Understanding Structures

Other Macmillan titles for Engineers:

Reinforced Concrete Design, 4th Edition

W. H. Mosley and J. H. Bungey

Civil Engineering Materials, 4th Edition

N. Jackson and R. Dhir

Fundamental Structural Analysis

W. J. Spencer

Structural Mechanics

J. Cain and R. Hulse

Surveying for Engineers, 3rd Edition

J. Uren and W. F. Price

**Civil Engineering Contract Administration and Control,
2nd Edition**

I. H. Seeley

Civil Engineering Quantities, 5th Edition

I. H. Seeley

Understanding Hydraulics

L. Hamill

Practical Soil Mechanics

G. Barnes

Understanding Structures

Analysis, materials,
design

Derek Seward

*Department of Engineering
University of Lancaster*

M
MACMILLAN

© Derek W. Seward 1994

All rights reserved. No reproduction, copy or transmission of this publication may be made without written permission.

No paragraph of this publication may be reproduced, copied or transmitted save with written permission or in accordance with the provisions of the Copyright, Designs and Patents Act 1988, or under the terms of any licence permitting limited copying issued by the Copyright Licensing Agency, 90 Tottenham Court Road, London W1P 9HE.

Any person who does any unauthorised act in relation to this publication may be liable to criminal prosecution and civil claims for damages.

First published 1994 by
THE MACMILLAN PRESS LTD
Houndmills, Basingstoke, Hampshire RG21 2XS
and London
Companies and representatives
throughout the world

ISBN 978-0-333-54199-9 ISBN 978-1-349-12083-3 (eBook)
DOI 10.1007/978-1-349-12083-3

A catalogue record for this book is available
from the British Library.

Contents

	Page
Preface	vii
Symbols	ix
1 Design	1
2 Basics	13
3 Materials	28
4 Loads	56
5 Pin-jointed trusses	77
6 Tension	103
7 Beams	119
8 Compression	174
9 Combined axial and bending stresses	191
10 Connections	209
11 Arches and portal frames	228
12 Foundations and retaining walls	240
13 Deflection	259
Appendix: Section Properties	271
Further reading	276
Index	277

Preface

This book explains the fundamentals of structural analysis, materials and design. These topics are often treated as separate subjects, but it is my belief that it is better to introduce all three topics in an integrated fashion. This enables the student to tackle realistic design problems in the shortest possible time, and, because he or she can see the relevance of the theory, it produces good motivation. It is also a way of providing early exposure to the actual **process** of design – from initial concept through to final details. Although much of the book deals with the design of individual structural elements in various materials, it also considers the way these elements are used in complete structures, which is the essence of structural form. To attempt to cover such a wide range of material in a modestly sized book has not been easy. In selecting material for inclusion I have given preference to those issues which occur most frequently in the real world of structural design.

The book is intended for students of civil and structural engineering, building, architecture and surveying. It is of use at both first year degree and BTEC level. Because it contains much real design data, it may also be useful as a work of reference for the non-specialist practitioner.

In order to produce safe and economic structures, a large part of the structural design process is inevitably numerical. However, where possible, the book avoids a mathematical approach. The aim is to develop a 'feel' and awareness for the physical behaviour of structures. As the title of the book suggests, the emphasis is placed on understanding. For this reason a large number of illustrations are used to portray structural behaviour. A minimum of mathematical knowledge is required – largely simple algebra and trigonometry. Where, as in certain proofs of formulae, slightly more advanced mathematics is unavoidable, it is presented in such a way that uninterested readers can avoid it without affecting their wider understanding of the book. The scope of the book is restricted to statically determinate structures, in the belief that a thorough understanding of these is required before moving on to structures which contain redundant members.

The treatment is in line with the latest limit state approach, now adopted by national standards for structural design in most materials. However, mention is also made of the more traditional permissible stress approach, which is still in common use for some materials. An unusual feature of the book is the inclusion of a chapter on structural loads. This vital stage in the design process is often difficult for the beginner, and yet is rarely covered in text books. A more controversial feature is the way that the book explains ultimate plastic bending strength before the elastic case. The basic design method adopted in national standards for the principal structural materials now assumes that full plastic strength can be developed. Indeed, run-of-the-mill design of steel and reinforced concrete beams can now take place without any knowledge of elastic theory. Plastic strength is also easier to understand. It is only for historical reasons that elasticity is usually taught before plasticity.

Each stage of the design process is illustrated by a realistic numerical example which is based on genuine design data. It is hoped that after reading this book the student will have developed a real skill for structural design, as well as sharing in the satisfaction, pleasure and excitement of this highly creative process.

Derek Seward

Symbols

A	cross-sectional area
A_c	area of concrete
A_e	effective area
A_s	area of tensile reinforcement
A_{sc}	area of compressive reinforcement
A_{sv}	area of two legs of shear link
a	pitch angle of roof
B	beam width
b	width of concrete
C	width of column
D	beam depth, depth of arch
d	effective depth of reinforcement
E	modulus of elasticity
e	eccentricity of load
F	axial force
f_{cu}	concrete characteristic strength
f_k	characteristic compressive strength of masonry
f_{kx}	characteristic tensile bending strength of masonry
f_y	reinforcement characteristic strength
f_{yv}	characteristic strength of shear links
G_k	characteristic dead load
H	horizontal component of force
I	second moment of area
j	number of joints
k_a	active earth pressure coefficient
k_p	passive earth pressure coefficient
L	length, length of span
L_E	effective length
M	bending moment
M_F	moment due to prestressing force
m	number of members
N	number of stress cycles, ultimate load capacity of a reinforced concrete column
P	concentrated point load, column load
P_{crit}	critical buckling load
p	hydrostatic pressure

p_b	bending strength
p_c	compressive strength
Q	first moment of area about neutral axis
Q_k	characteristic imposed load
q	ground pressure under foundation
q	shear flow
R	radius of curvature, resultant force
R_{AV}	vertical reaction force at A
r	radius of gyration
S	plastic section modulus, magnitude of stress fluctuation
s_v	spacing of shear links
t	beam web thickness, wall thickness
V	vertical component of force, shear force
v	design shear stress
v_c	concrete shear strength
W_k	characteristic wind load
w	magnitude of uniformly distributed load
x	an arbitrary or unknown distance, neutral axis depth in concrete, torsional index
Y	distance from beam surface to neutral axis
y	distance from neutral axis
Z	elastic section modulus
z	depth of liquid or soil, lever-arm in concrete beam
γ	unit weight
γ_f	partial safety factor for loads
γ_m	partial safety factor for material strength
Δ	deflection of structure
δ	extension of member
θ	angle
μ	slip factor
σ	stress
σ_y	yield stress
σ_u	ultimate stress
τ	shear stress

Acknowledgements

The author and publishers wish to thank the following for permission to use copyright material.

BSI Standards for extracts from British Standards. Extracts from British Standards are reproduced with the permission of BSI. Complete copies can be obtained by post from BSI Sales, Linford Wood, Milton Keynes, MK14 6LE.

The Appendix on standard rolled steel sections contains data from *A Check List for Designers* and is reproduced by kind permission of the Director, The Steel Construction Institute.

Cover design photographs of the Humber Bridge and the Forth Road Bridge were kindly provided by Acer Consultants Limited.

Every effort has been made to trace all the copyright holders, but if any have been inadvertently overlooked, the publishers will be pleased to make the necessary acknowledgements at the first opportunity.