The Institution of
StructuralEngineers

Conceptual design of buildings

IStructE Guide

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Authors

J Norman PhD MEng CEng MICE FHEA (University of Bristol) *Lead*
O Broadbent MEng MChem (Constructivist Ltd)
J F Carr BEng MPhil CEng FIStructE FHEA (University of Sheffield and Jon Carr Structural Design)
R De'Ath MEng CEng MIStructE MICE (University of Bristol and Arup)
R Harpin BEng CEng MIStructE (University of Sheffield)
G Knowles BEng CEng MIStructE (University of Bath)
I Lloyd PhD MSc(Eng) BSc(Geol) CGeol FGS FHEA (University of Bristol)

Reviewers

G Evans BSc(Hons) PhD CEng FICE FIStructE MBCS (Constructex) *Technical Products Panel*
T Ibell FREng PhD BSc(Eng) CEng FIStructE FICE FHEA (University of Bath)
J Lord MEng CEng MICE (Whitby Wood)
N Russell BSc CEng FIStructE FICE FASCE MCMI (Perega)

Publishing

L Baldwin BA(Hons) DipPub (The Institution of Structural Engineers)
R Thomas BA(Hons) MCLIP (The Institution of Structural Engineers)

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International HQ, 47–58 Bastwick Street, London EC1V 3PS, United Kingdom
T: +44(0)20 7235 4535
E: mail@istructe.org
W: www.istructe.org

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Contents

Notation (for Chapter 10)

Term	Definition
A_c	Cross-sectional area of concrete
A_{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_{eff}	Effective depth
d_{sect}	Depth of section
δ	Deflection
e	Eccentricity
E	Modulus of elasticity
$E_{0.05}$	Fifth percentile value of modulus of elasticity
E_{min}	Minimum value of modulus of elasticity
f_{all}	Allowable stress in steel section
f_{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
$\mathrm{f}_{m,k}$	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
γ_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_{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_{cr}	Buckling length
λ	Slenderness
λ_{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.

Prof. Tim Ibell
Department of Architecture and Civil Engineering, University of Bath, UK

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.

Isobel Lloyd – University of Bristol
Isobel has 20 years' design experience with BuroHappold, Atkins and Mott MacDonald, mostly in the UK but also in Europe, the Middle East and Hong Kong. She has six years' experience of working for various contractors including ground investigation companies, and has spent eight years in academia. Significant projects include the Globe Theatre, Royal Armouries Museum in Leeds, Valentine Bridge in Bristol, Extension to British Library and many school buildings.

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