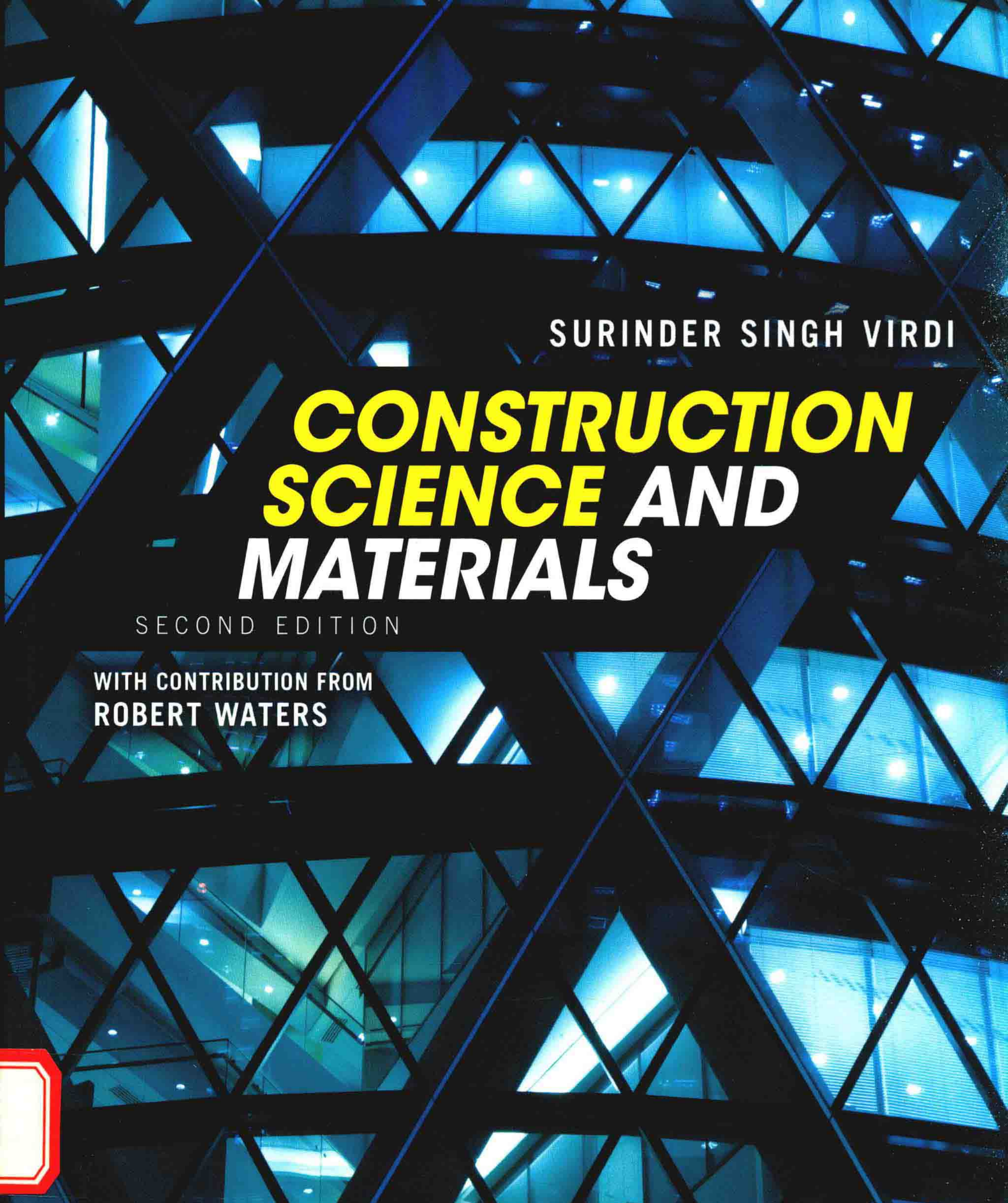

SURINDER SINGH VIRDI

CONSTRUCTION SCIENCE AND MATERIALS

SECOND EDITION

WITH CONTRIBUTION FROM
ROBERT WATERS

with website

WILEY Blackwell

Construction Science and Materials

Second Edition

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This edition first published 2017

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.

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Library of Congress Cataloging-in-Publication data applied for

ISBN: **9781119245056**

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

How to Use This Book

All students should spend some time studying the first seven chapters.

Students pursuing Level 2 courses should focus additionally on Chapters 9, 10 and 16.

Students pursuing Level 3/4/5 courses should study all chapters in this book.

Specimen assignment tasks are given in Chapter 17, which the students can try once they have studied the relevant topics. The model answers are given on the companion website http://www.wiley.com/go/virdiconstructionscience2e.

The website also includes solutions for the end-of-chapter exercises, information on the use of a scientific calculator, information on units, information on settlement and consolidation, the design of building foundations, the design of timber joists, daylight calculations and PowerPoint presentations on some topics.

Preface to the Second Edition

This book has been written for students pursuing full-time/part-time studies in level 2, 3, 4 and 5 programmes in Construction, Civil Engineering and Building Services. The book should also be informative for students on level 2/3 construction craft courses. The topics included cover most of the syllabus of the core subject of Construction Science and Materials. The syllabi cover a wide range of topics, and since Construction Materials is a subject on its own, the discussion in this book is focussed on a selection of nine materials that are used widely in building and civil engineering projects. Structural Mechanics is complex and is also a subject on its own; I have tried to include information on some of the basic concepts that students need to learn to achieve the relevant grading criteria.

The learning material has been divided among the first sixteen chapters, which provide information on construction science, construction materials and structural mechanics for the above courses. Two chapters from the first edition have been moved to the companion website, and two new chapters – Chapter 6 (Introduction to building services) and Chapter 11 (Forces and structures 3) – have been included in the second edition. Each chapter gives detailed explanations of the topics involved, and the text in the second edition is supported by a large number of illustrations and worked examples. To reinforce students' learning, almost all chapters have end-of-chapter exercises, and if a student has difficulty in obtaining the right answer, help is at hand in the form of solutions available on the companion website.

My thanks are due to my family, my students and colleagues for the interest they have shown in this project, and a special thank you to Robert Waters for his contribution towards the development of new material for this edition.

A big thank you to: Madeleine Metcalfe, Viktoria Vida (Editorial Assistant), Blesy Regulas (Project Editor) and Rajitha Selvarajan (Production Editor) for their support during the publication of this book.

Surinder Singh Virdi

About the Companion Website

Don't forget to visit the companion website for this book:

http://www.wiley.com/go/virdiconstructionscience2e

There you will find valuable material designed to enhance your learning, including:

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

Scan this QR code to visit the companion website:

Contents

1

Introduction to Physics

LEARNING OUTCOMES

1) Define speed, velocity and acceleration.
2) Explain mass, gravitation and weight.
3) Explain Newton's laws of motion and solve numerical problems based on these laws.
4) Explain work, energy and power, and solve numerical problems.

1.1 Speed and Velocity

In the study of moving objects, one of the important things to know is the rate of motion. The rate of motion of a moving object is what we call **speed**. It may be defined as the distance covered in a given time:

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Time taken}}$$

If the distance covered is in metres (m) and the time taken in seconds (s), then speed is measured in metres per second (m/s). If the distance is in kilometres (km) and the time in hours (h), the unit of speed is kilometres per hour (km/h).

When the direction of movement is combined with the speed, we have the **velocity** of motion. Quantities that have both magnitude and direction are known as **vector** quantities. Velocity is a vector quantity; its magnitude and direction can be represented by an arrow. Speed, on the other hand, has magnitude but no direction; therefore it is called a **scalar** quantity.

1.2 Acceleration

An object is said to accelerate if its velocity increases. The rate of increase of velocity is called the **acceleration**.

$$\text{Acceleration} = \frac{\text{Increase in velocity}}{\text{Time taken}}$$

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Companion website: www.wiley.com/go/virdiconstructionscience2e

If velocity is measured in metres and time in seconds, then acceleration is measured in metres per second per second (m/s/s) or metres per second squared (m/s^2). If the velocity of a moving object decreases, it is said to decelerate, i.e. the acceleration is negative. The following relationships may be used to solve problems involving velocity and acceleration:

- $v^2 - u^2 = 2as$
- $v = u + at$
- $v = ut + \frac{1}{2}at^2$

where, u = initial velocity
v = final velocity
a = acceleration
t = time
s = distance

1.3 Mass

The amount of matter contained in an object is known as its **mass**. The basic SI unit of mass is the kilogram (kg).

$$1 \text{ gram}(g) = 1000 \text{ milligrams}(mg)$$
$$1000 \text{ grams} = 1 \text{ kilogram}$$
$$1000 \text{ kilograms} = 1 \text{ tonne}(t)$$

The mass of an object remains constant irrespective of wherever it is.

1.4 Gravitation

Gravitation can be defined as the force of attraction that exists between all objects in the universe. According to Isaac Newton, every object in the universe attracts every other object with a force directed along the line of centres for the two objects that is proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$$F_g = \frac{G\, m_1\, m_2}{r^2}$$

where F_g = gravitational force between two objects
m_1 = mass of first object
m_2 = mass of second object
r = distance between the centres of the two objects
G = universal constant of gravitation

The value of constant G is so small that the force of attraction between any two objects is negligible. In 1798, Henry Cavendish performed experiments to determine the value of G and found it to be $6.67 \times 10^{-11}\ Nm^2/kg^2$.

If we consider an object and the Earth, the mass of Earth is so large (5.98×10^{24} kg) that, depending on the mass of the object, there could be a considerable force of attraction between the two. That is why when an object is dropped from a height, it falls towards the Earth, not away from it. The initial velocity of the object is zero m/s, but as the distance increases, the velocity of the falling object also increases. The rate of increase in velocity is called acceleration and, in the case of a free-falling object, it is known as the **acceleration due to gravity** (symbol: g).

The value of g is 9.807 m/s^2, but for all calculations in this book it will be approximated to 9.81 m/s^2 (m/s^2 can also be written as ms^{-2}).

Example 1.1 Find the gravitational force between the Earth and:

a) An object with a mass of 1 kg.
b) A person with a mass of 80 kg.

Given: mass of the Earth = 6.0×10^{24} kg; radius of the Earth = 6.4×10^6 m; $G = 6.7 \times 10^{-11}$ Nm^2/kg^2

Solution:

a)

$$F_g = \frac{G\, m_1\, m_2}{r^2} = \frac{6.7 \times 10^{-11} \times 6 \times 10^{24} \times 1}{\left(6.4 \times 10^6\right)^2} = 9.81\ N$$

b)

$$F_g = \frac{G\, m_1\, m_2}{r^2} = \frac{6.7 \times 10^{-11} \times 6 \times 10^{24} \times 80}{\left(6.4 \times 10^6\right)^2} = 785.16\ N$$

1.5 Weight

The **weight** of an object is the force with which it is attracted towards Earth. When an object falls freely towards Earth, the average value of the acceleration produced (g) is 9.81 m/s^2. The force (F) acting on the object due to Earth's gravitational pull (or the weight of the object) can be calculated as:

$$F = m \times g$$

where m is the mass of the object in kg.

The units of weight are the same as the units of force. If the mass is in kilograms, the unit of weight will be newtons (N).

The weight of a 1 kg mass will be:

$$F = 1 \times 9.81 = 9.81\ N$$