

# Conceptual design of buildings



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# Notation (for Chapter 10)

Term	Definition
$A_c$	Cross-sectional area of concrete
$A_{\text{chord}}$	Cross-sectional area of truss chord
$A_f$	Area of flange
$A_s$	Cross-sectional area of reinforcement
$A_v$	Shear area
$b$	Width of section
$b_f$	Width of flange
$c_f$	Outstand length of flange
$d$	Depth of truss
$d_{\text{eff}}$	Effective depth
$d_{\text{sect}}$	Depth of section
$\delta$	Deflection
$e$	Eccentricity
$E$	Modulus of elasticity
$E_{0.05}$	Fifth percentile value of modulus of elasticity
$E_{\text{min}}$	Minimum value of modulus of elasticity
$f_{\text{all}}$	Allowable stress in steel section
$f_{\text{ck}}$	Characteristic compressive cylinder strength of concrete
$f_{c,0,d}$	Design compressive strength parallel to grain
$f_{c,0,k}$	Characteristic compressive strength parallel to grain
$f_{m,d}$	Allowable bending strength parallel to grain
$f_{m,k}$	Characteristic bending strength parallel to grain
$f_y$	Yield strength of steel
$f_{yk}$	Characteristic tensile strength of reinforcement
$F_{b,0,d}$	Design buckling resistance parallel to grain
$F_{c,0,d}$	Design compressive resistance parallel to grain
$g_d$	Design uniformly distributed load due to permanent loads
$\gamma_m$	Partial material factor
$h$	Height of arch
$h_w$	Height of web
$i_y$	Radius of gyration, y-y axis
$I$	Second moment of area
$I_{\text{truss}}$	Second moment of area of truss
$k$	Modification factor for timber section
$k_{yy}, k_{zy}$	Interaction factors for steel columns
$L$	Span length
$L_{\text{cr}}$	Buckling length
$\lambda$	Slenderness
$\lambda_{\text{rel}}$	Relative slenderness
$M_{b,Rd}$	Design lateral torsional buckling resistance
$M_{Ed}$	Design bending moment



$M_{c,z,Rd}$	Design moment resistance, z-z axis
$N_{b,Rd}$	Design buckling resistance
$N_{c,Rd}$	Design resistance to axial compression
$N_{cr}$	Euler buckling resistance
$N_{Ed}$	Design axial force
$N_{c,Ed}$	Design axial compression force
$N_{t,Ed}$	Design axial tension force
$N_{pl,Rd}$	Design plastic resistance to axial forces
$q_d$	Design uniformly distributed load due to variable loads
$r$	Radius of circular arch
$R_H$	Horizontal reaction
$R_V$	Vertical reaction
$S$	Swept length of arch
$t_f$	Thickness of flange
$t_w$	Thickness of web
$V_{Ed}$	Design shear force
$v_{Ed}$	Design shear stress
$V_{pi,d}$	Design plastic shear resistance
$V_{Rd,c}$	Design shear resistance
$w_d$	Uniformly distributed load (UDL)
$W_d$	Design point load
$W_{el}$	Elastic modulus
$y$	Distance from neutral axis to centroid of member
$z$	Lever arm of internal forces

# Foreword

I wish I had this book when I was a student! It would have put into perspective so beautifully at the time what it really is to be a structural engineer. To dream a little and have ideas. To rely on deep technical skills to prioritise some of these ideas, and to work them up into reality such that the outcome enhances somebody's life. Wonderful. This is structural engineering, and a reflection of its power. This book oozes with reasons why our profession is so special.

It lays out the story for students and graduates about the realities of the day job right through to our contributions to humanity, and the excitement which these responsibilities provide. It is written by highly experienced authors whose communication skills ensure total accessibility to students and graduates in explaining clearly the entire process of the creative structural design of a building.

The aspect of the book which I like most is the desire by the authors for the book to become outdated quickly. Our climate emergency has placed our profession in the spotlight, given the embodied-carbon issues inherent in construction. This book reflects current best practice, but it also asks the big 'What if?' questions. What if we had no cement? What if we had to design according to an inventory-constrained palette of re-used components? What if we could rely on technology to mitigate risk of overload in buildings? If you ever wanted students and graduates to make the link between our commitments to the climate emergency 'declare' initiatives and the day job, the 'What if?' questions highlighted in this book provide just this inspiration. It takes our profession out of the spotlight and into the limelight.

This book reflects the extraordinary skills which structural engineers possess, and how they might think about deploying them. Additionally, it challenges us to be even better in the future. The guidance is priceless for those entering our fabulous profession.

A handwritten signature in blue ink, reading 'Tim Ibell'.

**Prof. Tim Ibell**

Department of Architecture and Civil Engineering, University of Bath, UK

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# The authors



## **James Norman – University of Bristol**

James has 12 years design experience working for Ramboll and Integral Engineering Design. He has nine years' academic experience, including a PhD at the University of Bristol. He has designed buildings out of mud, timber, steel and lots and lots of concrete, and worked for a year on the facade of the extension to the Tate Modern. James authored *Structural timber elements: a pre-scheme design guide* and is Associate Professor of Sustainable Design.

## **Oliver Broadbent – Constructivist Ltd**

Oliver is Founder of Constructivist Ltd, and specialises in helping engineers develop their creativity. He is a Royal Academy of Engineering Visiting Professor at Imperial College and hosts Eiffel Over, a podcast about engineering, creativity and practical philosophy.



## **Jon Carr – University of Sheffield and Jon Carr Structural Design**

Jon is a Senior University Teacher in Structural Design at the University of Sheffield, as well as running Jon Carr Structural Design, as a sole practitioner. Jon previously worked for Anthony Hunt Associates from 1988 to 2010, specialising in education and sports and leisure sector projects. His notable projects include the KCOM Stadium in Hull and, at the other end of the scale, the 'Hen House' in Sheffield.

## **Rachael De'Ath – University of Bristol and Arup**

Rachael has more than 16 years' design experience working for Arup, and has recently joined the University of Bristol to teach design, alongside her work in industry. She prefers working on re-use projects, where the existing structure is creatively re-imagined into something new. She was named as one of the Women's Engineering Society 'Top 50 female engineers' in 2018.



## **Richard Harpin – University of Sheffield**

Richard is a University Teacher in Structural Design at the University of Sheffield. He was previously a Lecturer in Structural Engineering and Architecture at Nottingham Trent University and, before this, spent 16 years working for Arup. Significant projects include Citibank European Headquarters at Canary Wharf, Pallant House Gallery in Chichester and the School of Theatre, Film and Television at the University of York.

**Gavin Knowles – University of Bath**

Gavin studied Civil Engineering at Oxford Brookes University and graduated in 2001. Since working in practice he gained his professional chartership with the Institution of Structural Engineers. He was an Associate with Bath-based engineering firm Integral Engineering Design, and is now a full-time lecturer at the University of Bath. Gavin's previous projects include many education and office buildings, along with conservation and refurbishment projects, interweaved with diverse structures, such as rammed chalk-walled houses, recycled material stages at WOMAD Festival and the odd sculpture.



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