

# 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.

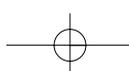
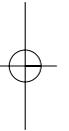
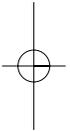
Gerry Shaw was until his tragic death a Visiting Professor in The Principles of Engineering Design at the University of Plymouth. The updated manual takes nothing away from the enthusiastic approach to masonry design evidenced by the Curtins' authors in the previous editions. Their pragmatic and practical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

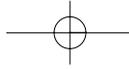
The new revision reflects changes in the industry with respect to health and safety, as well as Building Regulation requirements for heat loss, noise transmission and disproportionate collapse rules. The recent amendments to BS 5628 Parts 1, 2 and 3 are also included.

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

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

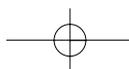
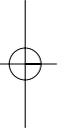
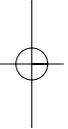
Mr J. Korff, Deputy Structural Engineer, GLC, for advice on accidental damage.

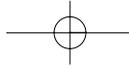
Mr W. Sharp, County Structural Engineer, Lancashire County Council, for particular help on strapping and tying.

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

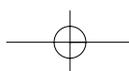
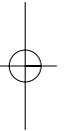
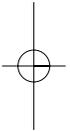
**W. G. Curtin** was the founder of Curtins Consulting Engineers plc, a highly respected civil and structural engineering consultancy. He was a member of the Institution of Structural Engineers Science and Research Committee, of numerous CIRIA committees and the Code of Practice Committee for Structural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

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