REINFORCED CONCRETE DESIGN

Other Macmillan titles of interest to civil engineers

Hulse/Mosley	<i>Reinforced Concrete Design by Computer</i>
Bolton	<i>Guide to Soil Mechanics</i>
Boxer	<i>Work Out Fluid Mechanics</i>
Jackson/Dhir	<i>Civil Engineering Materials</i> , 4th edition
John	<i>Work Out Engineering Materials</i>
Newton	<i>Structural Design</i>
Salter	<i>Highway Design and Construction</i> , 2nd edition
Salter	<i>Highway Traffic Analysis and Design</i> , 2nd edition
Seeley	<i>Civil Engineering Contract Administration and Control</i>
Seeley	<i>Civil Engineering Quantities</i>
Seeley	<i>Civil Engineering Specification</i>
Spencer	<i>Fundamental Structural Analysis</i>
Stone	<i>Management of Engineering Projects</i>
Uren/Price	<i>Surveying for Engineers</i> , 2nd edition
Wilson	<i>Engineering Hydrology</i> , 4th edition

REINFORCED CONCRETE DESIGN

W. H. Mosley

and

J. H. Bungey

*Department of Civil Engineering
University of Liverpool*

FOURTH EDITION

M
MACMILLAN

© W. H. Mosley and J. H. Bungey 1976, 1982, 1987, 1990

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, 33–4 Alfred Place, London WC1E 7DP.

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 1976

Reprinted 1977, 1978, 1980, 1981 (twice)

Second edition 1982

Reprinted 1983, 1984, 1985, 1986

Third edition 1987

Reprinted 1988, 1989

Fourth edition 1990

Reprinted 1991

Published by

MACMILLAN EDUCATION LTD

Houndmills, Basingstoke, Hampshire RG21 2XS

and London

Companies and representatives

throughout the world

British Library Cataloguing in Publication Data

Mosley, W. H. (William Henry)

Reinforced concrete design. - 4th ed.

1. Reinforced concrete structural components. Design

I. Title II. Bungey, J. H. (John Henry), 1944–

624.18341

ISBN 978-0-333-53718-3

ISBN 978-1-349-20929-3 (eBook)

DOI 10.1007/978-1-349-20929-3

Contents

<i>Preface to Fourth Edition</i>	viii
<i>Notation</i>	ix
1 Properties of Reinforced Concrete	1
1.1 Composite Action	1
1.2 Stress-Strain Relations	2
1.3 Shrinkage and Thermal Movement	7
1.4 Creep	11
1.5 Durability	12
1.6 Specification of Materials	12
2 Limit State Design	15
2.1 Limit States	16
2.2 Characteristic Material Strengths and Characteristic Loads	17
2.3 Partial Factors of Safety	18
2.4 Global Factor of Safety	19
3 Analysis of the Structure	24
3.1 Loads	24
3.2 Load Combinations	26
3.3 Analysis of Beams and Frames	28
3.4 Redistribution of Moments	48
4 Analysis of the Section	53
4.1 Stress-Strain Relations	53
4.2 The Distribution of Strains and Stresses across a Section	55
4.3 Bending and the Equivalent Rectangular Stress Block	57
4.4 Singly Reinforced Rectangular Section in Bending	58
4.5 Rectangular Section with Compression Reinforcement at the Ultimate Limit State	63
4.6 Flanged Section in Bending at the Ultimate Limit State	68
4.7 Moment Redistribution and the Design Equations	75

4.8	Bending Plus Axial Load at the Ultimate Limit State	79
4.9	The Rectangular-Parabolic Stress Block	88
4.10	The Triangular Stress Block	91
5	Shear, Bond and Torsion	98
5.1	Shear	98
5.2	Anchorage Bond	103
5.3	Laps in Reinforcement	106
5.4	Analysis of Section Subject to Torsional Moments	107
6	Serviceability, Durability and Stability Requirements	112
6.1	Detailing Requirements	113
6.2	Span-Effective Depth Ratios	117
6.3	Calculation of Deflections	119
6.4	Flexural Cracking	134
6.5	Thermal and Shrinkage Cracking	141
6.6	Other Serviceability Requirements	144
6.7	Stability	147
7	Design of Reinforced Concrete Beams	154
7.1	Preliminary Analysis and Member Sizing	156
7.2	Design for Bending	159
7.3	Design for Shear	174
7.4	Bar Spacing	180
7.5	Continuous Beams	180
7.6	Cantilever Beams	187
7.7	Design for Torsion	188
8	Design of Reinforced Concrete Slabs	192
8.1	Simplified Analysis	192
8.2	Shear in Slabs	193
8.3	Span-Effective Depth Ratios	198
8.4	Reinforcement Details	200
8.5	Solid Slabs Spanning in One Direction	201
8.6	Solid Slabs Spanning in Two Directions	209
8.7	Flat Slab Floors	214
8.8	Ribbed and Hollow Block Floors	222
8.9	Stair Slabs	226
8.10	Yield Line and Strip Methods	230
9	Column Design	239
9.1	Loading and Moments	239
9.2	Short and Slender Columns	241
9.3	Reinforcement Details	244
9.4	Design of Short Columns	246
9.5	Non-rectangular Sections	261
9.6	Design of Slender Columns	264

10 Foundations	270
10.1 Pad Footings	273
10.2 Combined Footings	280
10.3 Strap Footings	284
10.4 Strip Footings	286
10.5 Raft Foundations	289
10.6 Piled Foundations	291
11 Water-retaining Structures and Retaining Walls	296
11.1 Water-retaining Structures	296
11.2 Joints in Water-retaining Structures	298
11.3 Reinforcement Details	302
11.4 Design Methods	304
11.5 Retaining Walls	318
12 Prestressed Concrete	329
12.1 Principles of Prestressing	329
12.2 Methods of Prestressing	332
12.3 Analysis of Concrete Section Under Working Loads	335
12.4 Design for the Serviceability Limit State	341
12.5 Analysis and Design at the Ultimate Limit State	367
<i>Appendix</i>	382
<i>Further Reading</i>	386
<i>Index</i>	388

Preface to Fourth Edition

The purpose of this book is to provide a straightforward introduction to the principles and methods of design for concrete structures. It is directed primarily at students and young designers who require an understanding of the basic theory and a concise guide to design procedures. Although the detailed design methods are generally according to British Standards, much of the theory and practice is of a fundamental nature and should, therefore, be useful to engineers in other countries. Limit state concepts, as recently introduced in the new Codes of Practice, are used and the calculations are in SI units throughout.

The subject matter has been arranged so that chapters 1 to 5 deal mostly with theory and analysis while the subsequent chapters cover the design and detailing of various types of member and structure. In order to include topics that are usually in an undergraduate course, there is a chapter on earth-retaining and water-retaining structures, and also a final chapter on prestressed concrete.

Important equations that have been derived within the text are highlighted by an asterisk adjacent to the equation number.

In preparing the fourth edition of this book, the principal aim has been to incorporate new information relating to the design of water-retaining structures, as proposed by British Standard BS 8007. The remainder of the text, which relates to BS 8110, remains essentially unchanged with only very minor amendments.

It should be mentioned that standard Codes of Practice such as BS 8110 are always liable to be revised, and readers should ensure that they are using the latest edition of any relevant standard.

Extracts from the British Standards are reproduced by permission of the British Standards Institution, 2 Park Street, London W1A 2BS, from whom complete copies can be obtained.

Finally, the authors wish to thank Mrs B. Cotgreave who prepared the diagrams and Mrs F. Zimmermann who typed most of the draft and final copies of the manuscript.

Notation

Notation is generally in accordance with BS 8110, and the principal symbols are listed below. Other symbols are defined in the text where necessary. The symbols ϵ for strain and f for stress have been adopted throughout, with the general system of subscripts such that the first subscript refers to the material, c – concrete, s – steel, and the second subscript refers to the type of stress, c – compression, t – tension.

A_s	Cross-sectional area of tension reinforcement
A_s'	Cross-sectional area of compression reinforcement
A_{sb}	Cross-sectional area of shear reinforcement in the form of bent-up bars
A_{sv}	Cross-sectional area of shear reinforcement in the form of links
a	Deflection
a_{cr}	Distance from surface crack position to point of zero strain
b	Width of section
b_v	Breadth of web or rib of a member
b_w	Breadth of web or rib of a member
d	Effective depth of tension reinforcement
d'	Depth to compression reinforcement
E_c	Static secant modulus of elasticity of concrete
E_s	Modulus of elasticity of steel
e	Eccentricity
F	Ultimate load
f_{cu}	Characteristic concrete cube strength
f_{pu}	Characteristic strength of prestressing tendons
f_s	Service stress or steel stress
f_y	Characteristic strength of reinforcement
f_{yv}	Characteristic strength of link reinforcement
G_k	Characteristic dead load
g_k	Characteristic dead load per unit length or area
h	Overall depth of section in plane of bending
h_f	Thickness of flange
I	Second moment of area
k_1	Average compressive stress in the concrete for a rectangular-parabolic stress block

k_2	A factor that relates the depth to the centroid of the rectangular-parabolic stress block and the depth of the neutral axis
l_a	Lever-arm factor = z/d
l_e	Effective height of a column or wall
M	Bending moment
M_u	Ultimate moment of resistance
N	Axial load
n	Ultimate load per unit area
N_{bal}	Axial load on a column corresponding to the balanced condition
P	Final prestress force (chapter 12)
Q_k	Characteristic imposed load
q_k	Characteristic live load per unit length or area
$1/r_x$	Curvature of a beam at point x
r_{crit}	Critical steel ratio to control thermal cracks
s	Depth of equivalent rectangular stress block
s_{max}	Maximum likely crack spacing
s_v	Spacing of links along the member
T	Torsional moment
u	Perimeter
V	Shear force
v	Shear stress
v_c	Ultimate shear stress in concrete
W_k	Characteristic wind load
w_{max}	Maximum likely surface crack width
w_u	Ultimate load per unit length
x	Neutral axis depth
z	Lever arm
α_c	Coefficient of thermal expansion of mature concrete
α_e	Modular ratio
γ_f	Partial safety factor for load
γ_m	Partial safety factor for strength
ϵ_{sh}	Shrinkage strain
μ	Coefficient of friction
Φ	Bar size
ϕ	Creep coefficient