991 [1], draws designers' attention to the potential use of ENV Eurocodes as an alternative approach to Building Regulation compliance. ENV 1996-3 has been thoroughly examined over a period of several years and is considered to offer such an alternative approach, when used in conjunction with this NAD.

Compliance with ENV 1996-3:1999 and this NAD does not in itself confer immunity from legal obligations.

Users of this document are invited to comment on its technical content, ease of use and any ambiguities or anomalies. These comments will be taken into account when preparing the UK national response to CEN to the question of whether the ENV can be converted to an EN.

Comments should be sent in writing to BSI, British Standards House, 389 Chiswick High Road, London W4 4AL, quoting the document reference, the relevant clause and, where possible, a proposed revision.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, the ENV title page, pages 2 to 39 and a back cover.

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National Application Document

for use in the UK with ENV 1996-3:1999

Contents of National Application Document

Introduction

This National Application Document (NAD) has been prepared by Subcommittee B/525/6, Use of masonry. It has been developed from a textual examination of ENV 1996-3:1999.

It is anticipated that ENV 1996-3:1999 will have little general application in the UK. It is not a substitute for Approved Document A to the Building Regulations, and produces load bearing designs which are more conservative than either ENV 1996-1-1:1996 or BS 5628-1:1992. However, the simple rules for unreinforced basement walls and non-load bearing internal walls may be useful.

It should be noted that this NAD, in common with ENV 1996-3 and supporting European Standards, uses a comma (,) where a decimal point (.) would be traditionally used in the UK.

1 Scope

This NAD provides information required to enable ENV 1996-3:1999 to be used for the design of buildings to be constructed in the UK.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this NAD. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 648, *Schedule of weights of building materials*.

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

DD ENV 1996-1-1:1996, *Eurocode 6 — Design of masonry structures — Part 1-1: General rules for buildings — Rules for reinforced and unreinforced masonry (together with United Kingdom National Application Document).*

3 Boxed values

In general, the boxed values in ENV 1996-3:1999 should be used, but the boxed value of 50 mm, in **C.1** (2) should be taken to be 75 mm in the UK.

4 Loading codes

The loading codes given in BS 648 and BS 6399-1 should be used.

5 Reference standards

The supporting standards to be used, including materials specifications and standards for construction should be those given in Table 4 of the NAD to ENV 1996-1-1:1996.

6 Additional recommendations

In determining the vertical loading category from Table B.1 of ENV 1996-3:1999, the floor and roof elements included are assumed to be of concrete construction. Timber floors and roofs should be disregarded when using Table B.1 of ENV 1996-3:1999 in the UK.

Bibliography

Standards publication

BS 5628-1:1992, *Code of practice for use of masonry — Structural use of unreinforced masonry*.

Other document

[1] GREAT BRITAIN. The Building Regulations 1991. SI 1991 No. 2768. London, HMSO.

EUROPEAN PRESTANDARD
PRÉNORME EUROPÉENNE
EUROPÄISCHE VORNORM

ENV 1996-3

January 1999

ICS 91.010.30; 91.080.30

Descriptors: buildings, construction, masonry work, structures, computation

English version

Eurocode 6: Design of masonry structures - Part 3: Simplified calculation methods and simple rules for masonry structures

Eurocode 6: Calcul des structures en maçonnerie - Partie 3: Méthodes de calcul simplifiées

Eurocode 6: Berechnung und Ausführung von Mauerwerk - Teil 3: Vereinfachte Berechnungsmethoden und einfache Regeln für Mauerwerk

This European Prestandard (ENV) was approved by CEN on 27 March 1998 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

CEN members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. ENV 1996-3:1999 E

Contents

Foreword

Objectives and programme of the Eurocodes

(1) The structural Eurocodes comprise a group of standards for the structural and geotechnical design of buildings and civil engineering works.

(2) They cover execution and control only to the extent that it is necessary to indicate the quality of the construction products, and the standard of workmanship needed on and off site to comply with the assumptions of the design rules.

(3) Until the necessary set of harmonized technical specifications for products and the methods for testing their performance is available, some of the Structural Eurocodes will cover some of these aspects in informative annexes.

Background of the Eurocode programme

(4) The Commission of the European Communities (CEC) initiated the work of establishing a set of harmonized technical rules for the design of building and civil engineering works which would initially serve as an alternative to the different rules in force in the various member states and would ultimately replace them. These technical rules became known as the Structural Eurocodes.

(5) In 1990, after consulting their respective Members States, the CEC transferred the work of further development, issue and updating of the Structural Eurocodes to CEN, and the EFTA secretariat agreed to support the CEN work.

(6) CEN Technical Committee CEN/TC 250 is responsible for all Structural Eurocodes.

Eurocode programme

(7) Work is in hand on the following Structural Eurocodes, each generally consisting of a number of parts :

EN 1991 Eurocode 1 : Basis of design and 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 alloy structures.

(8) Separate sub-committees have been formed by CEN/TC 250 for the various Eurocodes listed above.

(9) This ENV 1996-3 is being published as a European Prestandard (ENV) with an initial life of three years.

(10) This prestandard is intended for experimental application and for the submission of comments.

(11) After approximately two years, CEN members will be invited to submit formal comments to be taken into account in determining future actions.

(12) Meanwhile feedback and comments on this prestandard should be sent to the Secretariat of CEN/TC 250/SC6 at the following address :

DIN
Burggrafenstrasse 6
10772 Berlin
Germany

or to your national standards organization.

National Application Documents (NADs)

(13) In view of the responsibilities of authorities in member countries for safety, health and other matters covered by the essential requirements of the Construction Products Directive (CPD), certain safety elements in this ENV have been assigned indicative values which are identified by □ ("boxed values").The authorities in each member country are expected to review the "boxed values" and may substitute alternative definitive values for these safety elements for use in national application.

(14) Some of the supporting European or International standards may not be available by the time this prestandard is issued. It is therefore anticipated that a National Application Document (NAD) giving any substitute definitive values for safety elements, referencing compatible supporting standards and providing guidance on the national application of this prestandard, will be issued by each member country or its standards organisation.

(15) It is intended that this prestandard is used in conjunction with the NAD valid in the country where the building and civil engineering work is located.

Matters specific to this prestandard

(16) The scope of Eurocode 6 is defined in clause 1.1.1 of ENV 1996-1-1 and the scope of this ENV 1996-3 is defined in clause 1.1 of this Part 3. Additional parts of Eurocode 6 which are planned are indicated in clause 1.1.3 of ENV 1996-1-1.

(17) Section 4.5 of this ENV 1996-3, relating to unreinforced basement walls, replaces normative Annex E of ENV 1996-1-1.

1 General

1.1 Scope

(1)P This ENV 1996-3 provides either simplified calculation methods or simple rules to facilitate the design of the following unreinforced masonry walls, subject to certain conditions of application.

Simplified calculation methods are given for :

- walls subjected to vertical loading, including wind loading ;

- walls subjected to concentrated loads ;

- shear walls ;

- basement walls subjected to lateral earth pressure and vertical loads ;

- walls subjected to vertical loading where the height of the building does not exceed 3 storeys above ground level ;

- shear walls where the height of the building does not exceed 3 storeys above ground level.

Simple rules are given for :

- basement walls subjected to lateral earth pressure and vertical loads where the height of the building does not exceed 4 storeys above ground level ;

- non loadbearing internal walls.

(2) This ENV 1996-3 gives Principles and Application Rules for designing structures for specified requirements in respect of the aforementioned functions.

NOTE : The rules given in this ENV 1996-3 are consistent with those given in ENV 1996-1-1, but are more conservative in respect of the conditions and limitations of their use.

(3) This ENV 1996-3 applies only to those masonry structures, or parts thereof, that are described in ENV 1996-1-1 and ENV 1996-2.

(4) The simplified calculation methods given in this ENV 1996-3 are not applicable to the design for accidental situations.

1.2 Distinction between Principles and Application Rules

(1)P Depending on the character of the individual clausess, a distinction is made in this ENV 1996-3 between principles and application rules.

(2)P The principles comprise :

- general statements and definitions for which there is no alternative ;

- requirements and analytical models for which no alternative is permitted unless specifically stated.

(3)P The principles are defined by the letter P, following the clause number, for example,(1)P.

(4)P The application rules are generally recognised rules which follow the principles and satisfy their requirements. Alternative rules different from the application rules given in this ENV 1996-3 may be used provided that it is shown that the alternative rule accords to the relevant principles and has at least the same reliability.

(5)P The application rules are all clausess not indicated as being principles.

1.3 Assumptions

(1)P The assumptions stated in clause 1.3 of ENV 1996-1-1 also apply to this ENV 1996-3.

1.4 Definitions

1.4.1 General

(1)P Unless otherwise stated in the following, the terminology given in clause 1.4 of ENV 1996-1-1 and clause 1.5 of ENV 1996-2, shall apply to this Part.

1.4.2 Special terms used

(1)P Basement wall - A wall constructed partly or fully below ground level.

1.5 S.I. units

(1)P S.I. units in accordance with ISO 1000 shall be used.

1.6 Symbols

(1)P The symbols given in clause 1.6 of ENV 1996-1-1 also apply to this ENV 1996-3.
q_d is the design wind load on the wall per unit area of the wall.

2 Basis of design

2.1 General

(1)P The basis of design shall be in accordance with the principles given in Section 2 of ENV 1996-1-1 and this section 2.

2.2 Combination of actions

(1) The design value of a combination of actions for fundamental design situations shall be the larger value determined from the following expressions :

- considering only the most unfavourable variable action :

$$\Sigma\gamma_{G,j}\, G_{k,j} + \boxed{1{,}5}\, Q_{k,1} \qquad (2.1)$$

- considering all unfavourable variable actions

$$\Sigma\gamma_{G,j}\, G_{k,j} + \boxed{1{,}35}\, \Sigma Q_{k,i} \qquad (2.2)$$

Where :

$G_{k,j}$ is the characteristic value of permanent actions ;

$Q_{k,1}$ is the characteristic value of the most unfavourable variable action ;

$Q_{k,i}$ is the characteristic value of unfavourable variable actions ;

$\gamma_{G,j}$ is the partial safety factor for permanent actions, taken as 1,0 for favourable effects and 1,35 for unfavourable effects.

2.3 Partial safety factors for masonry

(1)P Partial safety factors for masonry are given in table 2.1, where the masonry unit categories I and II and category of execution A, B and C are defined in ENV 1996-1-1.

Table 2.1 : Partial safety factors for masonry (γ_M)

		γ_M for categories of execution :		
		A	B	C
Category of manufacturing control of units	I	1,7	2,2	2,7
	II	2,0	2,5	3,0

3 Materials

(1)P The material used in the masonry walls referred to in this ENV 1996-3 shall be in accordance with Section 3 of ENV 1996-1-1.

NOTE : A simplified calculation of the characteristic compressive strength of masonry, using the boxed values for K as given in ENV 1996-1-1, is provided at Annex D.

4 Design of unreinforced masonry walls using simplified calculation methods

4.1 General

(1)P The overall stability of the building, of which the wall forms a part, shall be in accordance with the requirements given in clause 4.1 of ENV 1996-1-1.

4.2 Simplified calculation method for walls subjected to vertical loading

4.2.1 Conditions for application

4.2.1.1 General conditions

(1)P For use of the simplified method the following conditions shall be complied with :

- the height of the building above ground level does not exceed 20 m ; for buildings with a sloping roof the average height of the ridge and the eaves may be taken as the building height ;

- the span of the floors supported by the walls does not exceed [7 m] ;

- the span of the roof supported by the walls does not exceed [7 m] , except in the case of timber or steel trussed roof construction where the span should not exceed [14 m] ;

  NOTE : If the figures 7 m and 14 m are to be varied in an NAD, recalibration should be carried out.

- the clear storey height does not exceed 3 m ;

- the thickness of walls, acting as end supports to floors or roofs, that are subjected to wind loading, are the same at all storeys ;

- the characteristic values of the variable actions on the floors and the roof do not exceed 5,0 kN/m² ;

- no actions other than those listed are applied ;

- the walls are be laterally restrained by the floors and roof in the horizontal direction at right angles to the plane of the wall, either by the floors and roof themselves or by suitable methods e.g. ringbeams with sufficient stiffness ;

- the final creep coefficient of the masonry Φ_∞ does not exceed 2,0 ;

  NOTE : It has been assumed that the quality of execution does not led to an accidental eccentricity greater than $h_{ef}/450$.

(2) A further simplified calculation method, applicable to buildings not exceeding 3 storeys in height, is given in Annex A.

4.2.1.2 Additional conditions

(1)P For walls acting as end supports to floors (see figure 4.1), the simplified calculation method given in 4.2.2 may be applied only if :

$$l \leq 4{,}5 + 10\,t \quad \text{and} \quad l \leq 7 \qquad (4.1)$$

where :

l is the floor span, in metres ;

t is the actual thickness of the wall, or the loadbearing leaf of a cavity wall, acting as an end support, in metres.

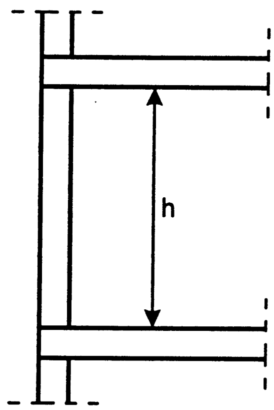


Figure 4.1 : Wall acting as end support

(2)P Walls acting as end supports to floors or roofs that are subjected to wind loading shall be designed according to 4.2.2 only if :

$$t \geq \frac{0,12 q_d . h^2}{N_{Sd}} + 0,017 h \qquad (4.2)$$

where :

h is the clear storey height, in metres ;

q_d is the design wind load on the wall per unit area of the wall, in kN/m² ;

N_{Sd} is the minimum design vertical load on the wall at the top storey, in kN/m ;

t is the actual thickness of the wall, or the loadbearing leaf of a cavity wall, acting as an end support, in metres.

(3) As an altemative to obtaining t from equation (4.2), t may be determined from the design method given in 4.1 of ENV 1996-1-3, provided that the minimum design vertical stress at the mid-height position of the top storey wall is 0,15 N/mm² or less and provided that neither major collapse nor total loss of stability of the building would result in the event of the failure of the top storey section of wall under consideration.

(4) If the method stated in clause (3) is adopted for the design of the wall then the vertical load resistance of the wall N_{Rd} should be derived from a presumed eccentricity at the ends of the wall of 0,4 t and a bearing depth of 0,2 t (see C1(3) & (4) of Annex C to ENV 1996-1-1).

4.2.2 Determination of design vertical load resistance of a wall

4.2.2.1 General

(1)P Under the ultimate limit state it shall be verified that :

$N_{Sd} \leq N_{Rd}$

where :

N_{Sd} is the design vertical load on the wall ;

N_{Rd} is the design vertical load resistance of the wall according to clause 4.2.2.2.

4.2.2.2 Design vertical load resistance

(1) The design vertical load resistance N_{Rd} may be determined from :

$$N_{Rd} = \frac{\Phi . f_k . A}{\gamma_M} \qquad (4.3)$$

where :

Φ is the capacity reduction factor allowing for the effects of slenderness and eccentricity of the loading, obtained from 4.2.2.3 ;

f_k is the characteristic compressive strength of the masonry ;

is the partial factor for the material, obtained from 2.3 ;

A is the net area of the masonry, taking into account any openings.

(2) The characteristic compressive strength of the masonry, f_k, should be obtained from 3.6.2 of ENV 1996-1-1, or from use of a simplified approach.

NOTE : A simplified method for obtaining f_k is given in Annex D.

4.2.2.3 Capacity reduction factor

(1) The capacity reduction factor Φ may be determined from :

$$\Phi = 0{,}85 - 0{,}0011 \left(\frac{h_{ef}}{t_{ef}}\right)^2 \qquad (4.4)$$

where :

h_{ef} is the effective height of the wall (see 4.2.2.4) ;

t_{ef} is the effective thickness determined in accordance with 4.4.5 of ENV 1996-1-1 ;

Φ is the capacity reduction factor which incorporates the buckling effect, the accidental eccentricity, the eccentricity due to loads and the creep effect.

4.2.2.4 Effective height of walls

(1) The effective height may be determined by

$$h_{ef} = \rho_n . h \qquad (4.5)$$

where :

h is the clear storey height ;

ρ_n is a reduction factor where n = 2, 3 or 4 depending on the edge restraint or stiffening of the wall.

(2) The reduction factor ρ_n may be determined as follows.

(i) For walls laterally and rotationally restrained at top and bottom only by reinforced or prestressed concrete floors or roof (see figure 4.2) and having a bearing of at least 2/3 the thickness of the wall, but not less than 85 mm :

$\rho_2 = \boxed{0,75}$

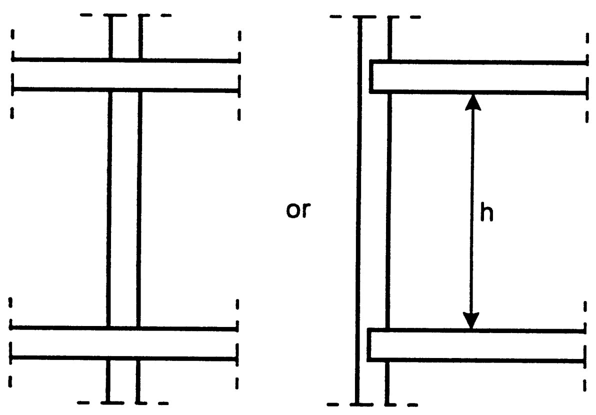


Figure 4.2 : Rotational restraint provided by floors or roof

(ii) For walls laterally restrained at top and bottom only (e.g. by ring beams of appropriate stiffness) but not rotationally restrained by the floors or roof (see figure 4.3) :

$\rho_2 =$ $\boxed{1,00}$

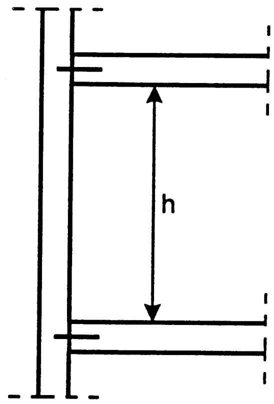


Figure 4.3 : No rotational restraint provided by floors or roof

(iii) For walls laterally restrained at top and bottom and at one vertical edge (see figure 4.4) :

$\rho_3 = 1,5 \frac{L}{h}$ $\leq$ $\boxed{0,75}$ in the case of rotational restraint at top and bottom only as in (i) above

$\leq$ $\boxed{1,00}$ in the case of no rotational restraint at top and bottom as in (ii) above

Where :

h is the clear storey height ;

L is the distance from the vertically supported edge to the free edge.

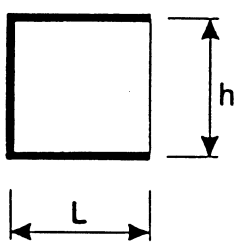


Figure 4.4 : Lateral restraint at top and bottom and at one vertical edge

(iv) For walls laterally restrained at top and bottom and at two vertical edges (see figure 4.5) :

$\rho_4 = \frac{L}{2h}$ $\leq$ $\boxed{0,75}$ in the case of rotational restraint at top and bottom only as in (i) above

$\leq$ 1,00 in the case of no rotational restraint at top and bottom as in (ii) above

where :

h is the clear storey height ;

L is the distance between the supports at the vertical edges.

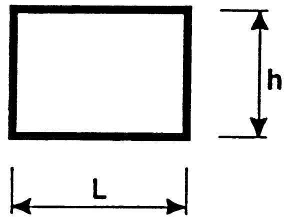


Figure 4.5 : Lateral restraint at top and bottom and two vertical edges

4.2.2.5 Slenderness ratio of walls

(1)P The slenderness ratio of a wall h_{ef}/t_{ef} shall not be greater than 27

4.3 Simplified calculation method for walls subjected to concentrated loads

(1) The design compressive stress locally under the bearing area of a concentrated load should not exceed the following :

$$\frac{f_k}{\gamma_M}\left(1{,}2+0{,}4\frac{a_1}{H}\right) \leq 1{,}5\frac{f_k}{\gamma_M} \qquad (4.6)$$

Where :

a_1 is the distance from the end of the wall to the nearer edge of the bearing area of the concentrated load (see Figure 4.6) ;

H is the height to the level of the load (see Figure 4.6).

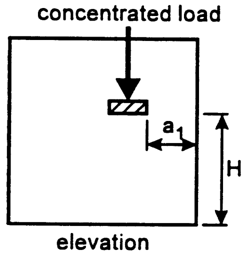


Figure 4.6 : Concentrated load in relation to a_1 and H

Provided that :

- the bearing area under the concentrated load neither exceeds ¼ of the cross sectional area of the wall nor exceeds the value $2t^2$, where t is the thickness of the wall ;

- the eccentricity of the load from the centre plane of the wall is not greater than t/4 ;

- the adequacy of the wall at its middle height section is verified in accordance with 4.2, assuming the concentrated load spreads at an angle of 60 ° ;

- the part of the wall in which enhanced compressive stresses are being allowed is made of group 1 units. For other unit groups no enhancement is allowed.

4.4 Simplified calculation method for shear walls

4.4.1 Verification of shear resistance of walls

(1)P Under the ultimate limit state, it shall be verified that :

$$V_{Sd} \le V_{Rd}$$

Where :

V_{Sd} is the design shear load on the wall

V_{Rd} is the design shear resistance of the wall.

(2) A further simplified calculation method of designing shear walls for buildings not exceeding 3 storeys in height, is given in Annex A.

4.4.2 Design shear resistance

(1) The design shear resistance V_{Rd} may be determined as follows :

If all vertical joints of the masonry are filled with mortar :

$$V_{Rd} = \frac{1}{\gamma_M}(t.l_c.f_{vko} + 0{,}4N_{Sd}) \qquad (4.7)$$

provided that $\frac{1}{\gamma_M}(t.l_c f_{vko}) \le V_{Rd} \le \frac{1}{\gamma_M} t.l_c . \boxed{0{,}065} f_b$

If the vertical joints of the masonry are not filled with mortar :

$$V_{Rd} = \frac{1}{\gamma_M}(0{,}5\,t.l_c.f_{vko} + 0{,}4N_{Sd}) \qquad (4.8)$$

provided that $\frac{1}{\gamma_M}(t.l_c f_{vko}) \le V_{Rd} \le \frac{1}{\gamma_M} t.l_c . \boxed{0{,}045} f_b$

Where :

l_c is the length of the compressed part of the wall (assuming a linear stress distribution (see figure 4.7) ;

t is the thickness of the web of the wall ;

f_b is the normalized compressive strength of the masonry unit ;

f_{vko} is the initial shear strength taken from ENV 1996-1-1 ;

N_{Sd} is the design vertical load.

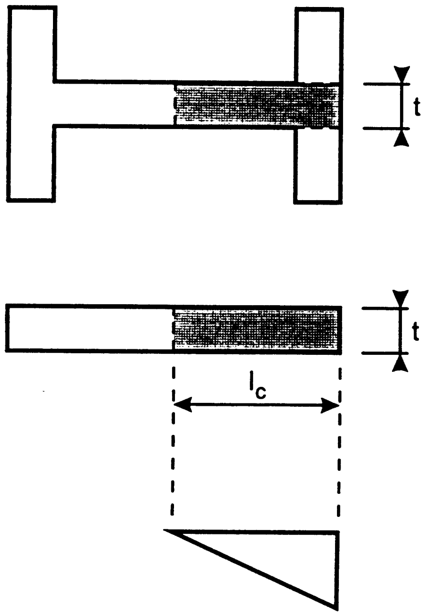


Figure 4.7 : Length of the compressed part of the wall

4.5 Simplified calculation method for basement walls subjected to lateral earth pressure

(1) The following simplified method may be used for designing basement walls subjected to lateral earth pressure providing the following conditions are fulfilled :

- the clear height of the basement wall, h ≤ 2600 mm, and the wall thickness, t ≥ 200 mm ;

- the floor over the basement acts as a diaphragm and is capable of withstanding the forces resulting from the soil pressure ;

- the imposed load on the ground surface in the area of influence of the soil pressure on the basement wall P_S , does not exceed 5 kN/m² and no concentrated load within 1 500 mm of the wall exceeds 15 kN (see also figure 4.8) ;

- the ground surface does not rise, away from the wall and the depth of fill does not exceed the wall height ;

- there is no hydrostatic pressure ;

- no slip plane is created by a damp proof course.

(2) The design of the wall may be derived on the basis of the following expressions, as appropriate :

(i) when $b_c \geq 2h$:

$$\frac{t.f_k}{3\gamma_M} \geq N \geq \frac{\rho_e.h.h_e^{\,2}}{20t} \tag{4.9}$$

(ii) when $b_c \leq h$:

$$\frac{t.f_k}{3\gamma_M} \geq N \geq \frac{\rho_e.h.h_e^{\,2}}{40t} \tag{4.10}$$

(iii) For values of b_c between h and 2h, linear interpolation between the values obtained from equations (4.9) and (4.10) is permitted.

Where :

N	is the vertical design load on the wall per unit length which results from permanent loading at the mid-height of the fill ;
b_c	is the distance apart of cross walls or other buttressing elements ;
h	is the clear height of the basement wall ;
h_e	is the depth of soil retained by the wall ;
t	is the wall thickness ;
ρ_e	is the bulk density of the soil ;
f_k	is the characteristic compressive strength of the masonry ;
γ_M	is the partial safety factor for material obtained from 2.3

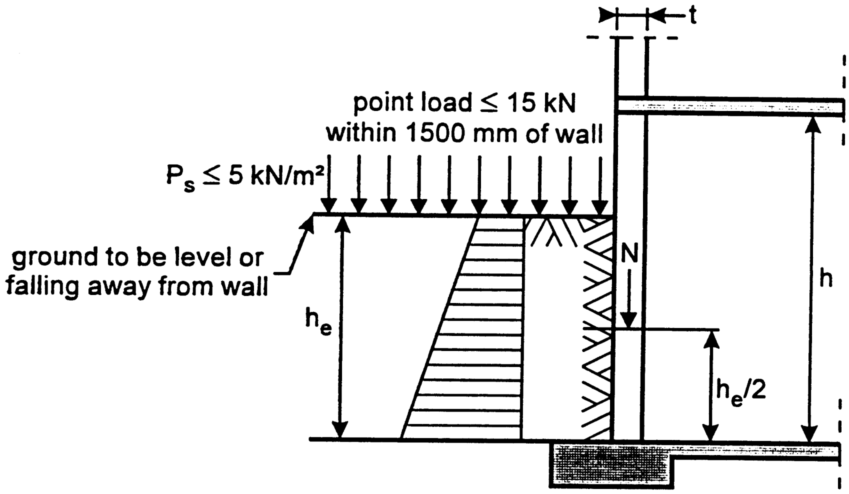


Figure 4.8 : Design loads for basement walls

NOTE : The method has been simplified in Annex B as a basis for determining the thickness of basement walls to buildings up to 4 storeys in height above ground level.

4.6 Simple rules for the design of non loadbearing internal walls

(1) Simple rules for determining the minimum thickness and limiting dimensions of non loadbearing internal walls having variable conditions of lateral restraint, conditional on certain restrictions, are given in Annex C.

Annex A (Normative)

Simplified calculation method for unreinforced masonry walls of buildings not greater than 3 storeys

A1 General conditions for application

(1) For buildings not greater than 3 storeys the simplified calculation method given in this Annex may be used, provided the following conditions are fulfilled.

- the building does not exceed 3 storeys in height above the ground level ;

- the walls are laterally restrained by the floors and roof in the horizontal direction at right angles to the plane of the wall, either by the floors and roof themselves or by suitable methods eg. ring beams with sufficient stiffness ;

- the floors and roof have a bearing on the wall of at least 2/3 of thickness of the wall but not less than 85 mm ;

- the clear storey height does not exceed 3 m ;

- cross walls or buttressing elements are provided as vertical restraints such that the length of any external wall measured between such vertical restraints is not more than 3 times its clear storey height ;

- the ratio h/t of internal and external walls is not greater than [18] ;

Where :

h is the clear storey height of the wall and t is the actual thickness of the wall, (or the loadbearing leaf of a cavity wall) ;

- the height of the building is not greater than three times its width ;

- the characteristic values of the variable actions on the floors and the roof do not exceed 5,0 kN/m² ;

- the maximum span of any floor is 6 m ;

- the maximum span of the roof is 6 m, except in the case of timber or steel trussed roof construction where the span does not exceed 12 m.

A2 Design vertical load resistance of the wall

(1) The design vertical load resistance N_{Rd} is given by the formula :

$$N_{Rd} = \frac{0,5\, f_k \cdot A}{\gamma_M} \qquad \text{(A1)}$$

where :

f_k is the characteristic compressive strength of the masonry, in N/mm² ;

A is the horizontal section of the wall excluding openings.

A3 Shear walls without verification of wind load resistance

(1) Shear walls may be designed without verification of the wind load resistance, if a sufficient number of walls stiffen the building against horizontal forces in both directions.

The walls may be presumed to be sufficient if :

- the characteristic wind load does not exceed 1 kN/m² ;
- there are two walls or more in both perpendicular directions ;
- the design vertical load resistance of the shear walls excluding wind loading, is verified in accordance with 4.2 assuming a reduced compressive strength of masonry of $0{,}8 \cdot f_k$;
- the layout of the shear walls is approximately symmetrical in plan (see figure A1) ;
- the sum of the web areas of shear walls in each perpendicular direction, considering only webs with a length of more than $0{,}2\ h_{tot}$ and excluding flanges, satisfies the following relationchip :

$\Sigma\, t \cdot l_x \geq k.L_y \cdot h_{tot}$ and $\Sigma\, t \cdot l_y \geq k.L_x \cdot h_{tot}$

where :

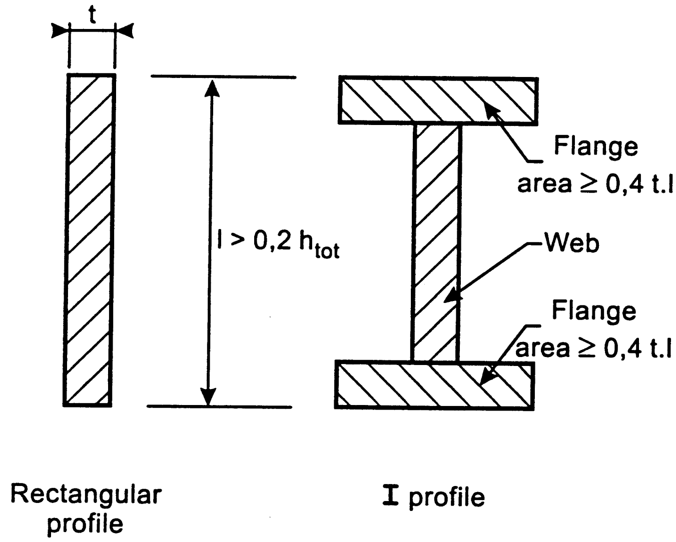
l_x, l_y are the shear wall lengths (see figure A1)

h_{tot} is the height of the building ;

k is obtained from table A1.

Table A1 : Values of k

Shear wall profile	8,0 N/mm² ≥ f_b ≥ 2.0 N/mm²	f_b > 8,0 N/mm²
Rectangular	k = 0,02	k = 0,03
I - Profile having flange areas in excess of 0,4 t.l.	k = 0,01	k = 0,02



Plan of shear walls

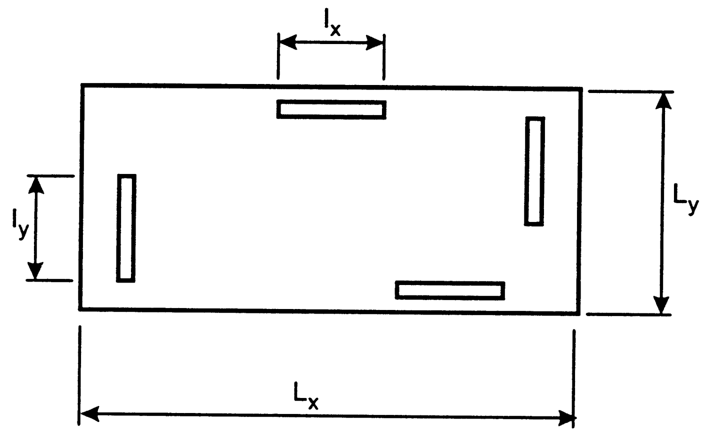


Figure A1 : Layout of shear walls

Annex B (Informative)

Simple rules for designing unreinforced basement walls for low rise buildings

B1 General

(1) This Annex applies only to buildings of the following generic forms where :

- the building is not greater than 4 storeys in height above ground floor level (see figure B.1) ;

- the roof (either flat or pitched) and the intermediate floors are of timber or concrete construction ;

- the floor at ground floor level is of suspended concrete construction ;

- the external walls above ground floor level are of masonry or concrete construction

- the basement walls are of masonry construction and support the external walls of the building above ground floor level (see figure B.1).

(2) The rules given in this Annex may only be used under the following conditions

- the clear headroom within the basement storey does not exceed 2.6 m ;

- the thickness of the external basement walls is not less than 200 mm ;

- the basement walls are not subjected to hydrostatic pressure ;

- no horizontal slip plane is created in the wall construction (eg. by the provision of an unbonded damp proof course) ;

- the ground and basement floors are of 300 kg/m² minimum mass and act as diaphragms providing adequate lateral restraint to the basement walls ;

- the ground surface immediately adjacent to the face of the basement wall is either level or falls away from the wall (see figure B.2) and is not subjected to an imposed loading in excess of 5 kN/m² nor a concentrated load, within 1,5 m distance from the wall, which exceeds 15 kN ;

- the basement wall has a minimum mass of 600 kg/m^3 ;

- if the roof is of concrete construction then its mass, including any screed or finishes, is not less than 225 kg/m² ;

- the masonry units used for the basement wall construction are of any of the types referred to in ENV 1996-1-1 under Groups 1, 2a and 2b having a minimum normalised compressive strength of 4,0 N/mm² ;

- the mortar used for the basement wall construction is M5 according to ENV 1996-1-1, or higher, classification.

B2 Determination of thickness of basement walls

(1) The minimum thickness of basement walls may be determined by the following procedure ;

- determine the mass (kg/m²) of the superstructure wall, inclusive of finishes, insulation, plaster, etc., ignoring any openings ;

- determine the mass (kg/m²) of the concrete ground floor, inclusive of finishes, plaster, etc., that spans onto the basement wall. Ignore mass of floor if spanning parallel to the length of the basement wall ;

- determine the average mass (kg/m²) of the concrete floors above the ground floor, inclusive of finishes, plaster, etc., that span onto the wall supported by the basement wall. Ignore mass of floor if of timber construction or if spanning parallel to the length of the basement wall ;

- determine the average extent of openings in the height of external wall above ground floor level supported by the basement wall. This may be assessed in percentage area terms for each linear length of basement wall not exceeding 5 m ie. by dividing the aggregated area of openings contained in each section of wall considered by the complete area of the section of wall and multiplying by 100 (see example given in figure B4) ;

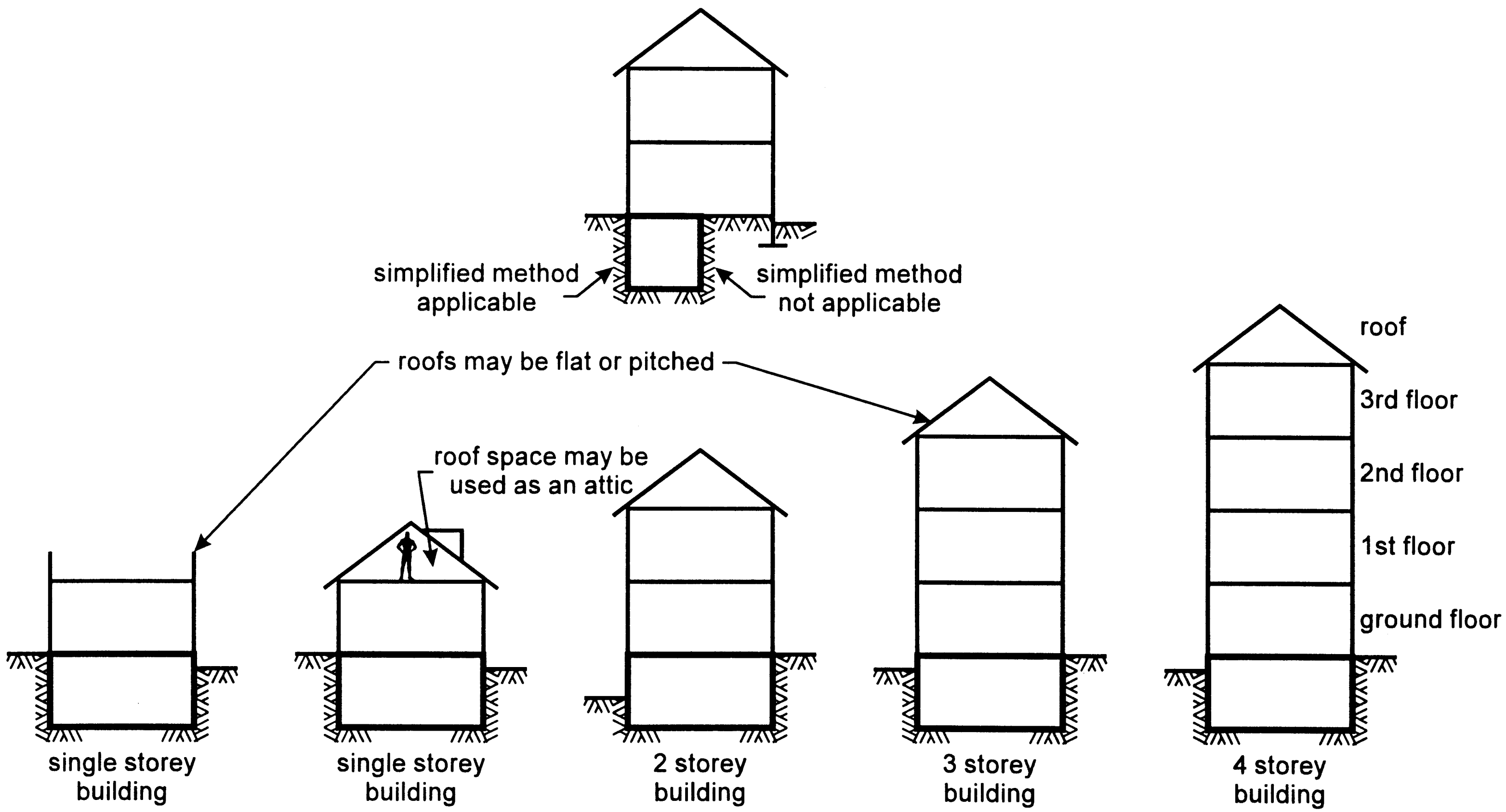
- determine the vertical loading category from table B1 ;

- from tables B2 (a to c) and B3 determine loading classification letter on the basis of the foregoing parameters ;

- if the basement wall supports a masonry gable wall which extends up to the verges of a pitched roof (see figure B3) raise the loading classification by 1 letter, eg. from E to F ;

- determine the height of retained ground (h_e) (see figure B2) ;

- from figure B5 determine the minimum thickness required for the basement wall on the basis of the loading classification letter and the value of the height of retained ground (h_e).



Floors and roofs may be either of concrete or timber construction, except for the floor at ground floor level which should be of concrete construction

Figure B1 : Application of simplified method of designing basements to low rise buildings

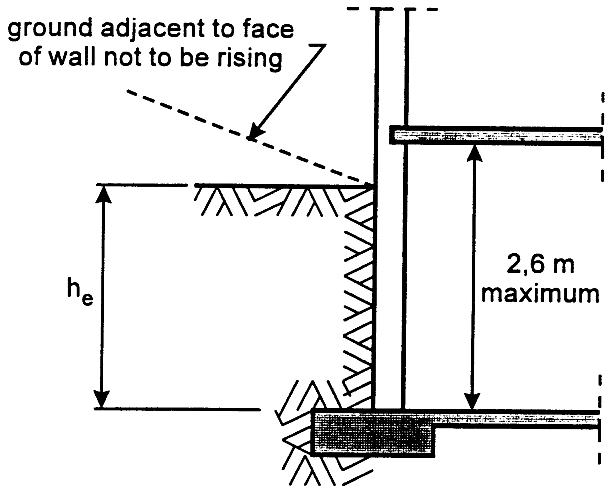


Figure B2 : Height of retained ground

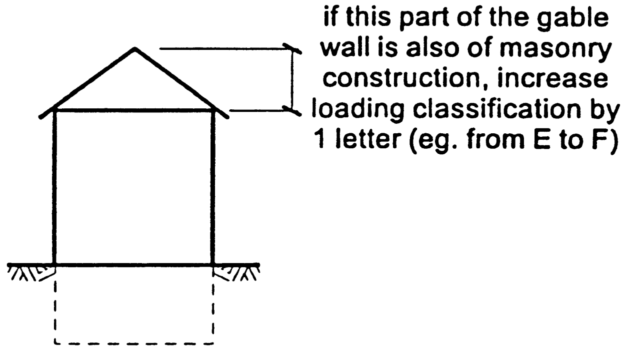
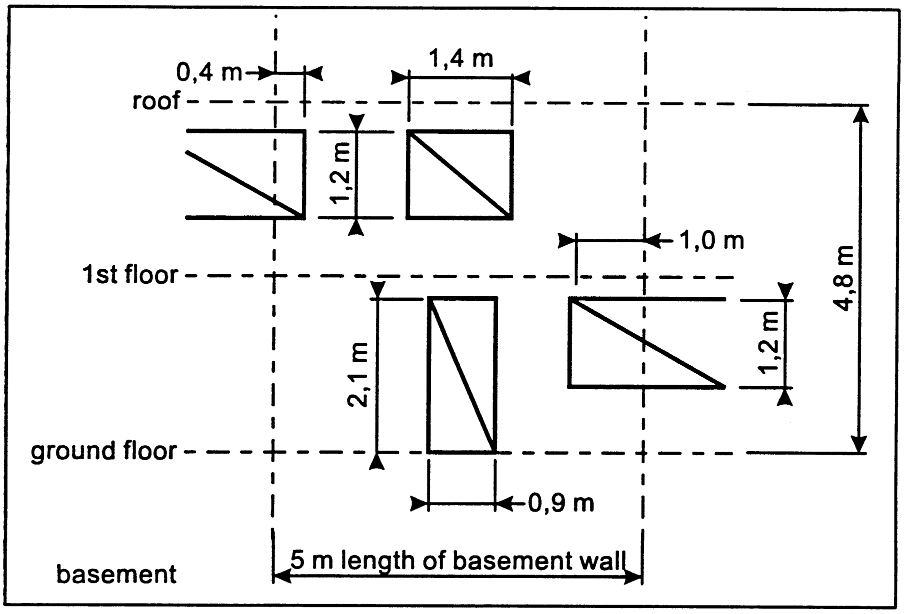


Figure B3 : Allowance for gable walls



Average extent of openings = $[\frac{(1,2x0,4)+(1,4x1,2)+(1,0x1,2)+(2,1x0,9)}{5x4,8}]x100 = 21,87\ \%$

Figure B4 : Example of determination of extent of wall openings

Table B1 : vertical loading categories

Vertical loading category	Elements of building supported by the basement wall
1	external wall
2	external wall + roof
3	external wall + ground floor
4	external wall + roof + ground floor
5	external wall + 1 upper floor
6	external wall + roof + 1 upper floor
7	external wall + ground floor + 1 upper floor
8	external wall + roof + ground roof + 1 upper floor
9	external wall + 2 upper floors
10	external wall + roof + 2 upper floors
11	external wall + ground floor + 2 upper floors
12	external wall + roof + ground floor + 2 upper floors
13	external wall + 3 upper floors
14	external wall + roof + 3 upper floors
15	external wall + ground floor + 3 upper floors
16	external wall + roof + ground floor + 3 upper floors

Table B.2 (a) : Loading classification for basement walls supporting

2 to 4 storey buidings

Mass of external wall above ground floor level kg/m²	Mass of suspended concrete floors kg/m²	No of storeys above ground floor	Average extent (%) of openings in external wall above basement	Loading classification: Vertical loading category (see table B.1)															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
300	300	2	< 10	B	C	C	D	C	D	D	E								
			< 30	A	B	B	C	B	C	D	D								
		3	< 10	C	D	D	E	D	E	C	F	C	F	G	C				
			< 30	B	C	C	D	C	D	E	E	E	E	F	G				
		4	< 10	D	E	F	F	F	F	G	H	G	H	H	J	H	J	J	K
			< 30	C	D	D	E	D	E	F	F	F	F	G	H	G	H	H	J
400	300	2	< 10	C	C	D	E	D	E	E	F								
			< 30	B	C	C	D	C	D	D	E								
		3	< 10	D	E	E	F	E	F	G	G	G	G	H	H				
			< 30	C	D	D	E	D	E	F	F	F	F	G	H				
		4	< 10	F	G	G	H	G	H	H	J	H	J	K	K	K	K	L	M
			< 30	D	E	F	F	F	F	G	H	G	H	H	J	H	J	J	K
500	300	2	< 10	C	D	E	E	E	E	F	G								
			< 30	C	C	D	E	D	E	E	F								
		3	< 10	F	F	G	H	G	H	H	J	H	J	J	K				
			< 30	D	E	E	F	E	F	G	G	G	G	H	J				
		4	< 10	H	J	J	K	J	K	K	L	K	L	L	M	L	M	M	M
			< 30	F	G	G	H	G	H	H	J	H	J	J	K	J	K	L	L

Table B.2 (b) : Loading classification for basement walls supporting

2 to 4 storey buildings

Loading classification																			
Mass of external wall above ground floor level kg/m²	Mass of suspended concrete floors kg/m²	No of storeys above ground floor	Average extent (%) of openings in external wall above basement	Vertical loading category (see table B.1)															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
300	400	2	< 10	B	C	C	D	C	D	E	F								
			< 30	A	B	C	D	C	C	D	E								
		3	< 10	C	D	E	E	E	E	F	G	F	G	H	J				
			< 30	B	C	D	E	D	D	E	F	E	F	G	J				
		4	< 10	D	E	F	G	F	G	H	H	H	H	J	K	J	K	L	M
			< 30	C	D	E	F	E	F	F	G	F	G	H	J	H	J	K	K
400	400	2	< 10	C	C	D	E	D	E	F	G								
			< 30	B	C	C	D	C	D	E	F								
		3	< 10	D	E	F	G	F	G	G	H	G	H	J	K				
			< 30	C	D	E	F	E	F	F	G	F	G	H	J				
		4	< 10	F	G	H	H	H	H	J	K	J	K	L	M	L	M	M	M
			< 30	D	E	F	G	F	G	H	H	H	H	J	K	J	K	L	M
500	400	2	< 10	C	D	E	F	E	F	G	G								
			< 30	C	C	D	E	D	E	F	G								
		3	< 10	F	F	G	H	G	H	J	K	J	K	K	L				
			< 30	D	E	F	G	F	G	G	H	G	H	J	K				
		4	< 10	H	J	J	K	J	K	L	M	L	M	M	M	M	M	M	M
			< 30	F	G	G	H	G	H	J	K	J	K	L	L	L	L	M	M

Table B.2 (c) : Loading classification for basement walls supporting

2 to 4 storey buildings

Loading classification																			
Mass of external wall above ground floor level kg/m²	Mass of suspended concrete floors kg/m²	No of storeys above ground floor	Average extent (%) of openings in external wall above basement	Vertical loading category (see table B.1)															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
300	500	2	< 10	B	C	D	E	D	E	F	G								
			< 30	A	B	C	D	C	D	E	F								
		3	< 10	C	D	E	F	E	F	G	H	G	H	J	K				
			< 30	B	C	D	E	D	E	F	G	F	G	H	J				
		4	< 10	D	E	F	G	F	G	H	J	H	J	K	L	K	L	M	M
			< 30	C	D	E	F	E	F	G	H	G	H	J	K	J	K	L	M
400	500	2	< 10	C	C	E	E	E	E	G	G								
			< 30	B	C	D	E	D	E	F	G								
		3	< 10	D	E	F	G	F	G	H	J	H	J	K	L				
			< 30	C	D	E	F	E	F	G	H	G	H	J	K				
		4	< 10	F	G	H	J	H	J	K	L	K	L	M	M	M	M	M	M
			< 30	D	E	F	G	F	G	H	J	H	J	K	L	K	L	M	M
500	500	2	< 10	C	D	E	F	E	F	G	H								
			< 30	C	C	E	E	E	E	G	G								
		3	< 10	F	F	H	H	H	H	K	K	K	K	M	M				
			< 30	D	E	F	G	F	G	H	J	H	J	K	L				
		4	< 10	H	J	K	L	K	K	M	M	M	M	M	M	M	M	M	M
			< 30	F	G	H	J	H	J	K	L	K	L	M	M	M	M	M	M

Table B.3 : Loading classification for basement walls suporting single storey buildings

Loading classification						
Mass of external wall above ground floor level kg/m²	Mass of suspended concrete floor kg/m²	Average extent (%) of openings in external wall above basement	Vertical loading category (see Table B.1)			
			1	2	3	4
300	300	< 10	A	B	B	D
		< 20	A	B	B	D
		< 30	A	B	B	C
		< 40	-	B	B	C
400	300	<10	A	C	C	D
		< 20	A	C	C	D
		< 30	A	B	B	D
		< 40	A	B	B	D
500	300	<10	B	C	C	E
		< 20	A	C	C	D
		< 30	A	C	C	D
		< 40	A	B	B	D
300	400	< 10	A	B	C	D
		< 20	A	B	C	D
		< 30	A	B	B	D
		< 40	-	B	B	D
400	400	< 10	A	C	C	E
		< 20	A	C	C	D
		< 30	A	B	C	D
		< 40	A	B	C	D
500	400	< 10	B	C	D	E
		< 20	A	C	C	E
		< 30	A	C	C	D
		< 40	A	B	C	D
300	500	< 10	A	B	C	E
		< 20	A	B	C	D
		< 30	A	B	C	D
		< 40	-	B	C	D
400	500	< 10	A	C	D	E
		< 20	A	C	C	E
		< 30	A	B	C	E
		< 40	A	B	C	D
500	500	< 10	B	C	D	E
		< 20	A	C	D	E
		< 30	A	C	C	E
		< 40	A	B	C	E

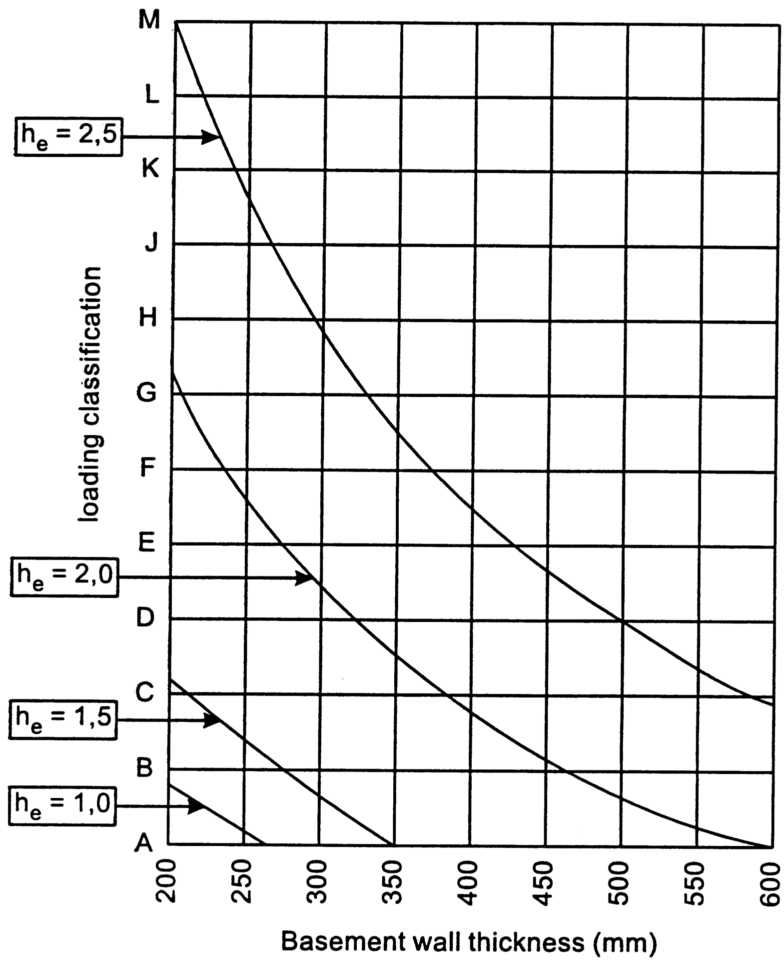


Figure B.5 : Determination of thickness of basement walls

Annex C (Normative)

Simple rules for the design of non loadbearing internal walls

C1 General conditions for application

(1) The rules given in this Annex apply only in circumstances where :

- the wall is situated inside a building ;

- the external facade of the building is not pierced by a large door, or similar openings ;

- the wall is not subjected to any permanent or exceptional variable actions (including wind loading), other than that due to its self weight ;

- the wall is not used as a support for heavy objects such as furniture, sanitary or heating equipment ;

- the wall is not subjected to crowd loading ;

- the stability of the wall is not adversely affected by the deformation of other parts of the building (eg. by deflection of floors) or by operations within the building ;

- the stability of the wall is not adversely affected by the provision of any door or other openings formed in the wall (see C.2 (2) for method of designing walls with openings) ;

- the stability of the wall is not adversely affected by the provision of any chase in the wall.

(2) Use of the rules given in this Annex is also dependent on the following dimensional and constructional requirements being adhered to :

- the height (H) of the wall does not exceed 6 m ;

- the length (L) of the wall does not exceed 12 m between vertical restraints ;

- the thickness of the wall, excluding any plaster, is not less than [50 mm] ;

- for walls designed as being restrained at the top, such restraint is purposely designed and constructed ;

- for walls designed as being restrained at the vertical edge, such restraint is purposely designed and constructed ;

- the masonry units used for the wall construction may be any of the types referred to in ENV 1996-1-1 under Groups 1, 2a, 2b and 3 ;

- the mortar used for the wall construction may be any of the types referred to in ENV 1996-1-1, but :

General purpose mortar should not be less than class M2.
Thin layer and lightweight mortar should not be less than M5.
Mortar used for Group 3 masonry units should not be less than M10.

C2 Determination of thickness and size limitation of non-loadbearing internal walls

(1) The minimum thickness and limiting dimensions of the wall may be determined from figure C1 which provides for the following conditions of lateral restraint to the wall :

- type a : walls restrained along 4 edges ;
- type b : walls restrained along all edges, except for 1 vertical edge ;
- type c : walls restrained along all edges, except at the top edge ;
- type d : walls restrained along the top and bottom edges only.

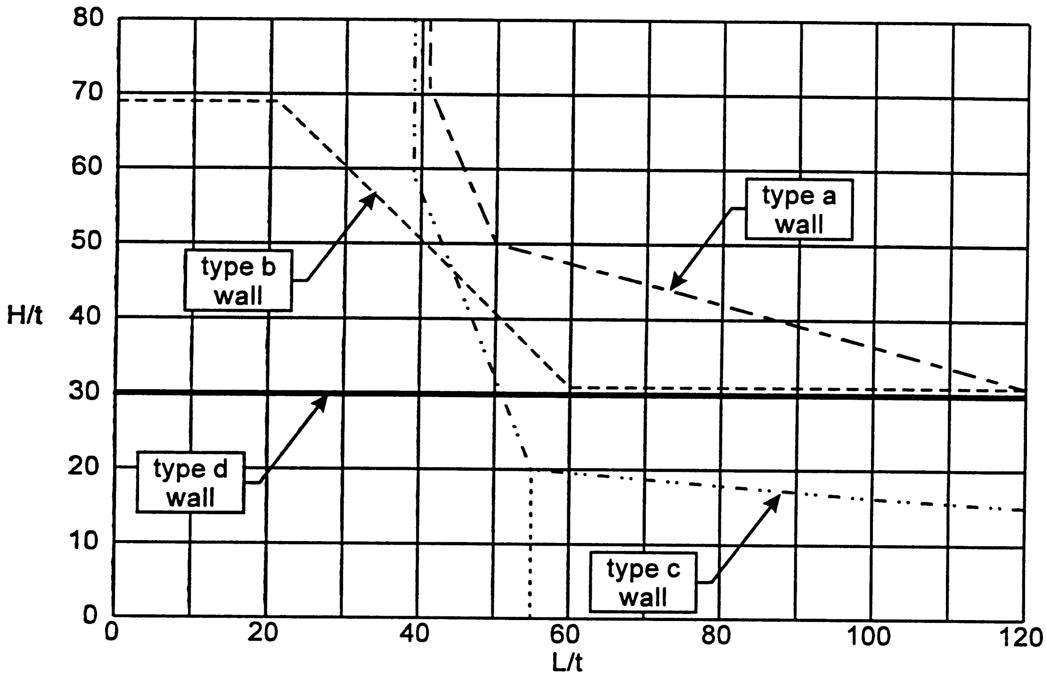
(2) For walls with openings the minimum thickness and limiting dimensions may also be determined from figure C.1 provided that the type of wall is derived from the basis illustrated in figure C.2.

(3) The effect of openings on the stability of the wall may be ignored in the following circumstances :

- where the aggregated area of the openings is not greater than 2,5 % of the area of the wall ;

and

- where the maximum area of any individual opening is not greater than 0,1 m^2.



NOTE : t is the wall thickness (in mm) which may include 13 mm maximum thickness of plaster on each side of the wall H is the wall height (in mm), and L is the wall length (in mm). The thickness of any dry lining materials should be ignored.

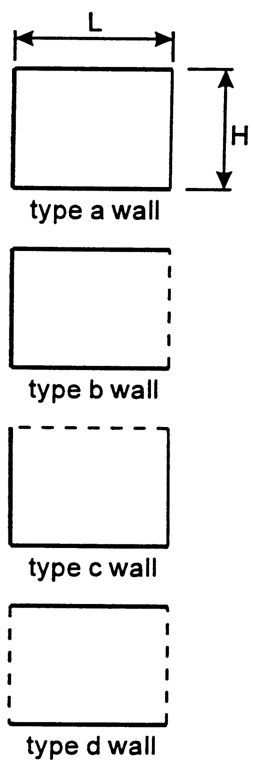
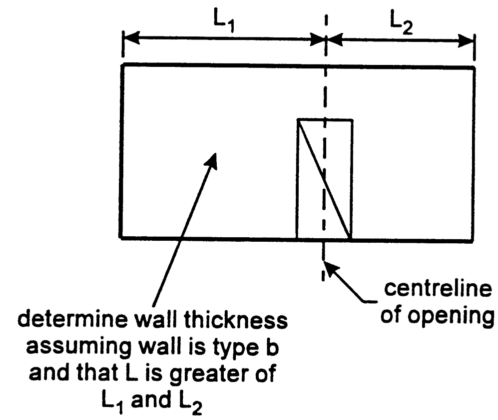
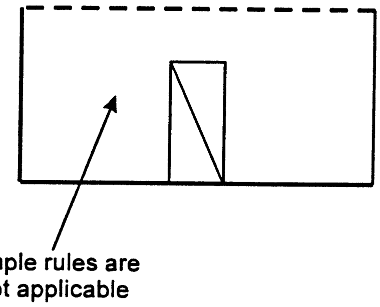


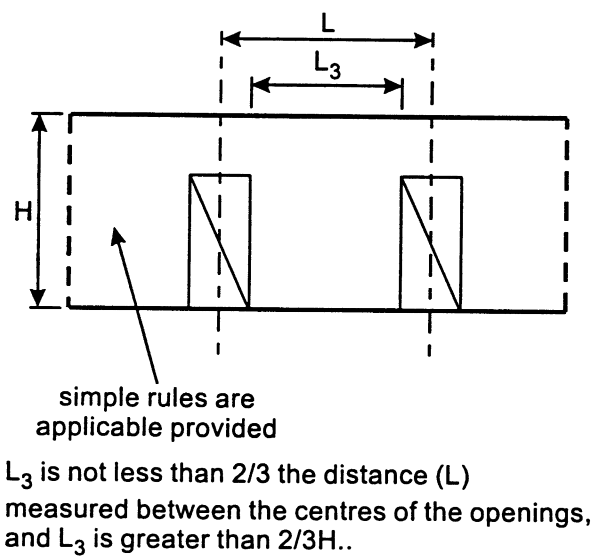
Figure C1 : Thickness and size limitation of non-loadbearing internal walls



Type a wall with opening



Type c wall with opening



Type d wall with openings

Figure C2 : Application of simple rules for non load-bearing walls with openings

Annex D (Informative)

Simplified method of determining the characteristic compressive strength of masonry

D1 General

(1) The determination of the characteristic compressive strength of masonry f_k, may be obtained by the following simplified methods applicable to various types of masonry construction only when the values of K given in the boxes in ENV 1996-1-1 are accepted for use without alteration.

D2 General purpose mortars

(1) The characteristic compressive strength may be determined from the following equation :

$$f_k = f_{ko} \cdot C_1 \qquad \text{(D2)}$$

where the values of f_{ko} and C_1 are obtained from tables D2.1 and D2.2 respectively.

Table D2.1 : Values of f_{ko} of unreinforced masonry

	f_{ko} (N/mm²) for mortar :			
f_b N/mm²	M 2,5	M 5	M 10	M 20
2	1,0	1,1	1,1	1,1
4	1,5	1,8	2,1	2,1
6	2,0	2,4	2,8	3,0
8	2,4	2,9	3,4	3,9
10	2,8	3,3	4,0	4,7
12	3,2	3,8	4,5	5,3
16	3,8	4,5	5,4	6,4
20	4,4	5,2	6,2	7,4
25	5,1	6,1	7,2	8,6
30	5,7	6,8	8,1	9,6

Table D2.2 : Values of C_1

	C_1 for unit group :			
	1	2a	2b	3
Masonry with no longitudinal joints	1,2	1,1	1,0	0,8
Masonry with longitudinal joints	1	0,9	0,8	0,8

D3 Thin layer mortars and group 1 calcium silicate units and autoclaved aerated concrete units without any longitudinal joint

(1) The characteristic compressive strength of group 1 calcium silicate units and autoclaved aerated concrete when laid with thin layer mortar may be determined from the following equation :

$$f_k = f_{ko} \qquad \text{(D3)}$$

where the values of f_{ko} are obtained from table D3.

Table D3 : Values of f_{ko} of unreinforced masonry

f_b N/mm²	f_{ko} N/mm²
2	1,4
4	2,6
6	3,7
8	4,7
10	5,7
12	6,6
16	8,4
20	10,2
25	12,3
30	14,4

D4 Thin layer mortars and units other than calcium silicate and autoclaved aerated concrete units

(1) The characteristic compressive strength of units other than group 1 calcium silicate units and autoclaved aerated concrete when laid with thin layer mortar may be determined from the following equation :

$$f_k = f_{ko} \cdot C_3 \qquad \text{(D4)}$$

where the values of f_{ko} and C3 are obtained from tables D4.1 and D4.2 respectively.

Table D4.1 : Values of f_{ko} of unreinforced masonry

	f_{ko} N/mm² for mortar :		
f_b N/mm²	M 5	M 10	M 20
2	1,1	1,1	1,1
4	1,8	2,1	2,1
6	2,4	2,8	3,0
8	2,9	3,4	3,9
10	3,3	4,0	4,7
12	3,8	4,5	5,3
16	4,5	5,4	6,4
20	5,2	6,2	7,4
25	6,1	7,2	8,6
30	6,8	8,1	9,6

Table D4.2 : Values of C_3

Unit Group	1	2a	2b	3
C3 (no longitudinal joint)	1,4	1,2	1,0	-

D5 Light weight mortar and units group 1, 2a, 2b without any longitudinal mortar joint

(1) The characteristic compressive of strength of units group 1.2a, 2b without any longitudinal mortar joint when laid with lightweight mortar may be determined from the following equation :

$$f_k = f_{ko} \cdot C_2 \qquad \text{(D5)}$$

where the values of f_{ko} and C_2 are obtained from tables D5.1 and D5.2 respectively.

Table D5.1 : Values of f_{ko}

f_b N/mm²	f_{ko} (N/mm²)
2	0,9
4	1,4
6	1,8
8	2,1
10	2,5
12	2,8

Table D5.2 : Values of C_2

Units and dry density of mortar		C2
Lightweight aggregate concrete and autoclaved aerated concrete units with mortar 600 - 1500 kg/m^3		1,45
All other units with mortar	700 - 1000 kg/m^3	1,27
	600 - 700 kg/m^3	1,00

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