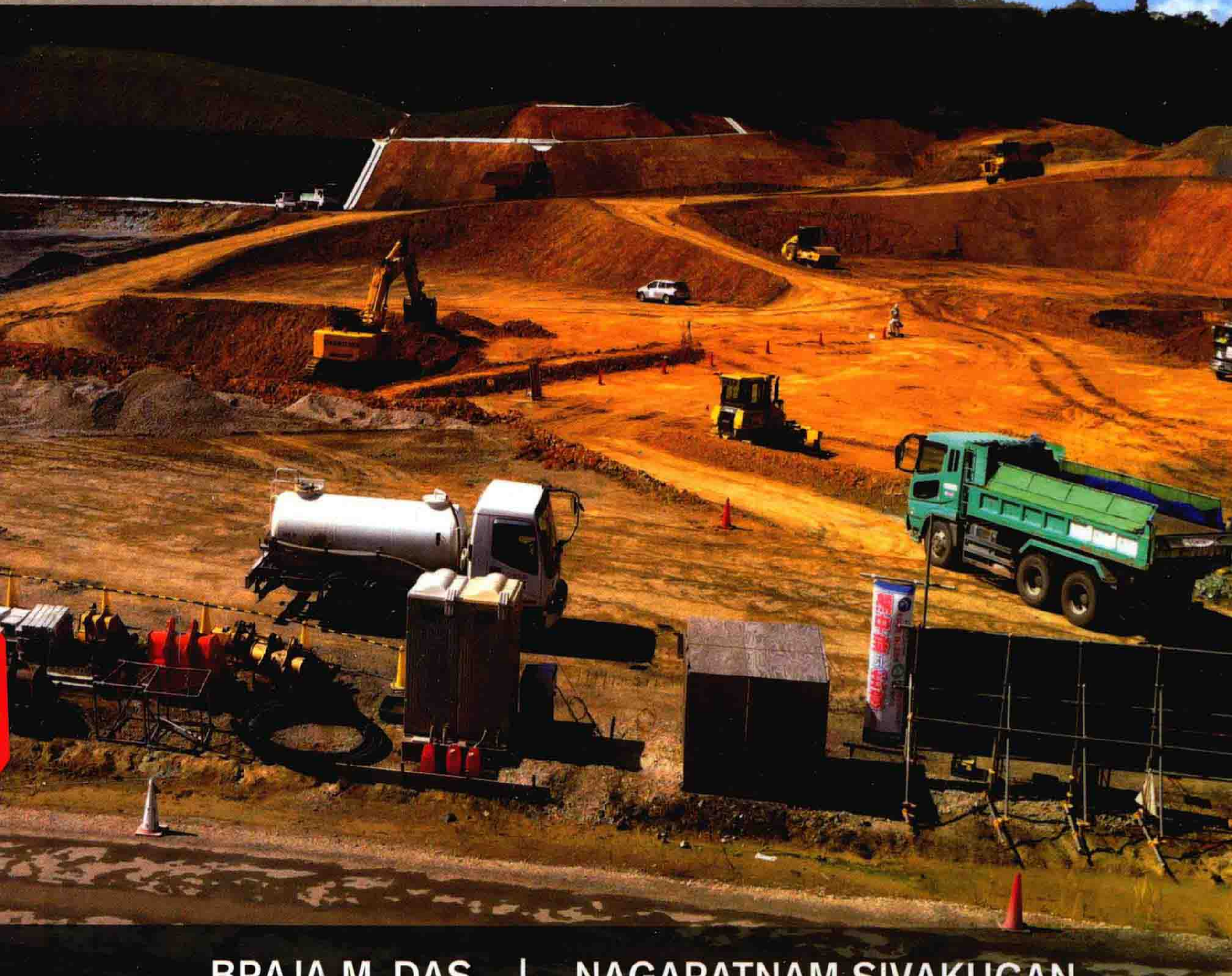
FIFTH EDITION

FUNDAMENTALS OF GEOTECHNICAL ENGINEERING



BRAJA M. DAS | NAGARATNAM SIVAKUGAN

Fundamentals of Geotechnical Engineering

Fifth Edition

Braja M. Das
Dean Emeritus, California State University
Sacramento, California, USA

Nagaratnam Sivakugan
Associate Professor, College of Science, Technology & Engineering
James Cook University, Queensland, Australia

CENGAGE Learning®

Australia • Brazil • Mexico • Singapore • United Kingdom • United States

CENGAGE
Learning®

Fundamentals of Geotechnical Engineering, Fifth Edition
Braja M. Das and Nagaratnam Sivakugan

Product Director, Global Engineering: Timothy L. Anderson

Senior Content Developer: Mona Zeftel

Media Assistant: Ashley Kaupert

Product Assistant: Alexander Sham

Marketing Manager: Kristin Stine

Director, Content and Media Production: Sharon L. Smith

Senior Content Project Manager: Kim Kusnerak

Production Service: RPK Editorial Services, Inc.

Copyeditor: Harlan James

Proofreader: Martha McMaster

Indexer: Braja Das

Compositor: MPS Limited

Senior Art Director: Michelle Kunkler

Internal Designer: Carmela Pereira

Cover Designer: Tin Box Studios

Cover Image: Rohini Sivakugan

Intellectual Property
  Analyst: Christine Myaskovsky
  Project Manager: Sarah Shainwald

Text and Image Permissions Researcher: Kristiina Paul

Senior Manufacturing Planner: Doug Wilke

© 2017, 2013 Cengage Learning®

WCN: 01-100-101

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced, transmitted, stored, or used in any form or by any means graphic, electronic, or mechanical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the publisher.

For product information and technology assistance, contact us at
Cengage Learning Customer & Sales Support, 1-800-354-9706
For permission to use material from this text or product,
submit all requests online at **www.cengage.com/permissions**
Further permissions questions can be emailed to
permissionrequest@cengage.com

Library of Congress Control Number: 2015937334

ISBN-13: 978-1-305-63518-0

Cengage Learning
20 Channel Center Street
Boston, MA 02210
USA

Cengage Learning is a leading provider of customized learning solutions with employees residing in nearly 40 different countries and sales in more than 125 countries around the world. Find your local representative at **www.cengage.com**

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

To learn more about Cengage Learning Solutions, visit **www.cengage.com/engineering.**

Purchase any of our products at your local college store or at our preferred online store **www.cengagebrain.com**

Unless otherwise noted, all items © Cengage Learning.

The cover photograph by Rohini Sivakugan is of the Shin-Meishin Expressway construction near Kyoto, Japan. This section connects Kobe and Takatsuki. The construction site is closer to Takatsuki.

Printed in the United States of America
Print Number: 01 Print Year: 2015

To Janice, Rohini, Joe,
Valerie and Elizabeth

Preface

Principles of Foundation Engineering and *Principles of Geotechnical Engineering* were originally published with 1984 and 1985 copyrights, respectively. These texts were well received by instructors, students, and practitioners alike. Depending on the needs of the users, the texts were revised and are presently in their eighth editions. These texts have also been translated in several languages.

Toward the latter part of 1998, there were several requests to prepare a single volume that was concise in nature but combined the essential components of *Principles of Foundation Engineering* and *Principles of Geotechnical Engineering*. In response to those requests, the first edition of *Fundamentals of Geotechnical Engineering* was published in 2000. This text includes the fundamental concepts of soil mechanics as well as foundation engineering, including bearing capacity and settlement of shallow foundations (spread footings and mats), retaining walls, braced cuts, piles, and drilled shafts.

New to This Edition

This fifth edition has been revised and prepared based on comments received from several reviewers and users without changing the philosophy on which the text was originally prepared. Professor Nagaratnam Sivakugan of James Cook University, Australia, has joined as a co-author of this edition. As in the previous editions, SI units are used throughout the text. This edition consists of 20 chapters and an appendix. The major changes from the fourth edition include the following:

- About forty additional photographs have been added.
- A number of additional example problems and homework problems have been added in each chapter.
- Each chapter has some critical thinking problem(s) added to the homework problem set.

此为试读，需要完整PDF请访问：www.ertongbook.com

- An interactive digital version of this text is now available. Please see the MindTap description on page xix.
- In Chapter 2 on "Soil Deposits—Origin, Grain-Size, and Shape" a discussion has been added for the U.S. sieve size designations. Details for the British standard sieves and the Australian standard sieves have also been added.
- In Chapter 3 on "Weight-Volume Relationships and Plasticity," a table for various unit-weight relationships has been added.
- Chapter 4 on "Soil Classification" has a new section on visual identification of soils.
- In Chapter 5 on "Soil Compaction," some recently published correlations for maximum dry unit weight and optimum moisture content has been added. Also added in this chapter is a brief description on various ground improvement methods.
- Chapter 9 on "Consolidation" now has a new section on the effects of initial excess pore water pressure distribution on U–T_v relationships. Also added to this chapter is a discussion on the construction time correction of consolidation settlement.
- A number of recently published correlations for effective stress friction angle (ϕ') and cohesion (c') for cohesive soils has been added to Chapter 10 on "Shear Strength of Soils." Also included in this chapter are several correlations for the undrained shear strength of remolded clays with liquidity index.
- Chapter 12 on "Subsurface Exploration" now has a section on field instrumentation.
- In Chapter 13 on "Slope Stability," an analysis to evaluate the factor of safety of clay slopes with the undrained cohesion increasing with depth has been added. This chapter now also has a discussion on the mass procedure for stability analysis of homogeneous clay slopes ($\phi = 0$) with earthquake forces.
- Chapter 15 has been renamed as "Retaining Walls, Braced Cuts, and Sheet Pile Walls." Analyses of cantilever sheet pile walls and anchored sheet pile walls have been added to this chapter.
- The bearing capacity of strip foundation under eccentrically inclined load has been discussed in greater detail in Chapter 16 on "Shallow Foundations—Bearing Capacity."
- An improved method for elastic settlement calculation of shallow foundations on granular soil taking into consideration the variation of soil stiffness with stress level has been added to Chapter 17 on "Settlement of Shallow Foundations."
- A new chapter (Chapter 20) on "Load and Resistance Factor Design (LRFD)" has been added to the text.

Instructor Resource Materials

A detailed *Instructor's Solutions Manual* and Lecture Note PowerPoint slides are available for instructors through a password-protected Web site at www.cengagebrain.com.

MindTap Online Course and Reader

This textbook is also available online through Cengage Learning's MindTap, a personalized learning program. Students who purchase the MindTap have access to the book's multimedia-rich electronic Reader and are able to complete homework and assessment material online, on their desktops, laptops, or iPads. Instructors who use a Learning Management System (such as Blackboard, Canvas, or Moodle) for tracking course content, assignments, and grading, can seamlessly access the MindTap suite of content and assessments for this course.

With MindTap, instructors can:

- Personalize the Learning Path to match their course syllabus by rearranging content or appending original material to the online content
- Connect a Learning Management System portal to the online course and Reader
- Customize online assessments and assignments
- Track student engagement, progress and comprehension
- Promote student success through interactivity, and exercises

Additionally, students can listen to the text through ReadSpeaker, take notes in the digital Reader, study from or create their own Flashcards, highlight content for easy reference, and check their understanding of the material through practice quizzes and automatically-graded homework. The MindTap for *Fundamentals of Geotechnical Engineering* also includes algorithmically generated problems, providing an endless pool for student practice and assessment.

Acknowledgments

Thanks are due to:

The following reviewers for their comments and constructive suggestions:

- Alierza Bayat, University of Alberta
- Raymond Haddad, California State University, Northridge
- Anne Lemnitzer, University of California, Irvine
- Matthew Sleep, Oregon Institute of Technology
- Kamal Tawfiq, Florida A&M University
- Alexandria Wayllace, Colorado School of Mines
- Attila Michael Zsaki, Concordia University, Canada

Several individuals in Cengage Learning, for their assistance and advice in the final development of the text—namely:

- Tim Anderson, Product Director
- Mona Zeftel, Senior Content Developer

Thanks are also due to Janice Das for her continuous help in the development of the original text and its subsequent four editions.

It is also fitting to thank Rose P. Kernan of RPK Editorial Services. She has been instrumental in shaping the style and overseeing the production of this edition of *Fundamentals of Geotechnical Engineering* as well as all previous editions.

Braja M. Das
Henderson, Nevada, USA

Nagaratnam Sivakugan
Townsville, Queensland, Australia

Contents

5 SOIL COMPACTION 104

6 HYDRAULIC CONDUCTIVITY 135

7 SEEPAGE 163

此为试读，需要完整PDF请访问：www.ertongbook.com

8 STRESSES IN A SOIL MASS 179

9 CONSOLIDATION 211

10 SHEAR STRENGTH OF SOIL 268

11 GROUND IMPROVEMENT 312

12 SUBSURFACE EXPLORATION 336

16 SHALLOW FOUNDATIONS—BEARING CAPACITY 568

17 SETTLEMENT OF SHALLOW FOUNDATIONS 612

18 PILE FOUNDATIONS 643

19 DRILLED SHAFT 712

20 LOAD AND RESISTANCE FACTOR DESIGN (LRFD) 741

此为试读，需要完整PDF请访问：www.ertongbook.com