

SURINDER SINGH VIRDI

CONSTRUCTION SCIENCE AND MATERIALS

SECOND EDITION

WITH CONTRIBUTION FROM
ROBERT WATERS



WILEY Blackwell

Construction Science and Materials

Second Edition

Surinder Singh Virdi

*Lecturer in Construction
South and City College Birmingham*

*Visiting lecturer
City of Wolverhampton College*

*With contribution from
Robert Waters
Lecturer in Construction
South and City College Birmingham*

WILEY Blackwell

This edition first published 2017
© 2017 by John Wiley and Sons Ltd

Registered Office

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom.

Editorial Offices

9600 Garsington Road, Oxford, OX4 2DQ, United Kingdom.
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom.

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

The right of the author to be identified as the author of this work has been asserted in accordance with the UK Copyright, Designs and Patents Act 1988.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty: While the publisher and author(s) have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. It is sold on the understanding that the publisher is not engaged in rendering professional services and neither the publisher nor the author shall be liable for damages arising herefrom. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Library of Congress Cataloging-in-Publication data applied for

ISBN: 9781119245056

00077650

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

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image: MACIEJ NOSKOWSKI/Gettyimages

Set in 10/12pt Warnock by SPi Global, Pondicherry, India
Printed and bound in Malaysia by Vivar Printing Sdn Bhd

10 9 8 7 6 5 4 3 2 1

Contents

Preface to the Second Edition	<i>xv</i>
About the Companion Website	<i>xvii</i>

1	Introduction to Physics	1
1.1	Speed and Velocity	1
1.2	Acceleration	1
1.3	Mass	2
1.4	Gravitation	2
1.5	Weight	3
1.6	Volume	4
1.7	Density	4
1.8	Specific Gravity	6
1.9	Newton's First Law of Motion	6
1.10	Newton's Second Law of Motion	6
1.11	Newton's Third Law of Motion	7
1.12	Friction	7
1.13	Work	8
1.14	Energy	9
1.14.1	Potential Energy	9
1.14.2	Kinetic Energy	10
1.15	Power	11
	Exercise 1.1	12
	Reference/Further Reading	12
2	Introduction to Chemistry	13
2.1	Introduction	13
2.2	Electrovalency and Covalency	15
2.2.1	Covalent Bond	17
2.3	Elements and Compounds	18
2.4	Symbols and Formulae	19
2.5	Acids and Bases	20
2.5.1	Acids	20
2.5.2	Bases	21
	Exercise 2.1	22
	References/Further Reading	23

3	Effects of Chemicals and the Atmosphere on Materials	25
3.1	Introduction	25
3.2	Oxidation	25
3.2.1	Experiment: To Show that Oxygen (Or Air) and Water are Necessary for the Rusting of Iron	26
3.3	Electrolysis	27
3.4	Electrolytic Corrosion	28
3.4.1	Examples of Electrolytic Corrosion	30
3.4.2	Protection of Steel from Corrosion	31
3.5	Applications of Electrolysis	32
3.5.1	Electroplating	32
3.5.2	Extraction of Aluminium	32
3.6	Acid Rain	33
	References/Further Reading	33
4	Electricity	35
4.1	Introduction	35
4.2	Coulomb's Law	35
4.3	Electric Current	36
4.4	Potential Difference	36
4.5	Electromotive Force (e.m.f.)	37
4.6	Ohm's Law	37
4.7	Electrical Resistivity and Conductivity	39
4.8	Resistors in Series/Parallel	39
4.8.1	Resistors in Series	39
4.8.2	Resistors in Parallel	40
4.9	Transformers	43
4.10	Power Generation	44
4.11	Power Distribution	45
4.12	Supply to Small Buildings	47
	Exercise 4.1	48
	Reference/Further Reading	49
5	Introduction to Construction Technology	51
5.1	Introduction	51
5.2	Substructure and Superstructure	51
5.2.1	Soil Investigation	52
5.3	Foundations	53
5.3.1	Settlement	54
5.4	Forms of Construction	55
5.5	The External Envelope	56
5.5.1	Functions of the External Envelope	57
5.5.2	Ground Floors	60
5.5.3	Cavity Walls	61
5.5.4	Suspended Timber Upper Floors	61
5.5.5	Roofs	61
	References/Further Reading	61

6	Introduction to Building Services	63
6.1	Introduction	63
6.2	Cold Water Supply	63
6.3	Hot Water Supply	65
6.4	Central Heating Systems	65
6.5	Underfloor Heating Systems	66
6.6	Drainage Systems	67
6.6.1	Below-ground Drainage System	67
6.6.2	Above-ground Drainage System	68
6.7	Integration of Services into Building Design	68
	References/Further Reading	72
7	Thermal Energy 1	73
7.1	Introduction	73
7.2	Temperature	73
7.2.1	Temperature Scales	74
7.3	Units of Heat	74
7.4	States of Matter	75
7.4.1	Changes in the Physical State	75
7.4.2	Experiment: The Physical States of Water	75
7.5	Expansion and Contraction of Solids	77
7.5.1	Linear Expansion	77
7.5.2	Experiment: Determination of Coefficient of Linear Expansion	78
7.5.3	Practical Examples of Expansion and Contraction	79
7.6	Heat Transfer	81
7.6.1	Conduction	81
7.6.2	Experiment: To Compare the Thermal Conductivity of Metals	84
7.6.3	Convection	84
7.6.4	Radiation	85
	Exercise 7.1	86
	References/Further Reading	86
8	Thermal Energy 2 (Including Humidity)	87
8.1	Introduction	87
8.2	Thermal Insulation	87
8.2.1	Experiment: To Compare the Thermal Insulation Values of Expanded Polystyrene, Vermiculite, Mineral Wool, Glass Fibre and Cork	88
8.3	Heat Transmission	90
8.3.1	Thermal Conductivity	90
8.3.2	Thermal Resistivity (r)	91
8.3.3	Thermal Resistance (R)	91
8.4	Thermal Transmittance	92
8.5	Heat Loss from Buildings	98
8.6	Temperature Drop Through Materials	102
8.7	Humidity	104
8.7.1	Measurement of Relative Humidity	105
8.8	Condensation	107

- 8.8.1 The Psychrometric Chart 108
- 8.8.2 Prevention of Surface Condensation 108
- 8.8.3 Interstitial Condensation 110
- Exercise 8.1 116
- References/Further Reading 117

9 Forces and Structures 1 119

- 9.1 Introduction 119
- 9.2 Force 119
- 9.2.1 Internal and External Forces 120
- 9.3 Bending 120
- 9.3.1 Deflection 122
- 9.4 Types of Loading 123
- 9.4.1 Dead Load 123
- 9.4.2 Imposed Load 123
- 9.4.3 Wind Load 123
- 9.4.4 Loading from other Effects 123
- 9.4.5 Point Load 123
- 9.4.6 Uniformly Distributed Load 125
- 9.4.7 Triangular Load 125
- 9.5 Stress and Strain 126
- 9.5.1 Stress 127
- 9.5.2 Strain 127
- 9.6 Elasticity 128
- 9.6.1 Experiment 1: Proof of Hooke's Law 128
- 9.6.2 Experiment 2: Proof of Hooke's Law 129
- 9.6.3 Factor of Safety 131
- Exercise 9.1 132
- References/Further Reading 133

10 Forces and Structures 2 135

- 10.1 Moment of a Force 135
- 10.1.1 Sign Convention 136
- 10.2 Laws of Equilibrium 139
- 10.3 Analysis of Beams 139
- 10.3.1 Beam Reactions 139
- 10.3.2 Shear Force (S.F.) 144
- 10.3.3 Bending Moment (B.M.) 149
- 10.4 Triangle of Forces 156
- 10.4.1 Bow's Notation 159
- 10.4.2 Frames and Roof Trusses 161
- Exercise 10.1 166
- References/Further Reading 169

11 Forces and Structures 3 171

- 11.1 Introduction 171
- 11.2 Beams 171
- 11.2.1 Tension and Compression in Beams 171

11.2.2	Shear	172
11.2.3	Deflection	173
11.2.4	Lateral Buckling	174
11.3	Reinforced Concrete (R.C.) Beams	175
11.3.1	Shear Reinforcement	175
11.4	Steel Beams	177
11.4.1	Bending	177
11.4.2	Plastic Hinge	178
11.4.3	Shear	178
11.5	Timber Joists	179
11.5.1	Failures in Timber Joists	180
11.5.2	Lateral Buckling	181
11.6	Slabs	182
11.7	Columns	183
11.7.1	Slenderness Ratio	183
11.7.2	Effective Height of Columns	184
11.7.3	Eccentric Loading on Columns	186
11.7.4	Steel Columns	187
11.7.5	Reinforced Concrete Columns	188
11.8	Foundations	188
11.8.1	Strip Foundation	189
11.8.2	Pad Foundation	190
11.8.3	Other Foundations	191
	References/Further Reading	192

12 Fluid Mechanics 193

12.1	Introduction	193
12.2	Pressure of Fluids at Rest	193
12.3	Why do Liquids Flow?	196
12.4	Centre of Pressure	197
12.5	The Flow of a Fluid	199
12.5.1	Flow Rate	200
12.5.2	Bernoulli's Theorem	201
12.5.3	The Venturimeter	204
12.5.4	Flow in Pipes: Energy Loss	205
12.5.5	Flow in Open Channels	206
	Exercise 12.1	208
	References/Further Reading	210

13 Sound 211

13.1	Introduction	211
13.2	Frequency, Wavelength and Velocity of Sound	212
13.2.1	Frequency (f)	212
13.2.2	Wavelength (λ)	212
13.2.3	Velocity (v)	212
13.3	Measurement of Sound	214
13.3.1	Threshold Values of Sound	215
13.3.2	The Decibel Scale	215

13.4	Addition of Sound Levels	217
13.4.1	Approximate Addition of Sound Levels	217
13.5	Transmission of Sound in Buildings	219
13.5.1	Noise	220
13.5.2	Requirements of Sound Insulation	220
13.5.3	Sound-Insulation Techniques	221
13.5.4	Noise in a Workplace	224
13.5.5	Measurement of Sound Insulation	224
13.6	Sound Absorption	225
13.6.1	Reverberation	227
13.6.2	Reverberation Time	227
13.6.3	Types of Sound Absorbers	231
13.7	Sound-level Meter	232
	Exercise 13.1	232
	References/Further Reading	233

14	Light	235
14.1	Introduction	235
14.2	Additive and Subtractive Colours	236
14.3	Measuring Light	237
14.3.1	Angular Measure	237
14.3.2	Solid Angle	237
14.3.3	Luminous Intensity (I)	238
14.3.4	Luminous Flux (F)	238
14.3.5	Illuminance (E)	239
14.3.6	Luminance	239
14.4	Inverse Square Law of Illuminance	240
14.5	Lambert's Cosine Law of Illuminance	241
14.6	Lamps and Luminaires	243
14.7	Design of Interior Lighting	245
14.7.1	Light Output Ratio	246
14.7.2	Direct Ratio	246
14.7.3	Room Index	247
14.7.4	Reflection of Light	247
14.7.5	Level of Illuminance	247
14.7.6	Utilisation Factor (UF)	249
14.7.7	Maintenance Factor (MF)	249
14.7.8	Lumen Design Method	252
14.7.9	SHR	253
14.8	Light Meter	258
14.9	Daylighting	258
14.9.1	Uniform Sky	258
14.9.2	CIE Standard Overcast Sky	258
14.9.3	Daylight Factor	259
	Exercise 14.1	261
	References/Further Reading	263

15	Human Comfort	265
15.1	Introduction	265
15.2	Temperature	265
15.2.1	Air Temperature	266
15.2.2	Mean Radiant Temperature	267
15.2.3	Environmental Temperature	267
15.2.4	Dry Resultant Temperature	267
15.2.5	Activity	268
15.2.6	Clothing	268
15.3	Air Movement	268
15.4	Humidity	269
15.5	Ventilation	269
15.6	Predicted Mean Vote	269
15.7	Noise	270
15.8	Lighting	271
	References/Further Reading	272
16	Construction Materials	273
16.1	Introduction	273
16.2	Bricks	274
16.2.1	Clay Bricks	274
16.2.2	Size	274
16.2.3	Classification	275
16.2.4	Manufacture	275
16.2.5	Properties	275
16.2.6	Deterioration of Brickwork	277
16.2.7	Environmental Implications	278
16.2.8	COSHH	278
16.3	Aerated Concrete Blocks	279
16.3.1	Manufacture	279
16.3.2	Size	279
16.3.3	Properties	279
16.3.4	Environmental Implications	280
16.4	Cement	280
16.4.1	Raw Materials	281
16.4.2	Manufacture	281
16.4.3	Setting and Hardening of Cement	282
16.4.4	Constituents of Portland Cement	282
16.4.5	Types of Cement	282
16.4.6	Compressive Strength	283
16.4.7	Environmental Implications	284
16.4.8	COSHH	284
16.5	Concrete	284
16.5.1	Raw Materials	285
16.5.2	Manufacture of Concrete	285
16.5.3	Concrete Mix	285

16.5.4	Properties of Fresh Concrete	287	
16.5.5	Properties of Hardened Concrete	289	
16.5.6	Deterioration of Concrete	290	
16.5.7	Environmental Implications	291	
16.6	Metals	291	
16.6.1	Ferrous Metals	291	
16.6.2	Non-Ferrous Metal: Aluminium	295	
16.7	Timber	296	
16.7.1	Seasoning	297	
16.7.2	Properties	298	
16.7.3	Deterioration	299	
16.7.4	Preservation	300	
16.7.5	Environmental Implications	300	
16.8	Plastics	300	
16.8.1	Raw Materials and Manufacture	301	
16.8.2	Classification	301	
16.8.3	Properties and Uses	302	
16.9	Glass	303	
16.9.1	Properties	303	
16.9.2	Types of Glass	305	
	References/Further Reading	306	
17	Assignments	307	
17.1	Assignments for Level 2 Courses	307	
17.1.1	Assignment No. 1	307	
17.1.2	Assignment No. 2	307	
17.1.3	Assignment No. 3	307	
17.2	Assignments for Level 3/4 Courses	308	
17.2.1	Assignment No. 1	308	
17.2.2	Assignment No. 2	309	
17.2.3	Assignment No. 3	310	
	Appendix 1	Formulae for Example 8.2	313
	Appendix 2	Solutions for Example 13.10	315
	Appendix 3	Answers to Exercises	317
	Index		325

CONSTRUCTION SCIENCE AND MATERIALS

SECOND EDITION

Construction Science and Materials is a core unit on all programmes offered by Pearson in the fields of construction, civil engineering and building services. It is also a core unit on City and Guilds' level 3 Construction Techbac. The unit deals with a range of topics on construction science, structural mechanics and constructional materials; this new edition of *Construction Science and Materials* covers these topic areas and provides detailed information in a user-friendly format.

The initial chapters of the book are devoted to some key concepts in physics, chemistry, construction technology and building services to provide underpinning knowledge for more complex topics. The topics are arranged into 17 chapters, each with written explanations supplemented by well-annotated diagrams and relevant solved examples. Students can check their learning by solving questions from the end-of-chapter exercises and reviewing answers at the end of the book and on the book's website. The book also includes extracts from British Standards, Building Regulations and construction companies' trade literature to provide information on recent developments in science, structures and building materials.

Students will find in this book all the information, explanations, exercises and assignments to empower them with the knowledge and skills to complete the relevant unit – BTEC Construction Science and Mathematics (Level 2) as well as Construction Science and Materials (Levels 3/4/5).

About the Author

SURINDER SINGH VIRDI is a lecturer in construction at South and City College Birmingham and visiting lecturer at City of Wolverhampton College. He worked as a civil and structural engineer for a number of years before starting his career in further and higher education. He has been teaching construction science, environmental science, mathematics, ICT and CAD on BTEC National and Higher National courses for over 25 years.

Other books of interest

Energy Audits: A Workbook for Energy Management in Buildings
Tarik Al-Shemmeri
Paperback ISBN 978-0-470-65608-2

Building Science: Concepts and Application
Jens Pohl
Paperback ISBN 978-0-470-65573-3



The book's companion website is at www.wiley.com/go/virdiconstructionscience2e you will find here valuable material designed to enhance your learning, including:

- Fully worked solutions to the exercises at the ends of chapters
- Model answers for the assignment tasks set in Chapter 17
- Explanations of settlement and consolidation in structures; details on the design of building foundations and daylight calculations
- A task + solution on the design of timber joists
- PowerPoint slides for lecturers on: Hooke's Law; Forces and their Effects; Temperature and Heat Loss



www.wiley.com/go/construction

WILEY Blackwell



Also available
as an e-book

ISBN 978-1-119-24505-6



9 781119 245056