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

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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_{id}	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

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_{tef} 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

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

α	Power used for obtaining characteristic compressive strength of masonry
α_t	Coefficient of thermal expansion of masonry
α_2	Bending moment coefficient
β	Enhancement factor for concentrated loads (Section 5.3.13 only)
β	Power used for obtaining characteristic compressive strength of masonry (Section 4.3.2 only)
γ_G	Partial factor for permanent actions, also accounting for model uncertainties and dimensional variations
$\gamma_{G,inf}$	Partial factor for permanent actions in calculating lower design value
$\gamma_{G,sup}$	Partial factor for permanent actions in calculating upper design value
γ_M	Partial factor for material property, also accounting for model uncertainties and dimensional variations
γ_Q	Partial factor for variable actions, also accounting for model uncertainty and dimensional variations
$\varepsilon_{c\infty}$	Final creep strain
ε_{el}	Elastic strain of masonry
η	Factor for use in calculating out-of-plane eccentricity of loading on walls
λ	Value used to obtain reduction factor within height of wall
λ_c	Value of slenderness ratio up to which eccentricities due to creep can be neglected
μ	Orthogonal ratio of flexural strengths of masonry
ρ_n	Reduction factor
ρ_t	Stiffness coefficient
σ_d	Design compressive stress (under permanent actions only for laterally loaded walls)
υ	Angle of inclination to vertical of structure
$\phi_¥$	Final creep coefficient of masonry
Φ	Reduction factor
Φ_i	Reduction factor at top or bottom of wall
Φ_m	Reduction factor within mid-height of wall
ψ_0	Factor for combination value of variable action
ψ_1	Factor for frequent value of variable action
ψ_2	Factor for quasi-permanent value of variable action

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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