DRAFT FOR DEVELOPMENT

DD ENV 1996-1-3:2001

Eurocode 6: Design of masonry structures —

Part 1.3: General rules for building — Detailed rules on lateral loading

(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

This Draft for Development, having been prepared under the direction of the Building and Civil Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Committee and comes into effect on 15 September 2001

Amendments issued since publication

Amd. No.	Date	Comments

The following BSI reference relates to the work on this Draft for Development:
Subcommittee reference B/525/6

ISBN 0 580 33278 0

Contents

National foreword

This Draft for Development was prepared by Subcommittee B/525/6, and is the English language version of ENV 1996-1-3:1998 *Eurocode 6: Design of masonry structures — Part 1-3: General rules for building — Detailed rules on lateral loading*, 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 1996-1-3:1998 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 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 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 1996-1-3 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.

The recommendations of DD ENV 1996-1-3 apply pending the publication of ENV 1996-2.

Compliance with ENV 1996-1-3:1998 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 viii, the ENV title page, pages 2 to 23 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

National Application Document

for use in the UK with ENV 1996-1-3:1998

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 1996-1-3:1998.

It should be noted that this NAD, in common with ENV 1996-1-1 and supporting European Standards, uses a comma (,) where a decimal point (.) would be traditionally used in the UK.

1 Scope

This NAD provides information to enable ENV 1996-1-3:1998 to be used for the design of buildings and civil engineering works 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.

BS 648:1964, *Schedule of weights of building materials*.

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

BS 6399-1:1996, *Loading for buildings — Part 1: Code of practice for dead and imposed loads*.

BS 6399-2:1997, *Loading for buildings — Part 2: Code of practice for wind loads*.

BS 6399-3:1998, *Loading for buildings — Part 3: Code of practice for imposed roof loads*.

CP 3:1972, *Code of basic data for the design of buildings — Chapter V: Loading — Part 2: Wind 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 Partial safety factors, combination factors and other boxed values

The values for partial safety factors (γ factors) should be relevant values chosen from those given in Table 1 of the NAD to ENV 1996-1-1:1995.

The values for combination factors (ψ factors) should be relevant values chosen from those given in Table 2 of the NAD to ENV 1996-1-1:1995.

The values for other boxed values should be relevant values chosen from those given in Table 3 of the NAD to ENV 1996-1-1:1995 except that the minimum thickness of the wall or one leaf of a cavity wall in **A.1** (3) should be 75 mm.

4 Loading codes

The loading codes given in BS 648, BS 6399-1, -2 and -3 and CP 3:1972, Chapter V-2 should be used.

When using these documents with ENV 1996-1-3 the following modifications should be noted.

a) Loads from separate sources acting on a member or a component should be considered as separate actions.

b) The design loading on a particular member or component may include the relevant load combination factors described in **2.3.2.2** and **2.3.4** of ENV 1996-1-1:1995. Alternatively for the ultimate limit state the simplification of design load given in **2.3.3.1** (3) of ENV 1996-1-1:1995 may be used.

c) The imposed floor loads of a building should be treated as one variable action to which the reduction factors given in BS 6399-1:1984 are applicable.

5 Reference documents and standards

Where reference is made in ENV 1996-1-3 to national regulations, such references refer to Building and Buildings [1] in England and Wales, to Building and Buildings [2] in Scotland and to Building Regulations [3] in Northern Ireland.

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 1996-1-1:1995.

6 Additional recommendations

6.1 Subclause 1.4: Symbols

The symbols f_k, h, q_{lat}, Z and α in ENV 1996-1-3:1998 may be taken as equivalent to the symbols f_k, h, q_{lat}, Z and α, respectively, in BS 5628-1:1992.

The symbols L, t and W_k in ENV 1996-1-3:1998 have the same engineering meaning as the symbols L, t and W_k, respectively, in BS 5628-1:1992 but, for the purposes of this NAD, the definitions in BS 5628-1:1992 should be used.

The term f_{xk} in ENV 1996-1-3:1998 should be taken to be equivalent to the term f_{kx} in BS 5628-1:1992.

The terms f_{xk1} and f_{xk2} in ENV 1996-1-3:1998 should be taken to be equivalent, respectively, to f_{kx} with the plane of failure parallel to the bed joints and f_{kx} with the plane of failure perpendicular to the bed joints in BS 5628-1:1992.

The term n_a in ENV 1996-1-3:1998 should be taken to be equivalent to the term n in BS 5628-1:1992.

The terms d, f_{xd}, M_d, M_{rd} and σ_{dp} in ENV 1996-1-3:1998 have no equivalent in BS 5268-1:1992 and the definitions should be as given in ENV 1996-1-3:1998.

6.2 Section 3: Materials

a) *Subclause 3.1*

The materials used in masonry walls subject to lateral loading shall be in accordance with **6.3** of the NAD to ENV 1996-1-1:1995.

b) *Subclause 3.2*

The characteristic flexural strength of unreinforced masonry, f_{xk}, should either be determined in accordance with **3.6.4** of ENV 1996-1-1:1995 or may be derived from Table 3 of BS 5628-1:1992.

c) *Subclause 3.3*

The design flexural strength of masonry should be calculated using the formula given in **3.3** of ENV 1996-1-3:1998 taking into account the equivalence of the terms f_{xk} in ENV 1996-1-3:1998 and f_{kx} in BS 5628-1:1992, and using the values of f_{xk} taken from BS 5628-1:1992.

6.3 Section 4: Design of masonry subjected to lateral loads

a) *Subclause 4.1.4*

The design should be to the formulae given in **4.1.4** of ENV 1996-1-3:1998 taking into account the equivalence of the terms in ENV 1996-1-3:1998 and in BS 5628-1:1992, and using the values of f_{xk} and f_{xk1} taken from BS 5628-1:1992.

b) *Subclause 4.2.2*

The formula from **36.8** of BS 5628-1:1992 should be substituted for the formula numbered (4.9) in **4.2.2** of ENV 1996-1-3:1998.

6.4 Section 5: Structural detailing

Pending publication of ENV 1996-2 structural detailing of masonry walls subjected to lateral loading should be in accordance with **6.5** of the NAD to ENV 1996-1-1:1995.

6.5 Section 6: Construction

Pending publication of ENV 1996-2 construction of masonry walls subjected to lateral loading should be in accordance with **6.6** of the NAD to ENV 1996-1-1:1995.

Bibliography

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

[2] GREAT BRITAIN. The Building Standards (Scotland) Regulations 1990. SI 1990 No. 2179 (S.187). London, HMSO.

[3] GREAT BRITAIN. The Building Regulations (Northern Ireland) 1990. SRNI 1990 No. 59. London, HMSO.

blank

EUROPEAN PRESTANDARD
PRÉNORME EUROPÉENNE
EUROPÄISCHE VORNORM

ENV 1996-1-3

June 1998

ICS 91.010.30; 91.080.30

Descriptors: buildings, construction, masonry work, computation, building codes, detail specification, loads : forces

English version

Eurocode 6: Design of masonry structures - Part 1-3: General rules for buildings - Detailed rules on lateral loading

Eurocode 6: Calcul des ouvrages en maçonnerie - Partie 1-3: Règles générales - Règles particulières pour les charges latérales

Eurocode 6: Bemessung und Konstruktion von Mauerwerksbauten Teil 1-3: Allgemeine Regeln - Detaillierte Regeln bei horizontaler Belastung

This European Prestandard (ENV) was approved by CEN on 26 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 1996-1-3:1998 E

Contents Page No

Foreword

Objectives 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 for the methods for testing their performance are available, some of the Structural Eurocodes 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 Member 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/TC250 for the various Eurocodes listed above.

(9) This Part 1-3 of ENV 1996 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 <u>may</u> 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 Part of Eurocode 6 is defined in clause 1.1 of this Part 1-3 of ENV 1996. Additional parts of Eurocode 6 which are planned are indicated in clause 1.1.3 of ENV 1996-1-1.

(17) This Part 1-3 of ENV 1996 will replace clauses 4.6.2 and 4.6.4 of ENV 1996-1-1.

(18) It is intended that the basis of design referred to in Section 2 of ENV 1996-1-1 and the materials referred to in Section 3 of ENV 1996-1-1 will also apply to this Part 1-3 of ENV 1996 and that the structural detailing and construction will be in accordance with Sections 5 and 6 of ENV 1996-1-1.

1 General

1.1 Scope

(1)P This Part 1-3 of ENV 1996 deals with the design of unreinforced masonry walls subjected to lateral wind loads and horizontal accidental loads (other than seismic actions) and shall be used in conjunction with ENV 1996-1-1.

Note: Reinforced masonry walls subjected to lateral loading can be designed using the relevant rules for reinforced masonry design in ENV 1996-1-1 and so are not covered again in this Part. The rules in Annex A are applicable only for unreinforced masonry.

(2) This Part 1-3 of ENV 1996 gives Principles and Application Rules (see clause 1.2 in ENV 1996-1-1) for designing structures for specified requirements in respect of the aforementioned functions and levels of performance.

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

1.2 Normative references

(1) This European prestandard incorporates by dated or undated reference, provisions from other publications; see ENV 1996-1-1: 1995 for a list of normative references.

1.3 Definitions

(1) Where appropriate, the definitions given in ENV 1996-1-1 apply.

1.4 Symbols

(1) Symbols used in this Part 1-3 of ENV 1996 are as follows:

- d deflection of arch under design lateral load;
- f_k characteristic compressive strength of masonry;
- f_{xd} design flexural strength of masonry;
- f_{xk} characteristic flexural strength of masonry;
- f_{xk1} characteristic flexural strength of masonry with the plane of failure parallel to the bed joints;
- f_{xk2} characteristic flexural strength of masonry with the plane of failure perpendicular to the bed joints;
- h clear height of a wall;
- L length of a panel between supports or between a support and a free edge;

M_d design moment applied to a wall;

M_{Rd} design moment of lateral resistance of a wall;

n_a design axial load per unit length of wall;

q_{lat} design lateral strength per unit area of wall;

t thickness of wall or leaf;

W_k characteristic value of wind action;

Note: including negative and positive pressures, as relevant to the load case.

Z section modulus;

α bending moment coefficient;

γ_Q partial safety factor for imposed actions;

γ_M partial safety factor for material properties;

μ ratio of characteristic flexural strength f_{kx1} divided by f_{kx2};

σ_{dp} design permanent vertical stress.

1.5 Units

(1)P SI units shall be used in conformity with ISO 1000.

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.

2.2 Actions

(1)P The characteristic wind action, W_k, shall be taken as the wind load calculated in accordance with ENV 1991-2-4.

3 Materials

3.1 General

(1)P The materials used in masonry walls shall be in accordance with Section 3 of ENV 1996-1-1.

3.2 Characteristic flexural strength of unreinforced masonry

(1)P The characteristic flexural strength of unreinforced masonry, f_{xk}, shall be determined in accordance with clause 3.6.4 of ENV 1996-1-1.

3.3 Design flexural strength of masonry

(1)P The design flexural strength of masonry shall be taken as the characteristic strength divided by the appropriate partial safety factor γ_M.

(2) The design flexural strength of masonry is given by :-

$$f_{xd} = \frac{f_{xk}}{\gamma_M} \qquad (3.1)$$

where γ_M has the appropriate value given in clause 2.3.3.2 of ENV 1996-1-1.

4 Design of unreinforced masonry walls subjected to lateral loads

4.1 Walls subjected to lateral wind loads

4.1.1 General

(1)P At the ultimate limit state, the design lateral load effect on a wall shall be less than or equal to the design lateral strength of the wall.

(2) The design of masonry walls subjected to lateral wind loads may be based on the approximate methods given in 4.1.4, or 4.1.5.

(3) Chases and recesses may reduce the value of the wind action, W_k, that can be resisted. The position and size of chases and recesses should be examined and the flexural strength of the wall should be checked using the reduced thickness of the wall at the chase or recess position, where they occur in a position, and are of such depth, as to reduce the strength of the wall.

(4) Where damp proof courses are used in walls, allowance should be made for any effect on the flexural strength.

4.1.2 Support conditions and continuity

(1)P In assessing the lateral resistance of masonry walls subjected to lateral wind loads, the support conditions and continuity over supports shall be taken into account.

(2) Where walls are bonded to supporting masonry walls or where reinforced concrete floors bear onto them, the support may be considered as being continuous. A damp-proof course should be considered as providing simple support. Where walls are connected to a supporting structure by ties at the side of a wall, partial moment continuity at the sides may be assumed.

(3) In the case of cavity construction, full continuity may be assumed even if only one leaf is continuously bonded across a support, provided that the cavity wall is provided with ties in accordance with clause 5.4.2.2 of ENV 1996-1-1. Where the leaves are of different thickness, the thicker leaf normally should be the continuous leaf unless it is clear that full continuity can be assumed from the stiffness and strength of a continuous thinner leaf. The load to be transmitted from a panel to its support may be taken by ties to one leaf only, provided that there is adequate connection between the two leaves particularly at the edges of the panels.

(4) The design lateral strength of a cavity wall should be taken as the sum of the design lateral strengths of the two leaves provided that the wall ties, or other connectors between the leaves, are capable of transmitting the actions to which the cavity wall is subjected (see clause 4.6.2.4 of ENV 1996-1-1).

(5) A movement joint in a wall should be treated as a free edge across which moment may not be transmitted.

Note: Some specialist anchors are designed to transmit moment across a movement joint; their use is not covered in this Part.

4.1.3 Serviceability limit state

(1)P Masonry walls subjected to lateral wind loads shall not deflect adversely under such loads, or accidental contact of persons, nor respond disproportionately to accidental impacts..

(2) A wall that satisfies the verification under the Ultimate Limit State may be considered to satisfy clause (1)P if its dimensions are limited in accordance with Annex A.

4.1.4 Verification of walls supported along edges

(1)P At the ultimate limit state, the design moment applied to a wall, M_d, shall be less than or equal to the design load resistance of the wall, M_{Rd}, such that:

$$M_d \leq M_{Rd} \tag{4.1}$$

Note: Masonry walls are not isotropic and there is an orthogonal strength ratio depending on the unit and the mortar used.

(2) When the wall is supported along 3 or 4 edges, the calculation of the design moment, M_d, should take into account the masonry properties in the two orthogonal directions and may be taken as either:

$$M_d = \alpha\ W_k\ \gamma_Q\ L^2 \text{ per unit height of the wall} \tag{4.2}$$

when relevant to the f_{xk2} direction , or

$$M_d = \mu\ \alpha\ W_k\ \gamma_Q\ L^2 \text{ per unit length of the wall} \tag{4.3}$$

when relevant to the f_{xk1} direction;

where:

α is a bending moment coefficient which depends on the orthogonal ratio, μ , the degree of fixity at the edges of the panels and the height to length ratio of the panels;

γ_Q is the partial safety factor for imposed loads, obtained from clause 2.3.3.1 of ENV 1996-1-1;

μ is the orthogonal ratio of the characteristic flexural strengths of the masonry, f_{xk1}/f_{xk2} as defined in 3.2(1)P;

L is the length of the panel between supports;

W_k is the characteristic wind load per unit area.

(3) Values of the bending coefficient α may be obtained from Table 4.1 or from a suitable calculation method.

(4) When the wall is supported along its bottom and top edges, the design moment, M_d , may be calculated from normal engineering principles, taking into account any continuity.

(5) When a design permanent vertical stress is present, the favourable effect of the vertical stress may be taken into account by increasing the apparent flexural strength, f_{xk1}, to that given by equation (4.4), the orthogonal ratio being modified accordingly.

$$\text{apparent } f_{xk1} = f_{xk1} + \gamma_M \ \sigma_{dp} \qquad (4.4)$$

where:

f_{xk1} is the characteristic flexural strength with the plane of failure parallel to the bed joints, as defined in 3.2(1)P;

γ_M is the partial safety factor for the material, obtained from clause 2.3.3.2 of ENV 1996-1-1;

σ_{dp} is the design stress, due to vertical load, on the wall at the level under consideration, not taken to be greater than 0.25 N/mm^2.

(6) The bending moment coefficient at a damp proof course may be taken as for an edge over which full continuity exists when the design permanent vertical stress on the damp proof course equals or exceeds the design tensile stress caused by the moment arising due to the wind action.

(7) When irregular shapes of panel, or those with substantial openings, are to be designed, an analysis, using a recognized method of obtaining bending moments in flat plates, for example, finite element method or yield line analogy, may be used. It will often be possible to divide such panels into sub-panels, which can then be calculated using the rules given in paragraphs (2) - (5) above (see also figure 4.1).

Note: Small openings in panels will have little effect on the strength of the panel in which they occur, and they can be ignored. When suitable timber or metal frames are built into openings, the strength of the frame, taken in conjunction with the masonry panel, will often be sufficient to replace the strength lost by the area of the opening. Such cases will have to be decided by the designer, as guidance is beyond the scope of this ENV.

(8) The design moment of lateral resistance of a masonry wall, M_{Rd}, per unit height or length, is given by:

$$M_{Rd} = \frac{f_{xk} \, Z}{\gamma_M} \qquad (4.5)$$

where:

f_{xk} is the characteristic flexural strength, obtained from clause 3.6.4 of ENV 1996-1-1, appropriate to the plane of bending;

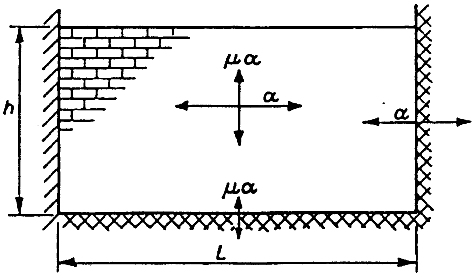
Z is the section modulus of unit height or length of wall

γ_M is the partial safety factor for the material, obtained from clause 2.3.3.2 of ENV 1996-1-1

Table 4.1: Bending moment coefficients, α, in laterally loaded wall panels

NOTE 1. Linear interpolation of μ and h/L is permitted.

NOTE 2. When the dimensions of a wall are outside the range of h/L given in this table, it will usually be sufficient to calculate the moments on the basis of a simple span. For example, a panel of type A having h/L less than 0.3 will tend to act as a freestanding wall, whilst the same panel having h/L greater than 2.00 will tend to span horizontally.



Key to support conditions

- ——— free edge
- ////// simply supported edge
- XXXXX an edge over which full continuity exists

Arrows and μ α are used to indicate vertical span moments

Arrows and α are used to indicate horizontal span moments

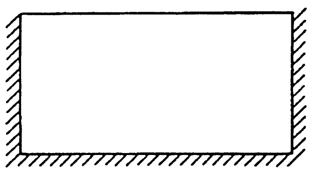
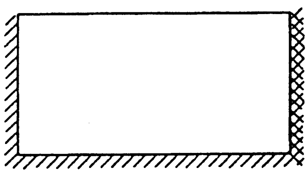
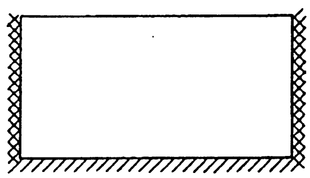
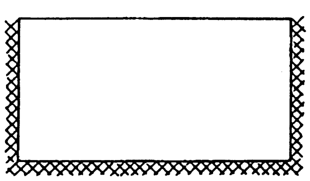
	μ	Values of α, h/L: 0.30	0.50	0.75	1.00	1.25	1.50	1.75	2.00
 A	1.00	0.031	0.045	0.059	0.071	0.079	0.085	0.090	0.094
	0.90	0.032	0.047	0.061	0.073	0.081	0.087	0.092	0.095
	0.80	0.034	0.049	0.064	0.075	0.083	0.089	0.093	0.097
	0.70	0.035	0.051	0.066	0.077	0.085	0.091	0.095	0.098
	0.60	0.038	0.053	0.069	0.080	0.088	0.093	0.097	0.100
	0.50	0.040	0.056	0.073	0.083	0.090	0.095	0.099	0.102
	0.40	0.043	0.061	0.077	0.087	0.093	0.098	0.101	0.104
	0.35	0.045	0.064	0.080	0.089	0.095	0.100	0.103	0.105
	0.30	0.048	0.067	0.082	0.091	0.097	0.101	0.104	0.107
 B	1.00	0.024	0.035	0.046	0.053	0.059	0.062	0.065	0.068
	0.90	0.025	0.036	0.047	0.055	0.060	0.063	0.066	0.068
	0.80	0.027	0.037	0.049	0.056	0.061	0.065	0.067	0.069
	0.70	0.028	0.039	0.051	0.058	0.062	0.066	0.068	0.070
	0.60	0.030	0.042	0.053	0.059	0.064	0.067	0.069	0.071
	0.50	0.031	0.044	0.055	0.061	0.066	0.069	0.071	0.072
	0.40	0.034	0.047	0.057	0.063	0.067	0.070	0.072	0.074
	0.35	0.035	0.049	0.059	0.065	0.068	0.071	0.073	0.074
	0.30	0.037	0.051	0.061	0.066	0.070	0.072	0.074	0.075
 C	1.00	0.020	0.028	0.037	0.042	0.045	0.048	0.050	0.051
	0.90	0.021	0.029	0.038	0.043	0.046	0.048	0.050	0.052
	0.80	0.022	0.031	0.039	0.043	0.047	0.049	0.051	0.052
	0.70	0.023	0.032	0.040	0.044	0.048	0.050	0.051	0.053
	0.60	0.024	0.034	0.041	0.046	0.049	0.051	0.052	0.053
	0.50	0.025	0.035	0.043	0.047	0.050	0.052	0.053	0.054
	0.40	0.027	0.038	0.044	0.048	0.051	0.053	0.054	0.055
	0.35	0.029	0.039	0.045	0.049	0.052	0.053	0.054	0.055
	0.30	0.030	0.040	0.046	0.050	0.052	0.054	0.055	0.056
 D	1.00	0.013	0.021	0.029	0.035	0.040	0.043	0.045	0.047
	0.90	0.014	0.022	0.031	0.036	0.040	0.043	0.046	0.048
	0.80	0.015	0.023	0.032	0.038	0.041	0.044	0.047	0.048
	0.70	0.016	0.025	0.033	0.039	0.043	0.045	0.047	0.049
	0.60	0.017	0.026	0.035	0.040	0.044	0.046	0.048	0.050
	0.50	0.018	0.028	0.037	0.042	0.045	0.048	0.050	0.051
	0.40	0.020	0.031	0.039	0.043	0.047	0.049	0.051	0.052
	0.35	0.022	0.032	0.040	0.044	0.048	0.050	0.051	0.053
	0.30	0.023	0.034	0.041	0.046	0.049	0.051	0.052	0.053

Table 4.1 (continued)

See Notes 1 and 2, key to support conditions and explanation of μ α and α on page 13

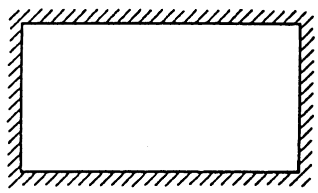
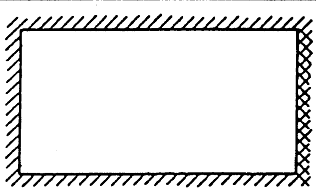
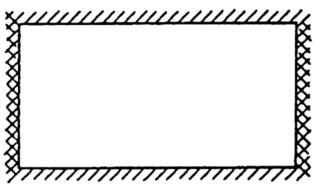
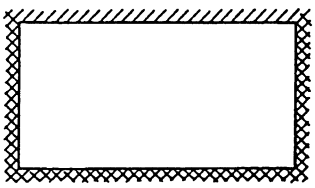
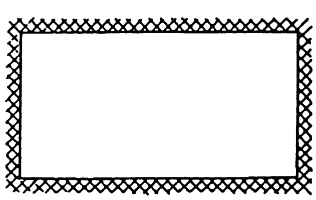
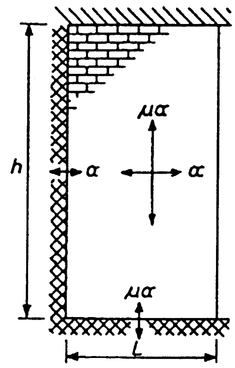
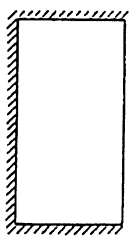
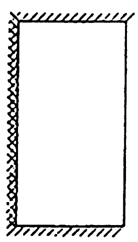
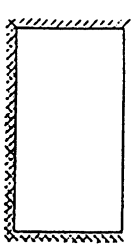
	μ	Values of α h/L 0.30	0.50	0.75	1.00	1.25	1.50	1.75	2.00
 E	1.00	0.008	0.018	0.030	0.042	0.051	0.059	0.066	0.071
	0.90	0.009	0.019	0.032	0.044	0.054	0.062	0.068	0.074
	0.80	0.010	0.021	0.035	0.046	0.056	0.064	0.071	0.076
	0.70	0.011	0.023	0.037	0.049	0.059	0.067	0.073	0.078
	0.60	0.012	0.025	0.040	0.053	0.062	0.070	0.076	0.081
	0.50	0.014	0.028	0.044	0.057	0.066	0.074	0.080	0.085
	0.40	0.017	0.032	0.049	0.062	0.071	0.078	0.084	0.088
	0.35	0.018	0.035	0.052	0.064	0.074	0.081	0.086	0.090
	0.30	0.020	0.038	0.055	0.068	0.077	0.083	0.089	0.093
 F	1.00	0.008	0.016	0.026	0.034	0.041	0.046	0.051	0.054
	0.90	0.008	0.017	0.027	0.036	0.042	0.048	0.052	0.055
	0.80	0.009	0.018	0.029	0.037	0.044	0.049	0.054	0.057
	0.70	0.010	0.020	0.031	0.039	0.046	0.051	0.055	0.058
	0.60	0.011	0.022	0.033	0.042	0.048	0.053	0.057	0.060
	0.50	0.013	0.024	0.036	0.044	0.051	0.056	0.059	0.062
	0.40	0.015	0.027	0.039	0.048	0.054	0.058	0.062	0.064
	0.35	0.016	0.029	0.041	0.050	0.055	0.060	0.063	0.066
	0.30	0.018	0.031	0.044	0.052	0.057	0.062	0.065	0.067
 G	1.00	0.007	0.014	0.022	0.028	0.033	0.037	0.040	0.042
	0.90	0.008	0.015	0.023	0.029	0.034	0.038	0.041	0.043
	0.80	0.008	0.016	0.024	0.031	0.035	0.039	0.042	0.044
	0.70	0.009	0.017	0.026	0.032	0.037	0.040	0.043	0.045
	0.60	0.010	0.019	0.028	0.034	0.038	0.042	0.044	0.046
	0.50	0.011	0.021	0.030	0.036	0.040	0.043	0.046	0.048
	0.40	0.013	0.023	0.032	0.038	0.042	0.045	0.047	0.049
	0.35	0.014	0.025	0.033	0.039	0.043	0.046	0.048	0.050
	0.30	0.016	0.026	0.035	0.041	0.044	0.047	0.049	0.051
 H	1.00	0.005	0.011	0.018	0.024	0.029	0.033	0.036	0.039
	0.90	0.006	0.012	0.019	0.025	0.030	0.034	0.037	0.040
	0.80	0.006	0.013	0.020	0.027	0.032	0.035	0.038	0.041
	0.70	0.007	0.014	0.022	0.028	0.033	0.037	0.040	0.042
	0.60	0.008	0.015	0.024	0.030	0.035	0.038	0.041	0.043
	0.50	0.009	0.017	0.025	0.032	0.036	0.040	0.043	0.045
	0.40	0.010	0.019	0.028	0.034	0.039	0.042	0.045	0.047
	0.35	0.011	0.021	0.029	0.036	0.040	0.043	0.046	0.047
	0.30	0.013	0.022	0.031	0.037	0.041	0.044	0.047	0.049
 I	1.00	0.004	0.009	0.015	0.021	0.026	0.030	0.033	0.036
	0.90	0.004	0.010	0.016	0.022	0.027	0.031	0.034	0.037
	0.80	0.005	0.010	0.017	0.023	0.028	0.032	0.035	0.038
	0.70	0.005	0.011	0.019	0.025	0.030	0.033	0.037	0.039
	0.60	0.006	0.013	0.020	0.026	0.031	0.035	0.038	0.041
	0.50	0.007	0.014	0.022	0.028	0.033	0.037	0.040	0.042
	0.40	0.008	0.016	0.024	0.031	0.035	0.039	0.042	0.044
	0.35	0.009	0.017	0.026	0.032	0.037	0.040	0.043	0.045
	0.30	0.010	0.019	0.028	0.034	0.038	0.042	0.044	0.046

Table 4.1 (continued)

See Notes 1. and 2, key to support conditions and explanation of μ α and α on page 13



		Values of α							
	μ	h/L							
		0.30	**0.50**	**0.75**	**1.00**	**1.25**	**1.50**	**1.75**	**2.00**
 J	**1.00**	0.009	0.023	0.046	0.071	0.096	0.122	0.151	0.180
	0.90	0.010	0.026	0.050	0.076	0.103	0.131	0.162	0.193
	0.80	0.012	0.028	0.054	0.083	0.111	0.142	0.175	0.208
	0.70	0.013	0.032	0.060	0.091	0.121	0.156	0.191	0.227
	0.60	0.015	0.036	0.067	0.100	0.135	0.173	0.211	0.250
	0.50	0.018	0.042	0.077	0.113	0.153	0.195	0.237	0.280
	0.40	0.021	0.050	0.090	0.131	0.177	0.225	0.272	0.321
	0.35	0.024	0.055	0.098	0.144	0.194	0.244	0.296	0.347
	0.30	0.027	0.062	0.108	0.160	0.214	0.269	0.325	0.381
 K	**1.00**	0.009	0.021	0.038	0.056	0.074	0.091	0.108	0.123
	0.90	0.010	0.023	0.041	0.060	0.079	0.097	0.113	0.129
	0.80	0.011	0.025	0.045	0.065	0.084	0.103	0.120	0.136
	0.70	0.012	0.028	0.049	0.070	0.091	0.110	0.128	0.145
	0.60	0.014	0.031	0.054	0.077	0.099	0.119	0.138	0.155
	0.50	0.016	0.035	0.061	0.085	0.109	0.130	0.149	0.167
	0.40	0.019	0.041	0.069	0.097	0.121	0.144	0.164	0.182
	0.35	0.021	0.045	0.075	0.104	0.129	0.152	0.173	0.191
	0.30	0.024	0.050	0.082	0.112	0.139	0.162	0.183	0.202
 L	**1.00**	0.006	0.015	0.029	0.044	0.059	0.073	0.088	0.102
	0.90	0.007	0.017	0.032	0.047	0.063	0.078	0.093	0.107
	0.80	0.008	0.018	0.034	0.051	0.067	0.084	0.099	0.114
	0.70	0.009	0.021	0.038	0.056	0.073	0.090	0.106	0.122
	0.60	0.010	0.023	0.042	0.061	0.080	0.098	0.115	0.131
	0.50	0.012	0.027	0.048	0.068	0.089	0.108	0.126	0.142
	0.40	0.014	0.032	0.055	0.078	0.100	0.121	0.139	0.157
	0.35	0.016	0.035	0.060	0.084	0.108	0.129	0.148	0.165
	0.30	0.018	0.039	0.066	0.092	0.116	0.138	0.158	0.176

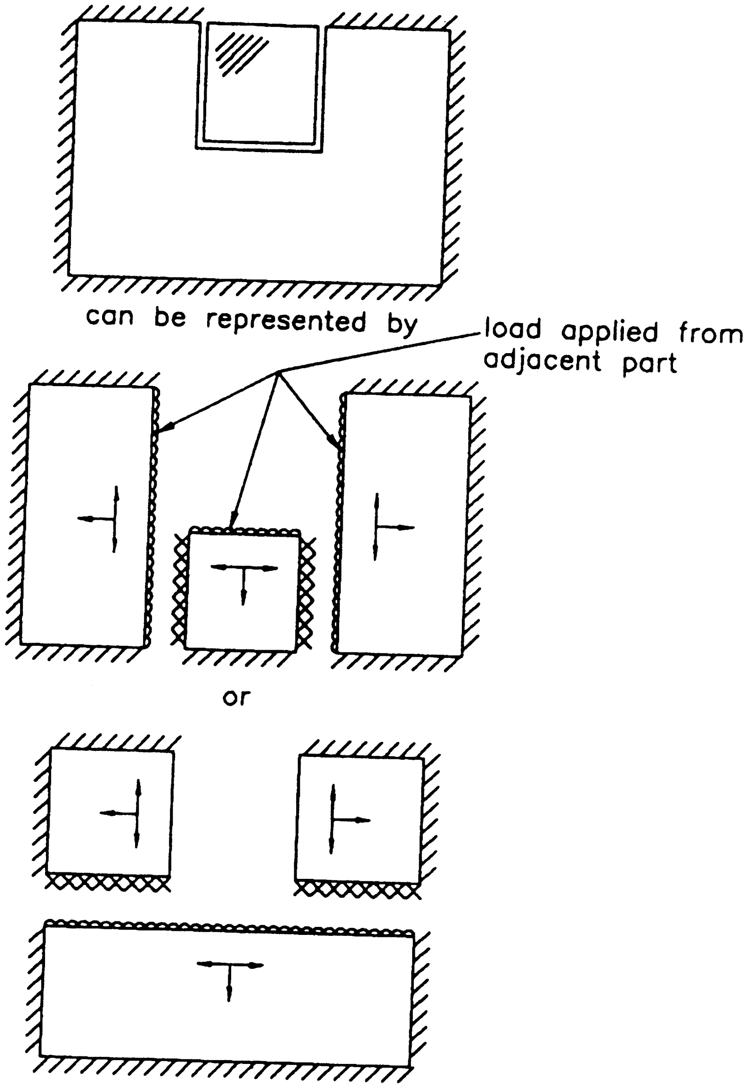


Figure 4.1 : Dividing a panel into parts to allow for openings

Note: Refer to figure at start of table 4.1 for explanation of support conditions and arrows. Supports indicated as "simply supported edge" are for example only: those relevant to the design situation need to be used.

(9) In assessing the section modulus of a pier in a wall, the outstanding length of flange from the face of the pier should be taken as:

- h/10 for walls spanning vertically between restraints;
- 2h/10 for cantilever walls;
- in no case more than half the clear distance between piers;

where h is the clear height of the wall.

4.1.5 Verification of walls arching between supports

(1)P At the ultimate limit state, the design lateral load effect due to arch action shall be less than or equal to the design load resistance under an arch action and the design strength of the support for the arch shall be greater that the effect of the lateral load.

(2) A masonry wall built solidly between supports capable of resisting an arch thrust may be designed assuming that an horizontal or vertical arch develops within the thickness of the wall.

Note: In the present state of knowledge, walls subjected to mainly lateral loads should be designed only for arching horizontally, except when accidental actions are considered. Supports capable of resisting an arch thrust exist when a number of walls are built continuously past supports.

(3) Calculation should be based on a three-pin arch and the bearing at the supports and at the central hinge should be assumed as 0,1 times the thickness of the wall, as indicated on figure 4.2. If chases or recesses occur near the thrust-lines of the arch, their effect on the strength of the masonry should be taken into account.

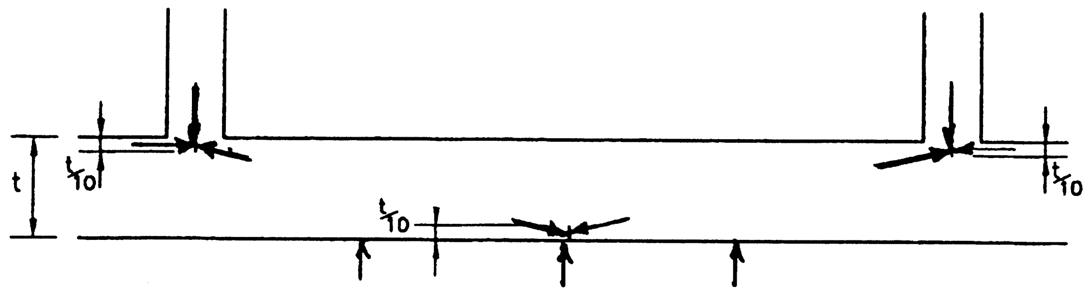


Figure 4.2 : Arch assumed for resisting lateral loads

(4) The arch thrust should be assessed from knowledge of the applied lateral load, the strength of the masonry in compression and the effectiveness of the junction between the wall and the support resisting the thrust. A change in length of a wall in arching can considerably reduce the arching resistance; if the masonry is built of masonry units that may shrink in service, the effect of the resulting change in length should be checked.

(5) The arch rise is given by:

$$0{,}9\,t - d \qquad (4.6)$$

where:

t is the thickness of the wall (but see clause 6.4.2.3(2) of ENV 1996-1-1);

d is the deflection of the arch under the design lateral load; it may be taken to be zero for walls having a length to thickness ratio of 25 or less.

(6) The maximum design arch thrust per unit length of wall may be assumed to be:

$$1{,}5\ \frac{f_k}{\gamma_M}\ \frac{t}{10} \qquad (4.7)$$

and where the lateral deflection is small, the design lateral strength is given by:

$$q_{lat} = \frac{f_k}{\gamma_M}\left[\frac{t}{L}\right]^2 \qquad (4.8)$$

where:

q_{lat} is the design lateral strength per unit area of wall;

t is the thickness of the wall (but see clause 6.4.2.3(2) of ENV 1996-1-1);

f_k is the characteristic compressive strength of the masonry, obtained from clause 3.6.2 of ENV 1996-1-1;

L is the length of the wall;

γ_M is the partial safety factor for the material, obtained from clause 2.3.3.2 of ENV 1996-1-1.

4.2 Verification of walls subjected to horizontal accidental loads (excluding seismic actions)

4.2.1 General

(1) Walls subjected to horizontal accidental loads, other than those resulting from seismic actions (for example, gas explosions), may be designed similarly to walls subjected to wind loads in accordance with 4.1. Axially loaded walls, with a slenderness ratio no greater than 20, may be designed on the basis of arching vertically between concrete floors. Allowance may be made for enhancement due to bonded piers or return walls. The resistance of damp proof courses or similar low friction planes, should be verified to ensure that the shear strength is not exceeded.

Note: EN 1052-4 gives a method of test for the shear resistance of damp proof courses.

4.2.2 Design lateral strength of axially loaded walls

(1) The design lateral strength of axially loaded walls may be calculated from consideration of the effective eccentricity due to the lateral load and any other eccentricity, or from the relationship:

$$q_{lat} = \frac{7{,}2\ t\ n_a}{h^2\ \gamma_M} \qquad (4.9)$$

Note: γ_M is used here as a stability safety factor.

where:

q_{lat} is the design lateral strength per unit area of wall;

n_a is the design axial load per unit length of wall in the central height of the wall;

h is the clear height of the wall between concrete surfaces or other construction capable of providing adequate resistance to rotation across the full thickness of a wall;

t is the thickness of the wall;

provided that:

- the arch thrust, which will be n_a, is less than or equal to $1,5 \frac{f_k}{\gamma_M} \frac{t}{10}$

- the wall is contained between concrete floors or other construction affording adequate lateral support and sufficient resistance to rotation across the full width of the wall to resist the load effect of the action;

- any damp proof course or other plane of low frictional resistance in the wall can transmit the relevant horizontal forces;

- the design stress due to vertical load is not less than 0.1 N/mm²;

- the slenderness ratio does not exceed 20.

(2) If the wall is supported by return walls which are capable of resisting the horizontal reaction transmitted to them, on a vertical edge or edges, the value of q_{lat} as given by the above equation may be increased, based on a suitable theory.

5 Structural detailing

5.1 General

(1)P Structural detailing of masonry walls subjected to lateral loading shall be in accordance with Section 5 of ENV 1996-1-1 and in accordance with ENV 1996-2.

6 Construction

6.1 General

(1)P Construction of masonry walls subjected to lateral loading shall be in accordance with Section 6 of ENV 1996-1-1 and in accordance with ENV 1996-2.

Annex A (Normative)

A.1 Limiting height and length to thickness ratios for walls for serviceability

(1) The size of the wall should be limited to that which results from use of figures A.1, A.2 or A.3, depending on the restraint conditions as shown on the figures, where h is the height of the wall, L is the length of the wall and t is the thickness of the wall; for cavity walls use t_{ef} in place of t.

(2) Where walls are restrained at the top but not at the ends, h should be limited to 30t.

(3) The minimum thickness of the wall, or one leaf of a cavity wall, should be [100] mm.

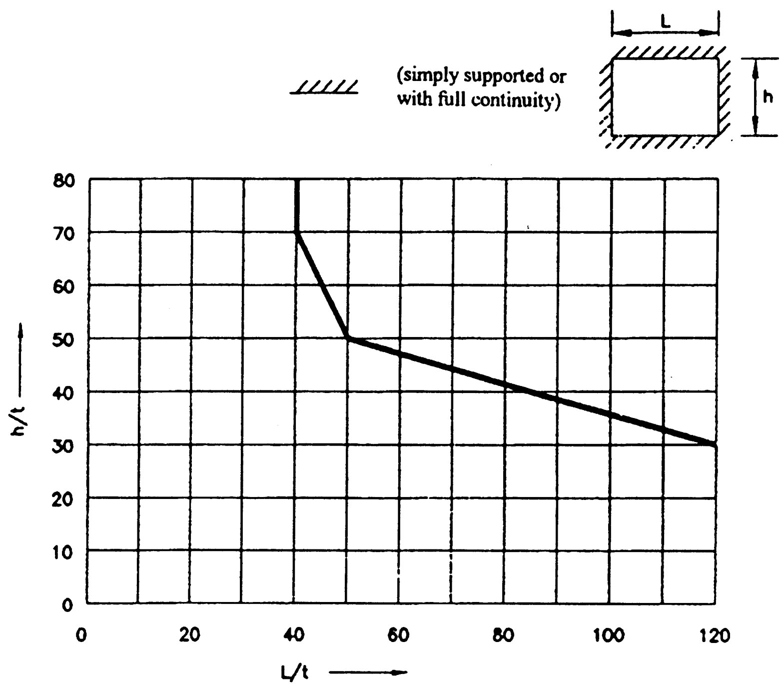


Figure A.1: Limiting height and length to thickness ratios of walls restrained on all four edges

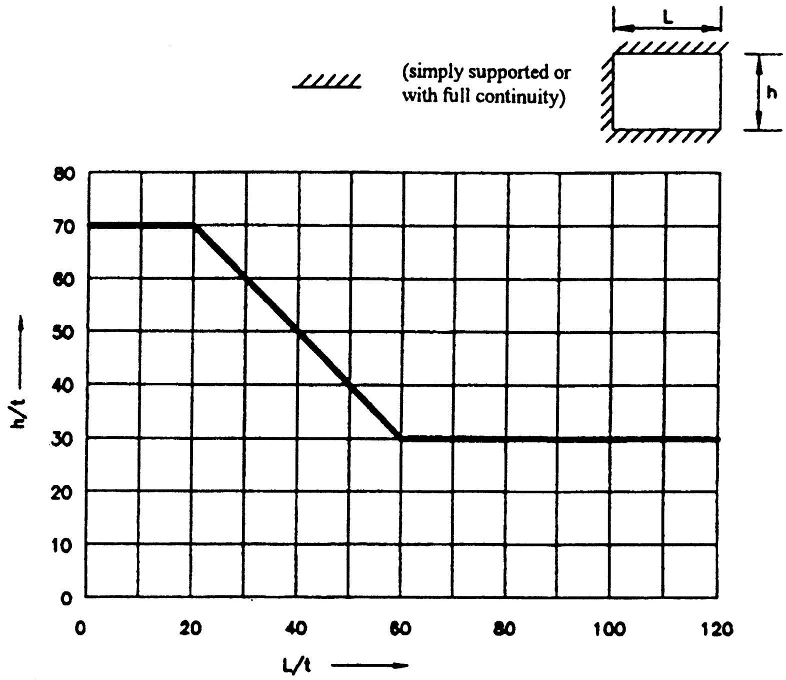


Figure A.2: Limiting height and length to thickness ratios of walls restrained at the bottom, the top and one vertical edge

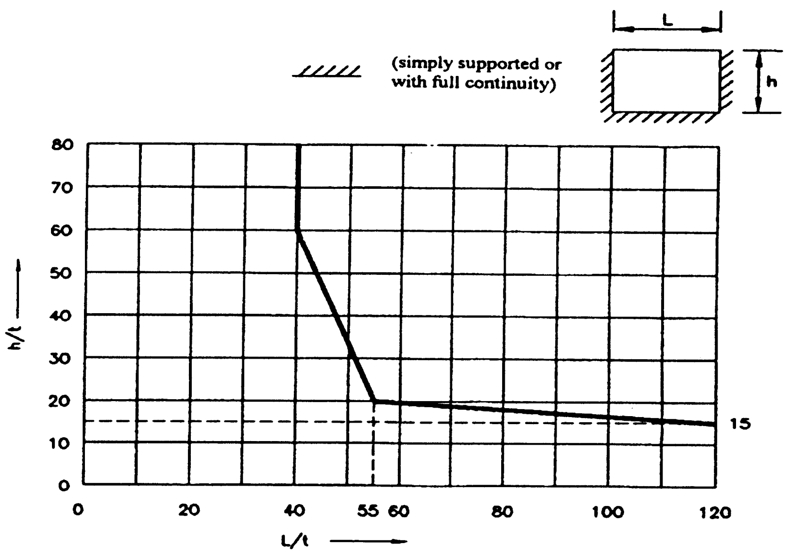


Figure A.3: Limiting height and length to thickness ratios of walls restrained at the edges, the bottom, but not at the top

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001. Standards are also available from the BSI website at http://www.bsi-global.com.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001. Further information about BSI is available on the BSI website at http://www.bsi-global.com.

BSI
389 Chiswick High Road
London
W4 4AL