

# Manual for the design of plain masonry in building structures to Eurocode 6 (Second edition)

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# Manual for the design of plain masonry in building structures to Eurocode 6

(Second edition)

*The Institution  
of Structural  
Engineers*



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# Notation

## Latin upper case letters

$A$	Loaded horizontal gross cross-sectional area of wall
$A_b$	Loaded area
$A_{ef}$	Effective area of bearing
$E$	Short-term secant modulus of elasticity of masonry
$E_i$	Modulus of elasticity of member, $i$
$E_{longterm}$	Long-term modulus of elasticity of masonry
$F_d$	Design compressive or tensile resistance of wall tie
$F_t$	Design horizontal tie force
$G_k$	Characteristic value of permanent action
$G_{k,inf}$	Lower characteristic value of permanent action
$G_{k,sup}$	Upper characteristic value of permanent action
$I$	Second moment of area
$I_i$	Second moment of area of member, $i$
$K$	Constant used in calculation of compressive strength of masonry
$L_a$	The lesser of the distance between loadbearing members in direction of tie, or five times clear height of wall
$M_{Ed}$	Design value of moment applied
$M_{Edu}$	Design value of moment above floor
$M_{Edf}$	Design value of moment below floor
$M_i$	End moment at node, $i$
$M_{id}$	Design value of bending moment at top or bottom of wall
$M_{md}$	Design value of greatest moment at mid-height of wall
$M_{Rd}$	Design value of moment of resistance
$M_{Rds}$	Design value of moment of resistance at base of wall due to gravity action
$N$	Sum of design vertical actions on building
$N_{ad}$	Maximum design arch thrust per unit length of wall
$N_{Ed}$	Design value of vertical load
$N_{Edc}$	Design value of concentrated vertical load
$N_{Edf}$	Design value of load applied by floor
$N_{Edu}$	Design value of load above floor
$N_{fd}$	Design value of vertical load at top or bottom of wall or column
$N_{md}$	Design value of vertical load at mid-height of wall or column
$N_{Rd}$	Design value of vertical resistance of masonry wall or column
$N_{Rdc}$	Design value of vertical concentrated load resistance of wall
$N_s$	Number of storeys including ground and basement
$Q_k$	Characteristic value of single variable action
$Q_{k,1}$	Characteristic value of leading variable action, 1
$Q_{k,i}$	Characteristic value of the accompanying variable action, $i$
$V_{Ed}$	Design value of shear load
$V_{Rd}$	Design value of shear resistance
$W_c$	Width of compressive stress block under design dead load

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$W_{Ed}$	Design lateral load per unit area
$Z$	Elastic section modulus of unit height or length of wall

### Latin lower case letters

$a, a_1$	Distance from end of wall to nearest edge of loaded area
$b_{ci}$	Width of stressed area
$d_a$	Deflection of arch under design lateral load
$e_{he}$	Eccentricity at top or bottom of wall, resulting from horizontal loads
$e_{hm}$	Eccentricity at middle of wall, resulting from horizontal loads
$e_i$	Eccentricity at top or bottom of wall
$e_{init}$	Initial eccentricity
$e_k$	Eccentricity due to creep
$e_m$	Eccentricity due to loads
$e_{mk}$	Eccentricity at middle of wall
$f_b$	Normalised mean compressive strength of masonry unit
$f_d$	Design compressive strength of masonry in direction being considered
$f_k$	Characteristic compressive strength of masonry
$f_m$	Compressive strength of masonry mortar
$f_{vd}$	Design shear strength of masonry
$f_{vk}$	Characteristic shear strength of masonry
$f_{vk0}$	Characteristic initial shear strength of masonry, under zero compressive stress
$f_{xk1}$	Characteristic flexural strength of masonry having plane of failure parallel to bed joints
$f_{xk2}$	Characteristic flexural strength of masonry having plane of failure perpendicular to bed joints
$h$	Clear height of masonry wall
$h_a$	Clear height of masonry wall between restraining surfaces
$h_c$	Height of wall to level of load
$h_{ef}$	Effective height of wall
$h_i$	Clear height of masonry wall, $i$
$h_{tot}$	Total height of structure (from top of foundation, wall or core)
$k_{ef}$	Factor used to obtain effective thickness of cavity wall
$l$	Length of wall (between other walls, between wall and opening, or between openings)
$l_a$	Length or height of wall between supports capable of resisting an arch thrust
$l_c$	Length of compressed part of wall
$l_{ch}$	Length of chase
$l_{efm}$	Effective length of bearing at mid-height of wall
$l_i$	Clear span of member, $i$
$l_m$	Length of masonry wall between movement joints
$n$	Number of storeys
$n_i$	Stiffness factor of members, $i$
$n_t$	Number of wall ties or connectors per $m^2$ of wall
$q_{lat,d}$	Design lateral strength per unit area of wall
$r$	Arch rise
$t$	Thickness of wall
$t_{ch,h}$	Maximum depth of horizontal or inclined chase
$t_{ch,v}$	Maximum depth of vertical chase or recess without calculation
$t_{ef}$	Effective thickness of wall

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$t_i$	Thickness of wall, $i$
$t_{\min}$	Minimum thickness of wall
$t_r$	Thickness of wall behind chase or recess
$U$	Value used to obtain reduction factor in mid-height of wall
$W_c$	Width of chase
$W_i$	Uniformly distributed design load, $i$
$x$	Maximum dimension of opening
$z$	Lever arm

### Greek letters

$\alpha$	Power used for obtaining characteristic compressive strength of masonry
$\alpha_t$	Coefficient of thermal expansion of masonry
$\alpha_2$	Bending moment coefficient
$\beta$	Enhancement factor for concentrated loads (Section 5.3.13 only)
$\beta$	Power used for obtaining characteristic compressive strength of masonry (Section 4.3.2 only)
$\gamma_G$	Partial factor for permanent actions, also accounting for model uncertainties and dimensional variations
$\gamma_{G,\text{inf}}$	Partial factor for permanent actions in calculating lower design value
$\gamma_{G,\text{sup}}$	Partial factor for permanent actions in calculating upper design value
$\gamma_M$	Partial factor for material property, also accounting for model uncertainties and dimensional variations
$\gamma_Q$	Partial factor for variable actions, also accounting for model uncertainty and dimensional variations
$\varepsilon_{c\infty}$	Final creep strain
$\varepsilon_{\text{el}}$	Elastic strain of masonry
$\eta$	Factor for use in calculating out-of-plane eccentricity of loading on walls
$\lambda$	Value used to obtain reduction factor within height of wall
$\lambda_c$	Value of slenderness ratio up to which eccentricities due to creep can be neglected
$\mu$	Orthogonal ratio of flexural strengths of masonry
$\rho_n$	Reduction factor
$\rho_t$	Stiffness coefficient
$\sigma_d$	Design compressive stress (under permanent actions only for laterally loaded walls)
$\nu$	Angle of inclination to vertical of structure
$\phi_{\Psi}$	Final creep coefficient of masonry
$\Phi$	Reduction factor
$\Phi_1$	Reduction factor at top or bottom of wall
$\Phi_m$	Reduction factor within mid-height of wall
$\psi_0$	Factor for combination value of variable action
$\psi_1$	Factor for frequent value of variable action
$\psi_2$	Factor for quasi-permanent value of variable action

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# Foreword

The Eurocode for the design of plain masonry structures (Eurocode 6) comprising BS EN 1996-1-1, BS EN 1996-1-2 and BS EN 1996-2 are available from the British Standards Institution (BSI). The UK National Annexes setting out the Nationally Determined Parameters (NDPs) to be used in the UK are also available from the BSI. They provide the necessary information to enable BS EN 1996 designs to comply with the Building Regulations. BS EN 1996-3 is not included in this *Manual* as the simplified calculation methods it contains are considered to be of limited use in the UK, although relevant parts of the scope are covered.

These documents, together with BS EN 1990 *Eurocode – Basis of Structural Design* and BS EN 1991 *Eurocode 1 – Actions on Structures*, and their respective National Annexes, provide a suite of information for the design of most types of unreinforced masonry building structures in the UK.

This *Manual* provides guidance on the design of loadbearing masonry and masonry infill to structural frames. The limit state design approach follows on from that used for many years in BS 5628. The *Manual* covers structural fire design of masonry and selection of materials and execution of masonry. Established good practice not covered in the Eurocode is included, and suitably identified. Expressions incorporating UK National Annex values are distinguished from the corresponding general expressions in Eurocode 6, and the values of NDPs adopted by the UK are shown in bold.

The Task Group, and indeed the Institution are grateful for the continued support of the Aircrete Products Association, the Brick Development Association and the Concrete Block Association in the production of this second edition.

Special thanks are due to all members of the Task Group and to their organisations, who have given their time voluntarily.

I join with the other members of the Task Group in commending this second edition to the industry.



Prof. John Roberts  
*Chairman*



This second edition (2018) updates the first (2008) to cover the design of structures to BS EN 1996-1-1:2005+A1:2012, BS EN 1996-1-2:2005 and BS EN 1996-2:2006 for construction in the UK. Nationally Determined Parameters from the UK National Annex — which have been significantly updated since the first edition — have informed the design formulae presented here. This edition also reflects the latest requirements of many other codes and standards.

This *Manual* focuses on structures that do not rely on bending in masonry for their overall stability (e.g. sway frame buildings), although the design of individual masonry elements subject to lateral loading and involving bending for their resistance, is included.

Specifically, the *Manual* covers:

- Choice of structural form (and conceptual design)
- Choice of materials
- General principles of limit state design for masonry walls and columns
- Design of loadbearing masonry
- Design of laterally loaded masonry (and masonry infill panels to framed structures)
- Details and construction
- Design for fire
- Design for accidental damage

Notably, the structural design of reinforced and prestressed masonry, as well as retaining walls and arched structures, are not covered here — although an exception is the use of bed joint reinforcement; for both laterally loaded walls and for crack control.

This *Manual* is also part of a 7-title suite of Eurocode manuals.

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