SI EDITION

PRINCIPLES OF GEOTECHNICAL ENGINEERING

BRAJA M. DAS • KHALED SOBHAN

Principles of Geotechnical Engineering

Eighth Edition, SI

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Preface

Principles of Geotechnical Engineering was originally published with a 1985 copyright and was intended for use as a text for the introductory course in geotechnical engineering taken by practically all civil engineering students, as well as for use as a reference book for practicing engineers. The book was revised in 1990, 1994, 1998, 2002, 2006, and 2010. This eighth edition has a coauthor, Khaled Sobhan, of Florida Atlantic University. As in the previous editions of the book, this new edition offers an overview of soil properties and mechanics, together with coverage of field practices and basic engineering procedures, without changing the basic philosophy of the original text. It is not the intent of this book to conform to any design codes.

Unlike the seventh edition, which had 18 chapters, this edition has 17 chapters. The chapter on Landfill Liners and Geosynthetics has been deleted from this edition since the subject has grown and matured over the years and is offered as a separate course in many civil engineering programs.

Most of the example problems and homework problems have been changed and/or modified. One or two critical thinking problems have been added to the homework problems in most chapters to challenge and enhance the thought process and understanding of students on the subject(s) covered in a given chapter.

Since geotechnical engineering is a practical and application-oriented subject, a few actual case histories have also been included. These case histories are presented in Chapters 11, 15, and 16 with the primary intention being to familiarize students with the unpredictable variability of soil in the field compared to the idealized situation in classroom teaching and learning. New photographs have also been added throughout.

Other noteworthy changes in the eighth edition include the following:

- An expanded section of the introduction at the beginning and a summary section at the end of each chapter have been provided.
- In Chapter 2, on Origin of Soil and Grain Size, several photographs of common rock-forming minerals, rocks, and structures built with or in rock have been added (Section 2.3). To help students in future field identification of rocks and rock-forming minerals, they are presented in color as well as in black and white.

- In Chapter 3, on Weight–Volume Relationships, the section on maximum and minimum void ratio of granular soil has been expanded.
- The procedure for determination of shrinkage limit of cohesive soils using the wax method (ASTM Test Designation 4943) has been described in detail in Chapter 4 (Plasticity and Structure of Soil).
- In Chapter 5, on Classification of Soil, line diagrams have been added in example problems to determine the *group names of soils* from *group symbols* (Unified Soil Classification System). These line diagrams will help the readers follow a step-by-step procedure in arriving at the proper group name of soil during soil classification.
- The chapter on Soil Compaction (Chapter 6) now includes several recent empirical correlations to estimate maximum dry unit weight and optimum moisture content based on the energy of compaction. A section on evaluation of soils as compaction material has been added.
- In Chapter 9, on *In Situ* Stresses, a mathematical derivation for a general case to obtain the seepage force per unit volume of soil is added. Also in this chapter, Harza's chart to obtain the exit gradient of flow under a hydraulic structure is provided. This chart is helpful in estimating the factor of safety against heaving. An example to show the use of a filter on the downstream side of a hydraulic structure to increase the factor of safety against heaving is given.
- A section on the vertical stress increase at a certain point and depth below the ground surface due to a linearly increasing vertical loading on a infinite strip has been added in Chapter 10, on Stresses in a Soil Mass.
- An improved explanation of the fundamentals of consolidation is given in Chapter 11, on Compressibility of Soil. This chapter also provides a general discussion on the effect of load duration on the $e - \log \sigma'$ plot.
- Chapter 12, on Shear Strength of Soils, updates the calculation procedure of undrained cohesion for tests conducted with a tapered vane based on ASTM (2010).
- The procedure for estimation of active earth pressure in a $c' - \phi'$ soil under earthquake conditions has been updated in Chapter 13 (Lateral Earth Pressure: At-Rest, Rankine, and Coulomb).
- The Caquot and Kerisel theory for estimation of passive earth pressure with granular backfill (inclined back face of wall and horizontal backfill, and vertical back face of wall and inclined backfill) has now been included in Chapter 14, on Lateral Earth Pressure: Curved Failure Surface.
- In Chapter 15, on Slope Stability, a detailed derivation on the factor of safety of infinite slopes with seepage is now included. Results of some recent studies on the critical circles of failure for slopes in clay ($\phi = 0$ condition) and $c' - \phi'$ soil is added in this chapter.
- A generalized case for Rankine active and passive pressure with granular backfill is provided in Appendix A.

In the preparation of an engineering text of this type, it is tempting to include many recent developments relating to the behavior of natural soil deposits found in various parts of the world that are available in journals and conference proceedings with the hope that they will prove to be useful to the students in their future practice. However, based on many years of teaching, the authors feel that clarity in explaining the fundamentals of soil mechanics is more important in a first course in this area without cluttering the book with too many details and alternatives. Many of the intricate details can be left to an advanced course in the area of geotechnical engineering. This approach

will most likely help in developing students' interest and appreciation in the geotechnical engineering profession at large.

Instructor Resource Materials

A detailed *Instructor's Solutions Manual* and PowerPoint slides of both figures and tables and equations and examples from the book are available for instructors through a password-protected Web site at www.cengagebrain.com.

Student Resource Materials

Self-Evaluation Multiple Choice Questions with Answers for each chapter are available for students on the book Web site. The students may also benefit from these questions as a practice tool in preparation for examinations.

To access additional course materials, please visit www.cengagebrain.com. At the cengagebrain.com home page, search for the ISBN of your title (from the back cover of your book) using the search box at the top of the page. This will take you to the product page where these resources can be found. If you require a password, follow directions for Instructor Resources.

The authors would not have been able to complete this revised manuscript without the support and encouragement of their wives, Janice and Samira, and their families. Janice Das was most helpful in getting the manuscript ready for publication. Professor Sanjay K. Shukla of Edith Cowan University, Australia, provided many valuable suggestions during the revision process. Finally, many thanks are due to Christopher Shortt, Publisher; Hilda Gowans, Senior Development Editor; and Lauren Betsos, Marketing Manager of Cengage Learning (Engineering) for their assistance and advice in the final development of the book. It is fitting also 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 *Principles of Geotechnical Engineering* as well as several previous editions.

Thanks are due to the following reviewers for their comments and constructive suggestions:

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Professor Braja Das is Dean Emeritus of the College of Engineering and Computer Science at California State University, Sacramento. He received his M.S. in Civil Engineering from the University of Iowa and his Ph.D. in the area of Geotechnical Engineering from the University of Wisconsin. He is the author of several geotechnical engineering texts and reference books and has authored more than 250 technical papers in the area of geotechnical engineering. His primary areas of research include shallow foundations, earth anchors, and geosynthetics. He is a Fellow and Life Member of the American Society of Civil Engineers, Life Member of the American Society for Engineering Education, and an Emeritus Member of the Chemical and Mechanical Stabilization Committee of the Transportation Research Board of the National Research Council (Washington, D.C.). He has previously served as a member of the editorial board of the *Journal of Geotechnical Engineering* of ASCE, a member of the *Lowland Technology International* journal (Japan), associate editor of the *International Journal of Offshore and Polar Engineering* (ISOPE), and co-editor of the *Journal of Geotechnical and Geological Engineering* (Springer, The Netherlands). Presently he is the editor-in-chief of the *International Journal of Geotechnical Engineering* (J. Ross, Ft. Lauderdale, FL). Dr. Das has received numerous awards for teaching excellence, including the AMOCO Foundation Award, AT&T Award for Teaching Excellence from the American Society for Engineering Education, the Ralph Teetor Award from the Society of Automotive Engineers, and the Distinguished Achievement Award for Teaching Excellence from the University of Texas at El Paso.

Professor Khaled Sobhan is an Associate Professor of Civil Engineering at Florida Atlantic University. He received his M.S. degree from The Johns Hopkins University and his Ph.D. degree from Northwestern University, both in the area of Geotechnical Engineering. His primary research areas include ground improvement, geotechnology of soft soils, experimental soil mechanics, and geotechnical aspects of pavement engineering. He served as the Chair of the Chemical and Mechanical Stabilization Committee (AFS90) of the Transportation Research Board (2005–2011) and coauthored the TRB Circular titled *Evaluation of Chemical Stabilizers: State-of-the-Practice Report* (E-C086). He is currently serving as an Associate Editor of ASCE *Journal of Materials in Civil*

Engineering, and on the editorial board of the ASTM *Geotechnical Testing Journal, Geotechnical and Geological Engineering* (Springer, The Netherlands) and *International Journal of Geotechnical Engineering* (J. Ross, Ft. Lauderdale, FL). He is a recipient of the distinguished Award for Excellence and Innovation in Undergraduate Teaching (2006) and the Excellence in Graduate Mentoring Award (2009) from Florida Atlantic University. He has published more than 75 technical articles and reports in the area of Geotechnical Engineering.

Contents

5 Classification of Soil 123

6 Soil Compaction 146

7 Permeability 198

13 Lateral Earth Pressure: At-Rest, Rankine, and Coulomb 491

14 Lateral Earth Pressure: Curved Failure Surface 550