Braja M. Das
Nagaratnam Sivakugan

Introduction to Geotechnical Engineering

Second Edition

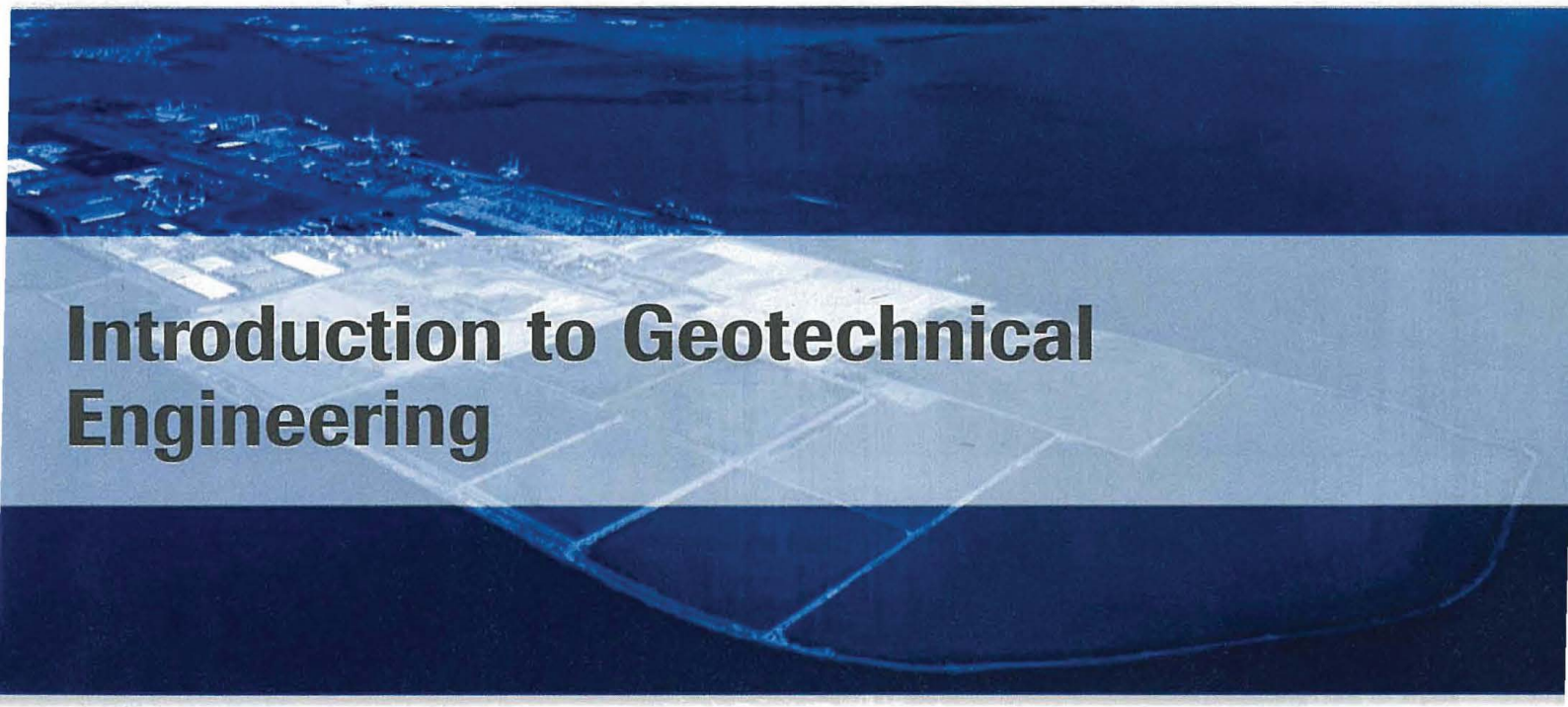
CONVERSION FACTORS FROM SI TO ENGLISH UNITS

Length:	1 m	= 3.281 ft
	1 cm	= 3.281×10^{-2} ft
	1 mm	= 3.281×10^{-3} ft
	1 m	= 39.37 in.
	1 cm	= 0.3937 in.
	1 mm	= 0.03937 in.
Area:	1 m^2	= 10.764 ft^2
	1 cm^2	= 10.764×10^{-4} ft^2
	1 mm^2	= 10.764×10^{-6} ft^2
	1 m^2	= 1550 in^2
	1 cm^2	= 0.155 in^2
	1 mm^2	= 0.155×10^{-2} in^2
Volume:	1 m^3	= 35.32 ft^3
	1 cm^3	= 35.32×10^{-4} ft^3
	1 m^3	= 61,023.4 in^3
	1 cm^3	= 0.061023 in^3
Force:	1 N	= 0.2248 lb
	1 kN	= 224.8 lb
	1 kgf	= 2.2046 lb
	1 kN	= 0.2248 kip
	1 kN	= 0.1124 U.S. ton
	1 metric ton	= 2204.6 lb
	1 N/m	= 0.0685 lb/ft

Stress:	1 N/m^2	= 20.885×10^{-3} lb/ft^2
	1 kN/m^2	= 20.885 lb/ft^2
	1 kN/m^2	= 0.01044 U.S. ton/ft^2
	1 kN/m^2	= 20.885×10^{-3} kip/ft^2
	1 kN/m^2	= 0.145 lb/in^2
Unit weight:	1 kN/m^3	= 6.361 lb/ft^3
	1 kN/m^3	= 0.003682 lb/in^3
Moment:	1 N·m	= 0.7375 lb-ft
	1 N·m	= 8.851 lb-in.
Energy:	1 J	= 0.7375 ft-lb
Moment of inertia:	1 mm^4	= 2.402×10^{-6} in^4
	1 m^4	= 2.402×10^{6} in^4
Section modulus:	1 mm^3	= 6.102×10^{-5} in^3
	1 m^3	= 6.102×10^{4} in^3
Hydraulic conductivity:	1 m/min	= 3.281 ft/min
	1 cm/min	= 0.03281 ft/min
	1 mm/min	= 0.003281 ft/min
	1 m/sec	= 3.281 ft/sec
	1 mm/sec	= 0.03281 ft/sec
	1 m/min	= 39.37 in./min
	1 cm/sec	= 0.3937 in./sec
	1 mm/sec	= 0.03937 in./sec
Coefficient of consolidation:	1 cm^2/sec	= 0.155 in^2/sec
	1 m^2/yr	= 4.915×10^{-5} in^2/sec
	1 cm^2/sec	= 1.0764×10^{-3} ft^2/sec

CONVERSION FACTORS FROM ENGLISH TO SI UNITS

Length:	1 ft	= 0.3048 m
	1 ft	= 30.48 cm
	1 ft	= 304.8 mm
	1 in.	= 0.0254 m
	1 in.	= 2.54 cm
	1 in.	= 25.4 mm
Area:	1 ft^2	= 929.03×10^{-4} m^2
	1 ft^2	= 929.03 cm^2
	1 ft^2	= 929.03×10^2 mm^2
	1 in^2	= 6.452×10^{-4} m^2
	1 in^2	= 6.452 cm^2
	1 in^2	= 645.16 mm^2
Volume:	1 ft^3	= 28.317×10^{-3} m^3
	1 ft^3	= 28.317×10^3 cm^3
	1 in^3	= 16.387×10^{-6} m^3
	1 in^3	= 16.387 cm^3
Force:	1 lb	= 4.448 N
	1 lb	= 4.448×10^{-3} kN
	1 lb	= 0.4536 kgf
	1 kip	= 4.448 kN
	1 U.S. ton	= 8.896 kN
	1 lb	= 0.4536×10^{-3} metric ton
	1 lb/ft	= 14.593 N/m
Stress:	1 lb/ft^2	= 47.88 N/m^2
	1 lb/ft^2	= 0.04788 kN/m^2
	1 U.S. ton/ft^2	= 95.76 kN/m^2
	1 kip/ft^2	= 47.88 kN/m^2
	1 lb/in^2	= 6.895 kN/m^2
Unit weight:	1 lb/ft^3	= 0.1572 kN/m^3
	1 lb/in^3	= 271.43 kN/m^3
Moment:	1 lb-ft	= 1.3558 N·m
	1 lb-in.	= 0.11298 N·m
Energy:	1 ft-lb	= 1.3558 J
Moment of inertia:	1 in^4	= 0.4162×10^6 mm^4
	1 in^4	= 0.4162×10^{-6} m^4
Section modulus:	1 in^3	= 0.16387×10^5 mm^3
	1 in^3	= 0.16387×10^{-4} m^3
Hydraulic conductivity:	1 ft/min	= 0.3048 m/min
	1 ft/min	= 30.48 cm/min
	1 ft/min	= 304.8 mm/min
	1 ft/sec	= 0.3048 m/sec
	1 ft/sec	= 304.8 mm/sec
	1 in./min	= 0.0254 m/min
	1 in./sec	= 2.54 cm/sec
	1 in./sec	= 25.4 mm/sec
Coefficient of consolidation:	1 in^2/sec	= 6.452 cm^2/sec
	1 in^2/sec	= 20.346×10^3 m^2/yr
	1 ft^2/sec	= 929.03 cm^2/sec



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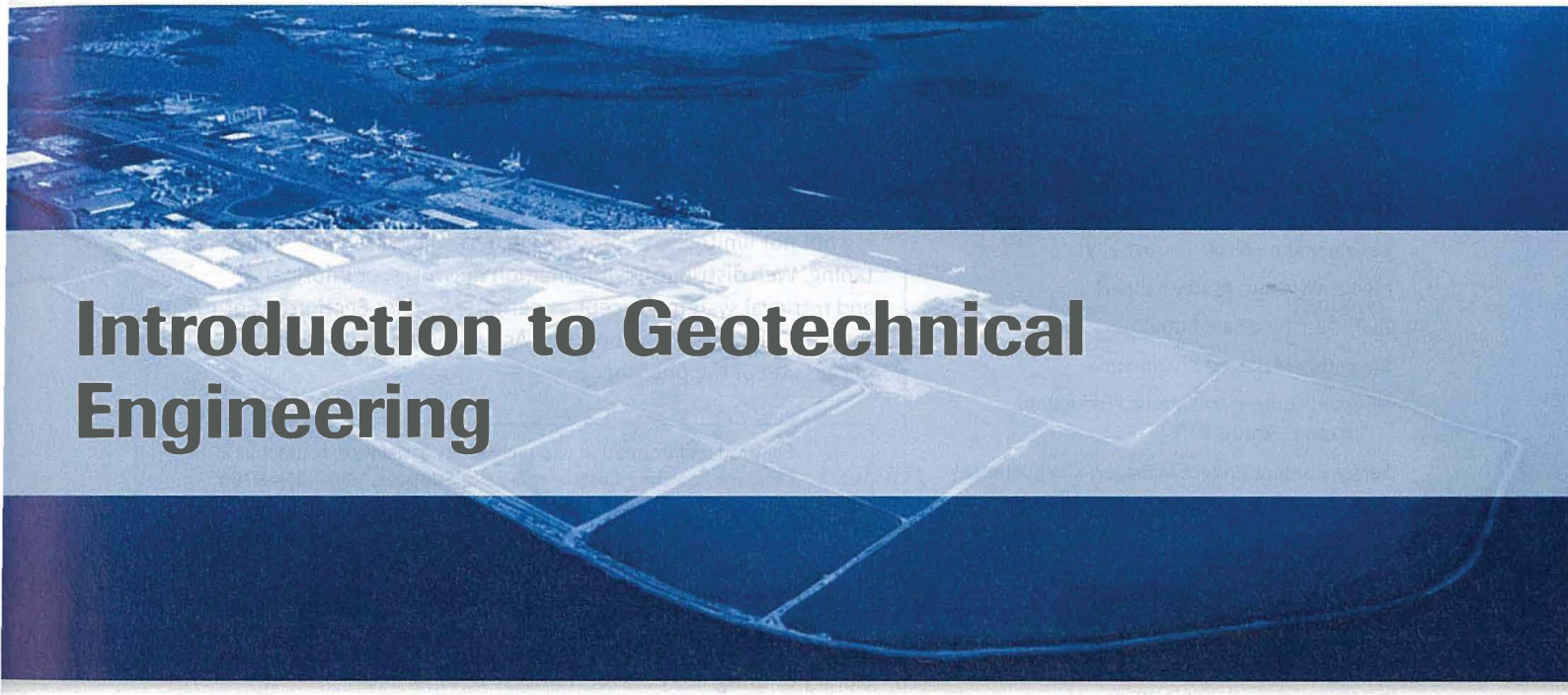

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Second Edition

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To Janice, Rohini, Joe,
Valerie, and Elizabeth

Contents

Preface

During the past half century, geotechnical engineering—soil mechanics and foundation engineering—have developed rapidly. Intensive research and observation in the field and laboratory have refined and improved the science of foundation design. *Introduction to Geotechnical Engineering, Second Edition,* uses those materials, and they are presented in a simple and concise form. This book is designed primarily for classroom instruction in Civil Engineering Technology and Construction Management programs. It is non-calculus based. It will be a useful reference book for civil engineering practitioners. It also can be used as a text for students in Civil Engineering programs where soil mechanics and foundations are combined into one course and covered in one semester. However, some supplemental material may be necessary.

The first edition of this text was published in 2008. The majority of the materials in the first edition of the text were drawn from *Principles of Foundation Engineering* and *Principles of Geotechnical Engineering*, which were originally published with 1984 and 1985 copyrights, respectively. These books are now in their eighth editions.

The present edition of the text has added a co-author—Dr. Nagaratnam Sivakugan, Associate Professor and Head of Civil Engineering at James Cook University, Townsville, Australia. In this edition, the following changes and additions have been incorporated.

- Since several users of the first edition preferred SI units, dual units (English and SI) have been used in the text.
- Several additional examples and homework problems have been added. These problems are approximately 50/50 in English and SI units. There are 113 example problems and 246 homework problems.
- Several new photographs have been added to help students visualize the material under discussion.
- Chapter 1, entitled "Geotechnical Engineering," is new and explains what geotechnical engineering is in general terms.
- Chapter 2 presents a general description of soil grain-size and grain-size analysis.
- Soil compaction has now been moved to Chapter 5.
- Based on the review comments, several additions and clarifications have been incorporated into the text.

Instructors must emphasize the difference between soil mechanics and foundation engineering in the classroom. Soil mechanics is the branch of engineering that involves the student of the properties of soils and their behavior under stress and strain under idealized conditions. Foundation engineering is the application of the principles of soil mechanics and geology in the planning, design, and construction of foundations for buildings, highways, dams, and so forth. Approximations and deviations from idealized conditions of soil mechanics become necessary for proper foundation design, because natural soil deposits are not homogeneous in most cases. However, if a structure is to function properly, these approximations only can be made by an engineer with a good background in soil mechanics. This book provides that background.

Instructor Resource Materials

A detailed *Instructor's Solutions Manual* is available for instructors.

MindTap Online Course and Reader

In addition to the print version, this textbook also will be available online through MindTap, which is a personalized learning program. Students who purchase the MindTap version will have access to the book's MindTap Reader and will be able to complete homework and assessment material online, through their desktop, laptop, or iPad. If your class is using a Learning Management System (such as Blackboard, Moodle, or Angel) for tracking course content, assignments, and grading, you can seamlessly access the MindTap suite of content and assessments for this course.

In MindTap, instructors can

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

Additionally, students can listen to the text through ReadSpeaker, take notes and highlight content for easy reference, and check their understanding of the material.

Acknowledgements

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- The three reviewers, including Professor Saeed Daniali of the University of Washington, for their comments and helpful suggestions.
- Janice F. Das, in helping to complete the Instructor's Solution Manual and providing other suggestions and advice in the preparation of the revision.

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

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  Hilda Gowans, formerly Senior Development Editor, Cengage
  Eavan Cully, Development Editor, Cengage

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 *Introduction to Geotechnical Engineering* as well as the first edition.

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