Preface to the Third Edition

The original Structural Masonry Designers' Manual was viewed by many in the industry as a seminal reference for structural engineers designing masonry structures. The authors were founding members and directors of Curtins Consulting Engineers, a civil engineering consultancy practice, which was synonymous with the innovative and creative use of structural masonry in the latter part of the last century (1970s onwards). Both Bill Curtin and Gerry Shaw were educated in the old way which consisted of working by day and studying by night. This engendered a passion for their subject, which is evident in the previous editions of this book.

Gerry Shaw was until his tragic death a Visiting Professor in The Principles of Engineering Design at the University of Plymouth. The updated manual takes nothing away from the enthusiastic approach to masonry design evidenced by the Curtins' authors in the previous editions. Their pragmatic and practical approach to masonry design is retained in its fullness.

The new revision reflects changes in the industry with respect to health and safety, as well as Building Regulation requirements for heat loss, noise transmission and disproportionate collapse rules. The recent amendments to BS 5628 Parts 1, 2 and 3 are also included.

One major change is the transition from British specifications for materials to European Standard specifications. European specifications are based on performance criteria rather than prescriptive criteria and this will require structural engineers to be more aware of the materials that they specify.

Many changes have taken place in masonry construction since the last edition of the book was published. Many of these changes are quite rightly related to health and safety issues, which now appear to influence both the structural form and the choice of material. The current shortage of skilled labour within the construction industry further affects the design decisions made by structural engineers. However, innovative work in the use of structural masonry is still in evidence in structural engineering design.

The format of the book has remained unchanged since it is meant to be a discussion of process, both theoretical and practical, rather than a series of calculation sheets without explanation. The drawings have been updated, but have also been produced in an illustrative format rather than a technical drawing format. This is intended to aid the reader in the understanding of the principles.

Acknowledgements

We appreciate the help given by many friends in the construction industry, design professions and organisations. We learnt much from discussions (and sometimes, arguments) on site, in design team meetings and in the drawing office. To list all who helped would be impossible – to list none would be churlish. Below, in alphabetical order, are some of the organisations and individuals to whom we owe thanks:

Brick Development Association
British Standards Institution
Building Research Establishment
Cement and Concrete Association
} for general assistance

Professor Heyman for permission to quote from his book, *Equilibrium of Shell Structures*.

Mr J. Korff, Deputy Structural Engineer, GLC, for advice on accidental damage.

Mr W. Sharp, County Structural Engineer, Landcashire County Council, for particular help on strapping and tying.

Acknowledgements are also due to the BCRA for permission to quote from their SP93 'Strapping & Tying', which was largely based on information supplied by Lancashire County Council's structural engineer and W. G. Curtin and Partners.

Extracts from BS 5628 1985 and 1992 are reproduced by permission of BSI. Complete copies can be obtained from them at Linford Wood, Milton Keynes MK14 6LE.

Finally, the authors are grateful to the Institution of Structural Engineers for giving their permission to reproduce extracts from the Profile of Dr Bill Curtin, the original and full version of which was published in *The Structural Engineer*, **69** (21), 1991.

The Authors

W. G. Curtin was the founder of Curtins Consulting Engineers plc, a highly respected civil and structural engineering consultancy. He was a member of the Institution of Structural Engineers Science and Research Committee, of numerous CIRIA committees and the Code of Practice Committee for Structural Masonry, and of the Structural Engineering and Building Board of the Institution of Civil Engineers. His experience embraced over 50 years of designing, building, supervising and researching including masonry structures. For this he was awarded the Henry Adams Bronze Medal (twice) and the Oscar Faber Diploma by the Institution of Structural Engineers.

G. Shaw was a director of Curtins with around 40 years' experience in the building industry including more than 30 years as a consulting engineer. He was continuously involved with innovative developments in structural masonry with direct responsibility for numerous important masonry structures, including the world's first prestressed masonry box girder footbridges. He was also involved in research working closely with the University of Plymouth and the Building Research Establishment and was a member of EPSRC Built Environment College. He was co-author of a number of design notes and major text books including *Structural Foundation Designers' Manual* and *Structural Masonry Detailing*.

J. K. Beck, a former director of Curtins, is an engineer with many years' experience at home and abroad. Among the many structural masonry projects he has designed and supervised is, probably, the tallest slender crosswall structure in Europe. He served on the Institution of Structural Engineers ad hoc committee on Design of Masonry Structures and was co-author of *Structural Masonry Detailing*.

W. A. Bray joined Curtins in 1977. He was a group leader responsible for the design and supervision of many masonry structures including the world's first post-tensioned diaphragm wall structure. He later left the practice to follow another career path, via contracting.

Dave Easterbrook is a chartered engineer who has worked in local authority and consultancy for 13 years before joining The School of Civil and Structural Engineering at the University of Plymouth in 1991. He lectures in structural design and his research is focused on structural masonry. He worked in conjunction with the late Gerry Shaw of Curtins on the construction of the first prestressed masonry flat arch structures built at Tring, Herts, and alongside Gerry in his role as a Professor in the principles of engineering design at Plymouth. He is a member of The Institution of Structural Engineers' Codes Panel.

Notation

A	cross-sectional area
A_s	cross-sectional area of primary reinforcing steel
A_{sc}	area of compressive reinforcement
A_{sv}	area of shear reinforcement
a	depth of stress block or shear span
a_v	shear span (distance from support to concentrated load)
B	width of bearing under a concentrated load
B_r	centre-to-centre of cross-ribs in diaphragm wall
BM	bending moment
b	width of section
b_c	breadth of compression face
b_r	clear dimension between diaphragm cross-ribs
C	compressive force
C_c	total compressive force
C_s	compressive force in reinforcement
C_{pe}	wind, external pressure coefficient
C_{pi}	wind, internal pressure coefficient
D	overall depth of diaphragm wall section or depth of arch
Dia	diameter of reinforcing bar
d	effective depth to tensile reinforcement and depth of cavity (void) in diaphragm wall
d_n	depth to neutral axis
d_2	depth to compression reinforcement
E	Young's modulus of elasticity
E_m	modulus of elasticity of masonry
E_u	nominal earth and water load
e	eccentricity
e_a	additional eccentricity due to deflection in wall
e_{ef}	effective eccentricity
e_m	the larger of e_x and e_t
e_{max}	maximum eccentricity that can be practically accommodated in section
e_t	total design eccentricity at approximately mid-height of wall
e_x	eccentricity at top of wall
F_k	characteristic load
F_m	average of the maximum loads carried by two test panels
F_t	tie force
F_b, f_b	characteristic anchorage bond strength
f_{bs}	characteristic local bond strength
f_c	design axial stress due to minimum vertical load
f_k	characteristic compressive strength of masonry
f_{ki}	characteristic compressive strength of masonry at age when post-tensioning force is applied
f_{kx}	characteristic flexural strength (tensile) of masonry
f_{kxpar}	value of f_{kx} when plane of failure is parallel to bed joints
f_{kxperp}	value of f_{kx} when plane of failure is perpendicular to bed joints
f_t	theoretical flexural tensile stress or flange thickness
f_{uac}	design axial compressive stress
f_{ubc}	flexural compressive stress at design load
f_{ubt}	flexural tensile stress at design load
f_v	characteristic shear strength of masonry
f_w	flange width
f_y	characteristic tensile strength of steel
G_k	characteristic dead load
g_A	design vertical load per unit area
g_B	design load per unit area due to loads acting at right angles to the bed joints
g_d	design vertical dead load per unit area
H_z	thrust at crown of arch
h	clear height of wall or column between lateral supports
h_a	clear height of wall between concrete surfaces or other construction capable of providing adequate resistance to rotation across the full thickness of the wall
h_{ef}	effective height or length of wall or column
h_L	clear height of wall to point of application of lateral load
I	second moment of area/moment of inertia
I_{na}	second moment of area about neutral axis
K	stiffness coefficient
K_a	constant term relating design strengths of steel and masonry
K_1	shear stress coefficient for diaphragm walls
K_2	trial section stability moment coefficient for diaphragm walls
k	multiplication factor for lateral strength of axially loaded walls
k_1	$\frac{1 - \sin\theta}{1 + \sin\theta}$ from Rankine's formula for retained materials
L	length
L_a	a span in accidental damage design
L_{ef}, l_{ef}	effective length
L_f	spacing of fins, centre-to-centre
l_a	lever arm
M, M_A	applied design bending moment
M_a	design bending moment at base of wall
M_d	design moment of resistance
MR	moment of resistance
MR_s	stability moment of resistance
M_{rb}	moment of resistance of a balanced section
M_{rs}	moment of tensile resistance
M_w	design bending moment in height of wall

N	design vertical axial load
N_b	design vertical axial strength at balanced condition
N_d	design vertical axial strength
N_0	design vertical axial strength when loaded on the centroidal axis
N_s	number of storeys in building
NA	neutral axis
n	axial load per unit length of wall, available to resist arch thrust
n_w	design vertical load per unit length of wall
P	design post-tensioning force
P_k	characteristic post-tensioning force
P_{lim}	acceptance limit for compressive strength of units
P_0	specified compressive strength of units
P_u	mean compressive strength of units
p_{ubc}	allowable flexural compressive stress
p_{ubt}	allowable flexural tensile stress
Q	constant term for design flexural strength of masonry in compression or radius of arch curve
Q_k	characteristic superimposed load
q	dynamic wind pressure
q_{lat}	design lateral strength per unit area
q_1	design horizontal pressure at any depth (from retained material)
R	radius of arch
r	ratio of area of reinforcement to area of section or width of flat metal shear connector or radius of gyration
r_d	projection of rib (or fin) beyond flange (in a T profile)
r_t	rib (or fin) thickness (in a T profile)
s	vertical spacing of flat metal shear connectors
S	clear span of arch
SR	slenderness ratio
S_d	section depth
S_n	strain constant
S_v	spacing of link reinforcement
T	total tensile force or thickness of diaphragm leaf or flange
t	thickness of wall (or depth of section)
t_{ef}	effective thickness of wall
t_f	thickness of flange
t_p	thickness of a pier
t_r	thickness of a cross-rib in a diaphragm wall
t_w	width of masonry section in vertical shear
u	thickness of flat metal shear connector
UDL	uniformly distributed load
V, v	shear force
v_h	design vertical shear stress on masonry section
W, w	axial load
W	own weight of effective area of fin wall per metre height
W_k	characteristic wind load
W_{k1}	design wind pressure, windward wall
W_{k2}	design wind pressure, leeward wall
W_{k3}	design wind pressure uplift (on roof)
w_s	width of stress block
x_n	depth to neutral axis from top of beam
Y_1	fin dimension, neutral axis to end of fin
Y_2	fin dimension, neutral axis to flange face
Y_u	deflection of test wall in mid-height region
Z	section modulus
Z_1	minimum section modulus of fin
Z_2	maximum section modulus of fin
z	lever arm
α	bending moment coefficient for laterally loaded panels
β	capacity reduction factor
γ_f	partial safety factor for loads
γ_m	partial safety factor for materials
γ_{mb}	partial safety factor for bond between reinforcement and mortar or grout
γ_{mm}	partial safety factor for compressive strength of masonry
γ_{ms}	partial safety factor for steel reinforcement
γ_{mv}	partial safety factor for masonry in shear
δ	deflection
δL	short linear measurement
ε	strain in reinforcement
μ	orthogonal ratio
ρ	density
Σu	sum of the perimeters of the tensile reinforcement
Ψ_m	reduction factor for strength of mortar
ψ_u	unit reduction factor
Ω	trial section coefficient for fin walls