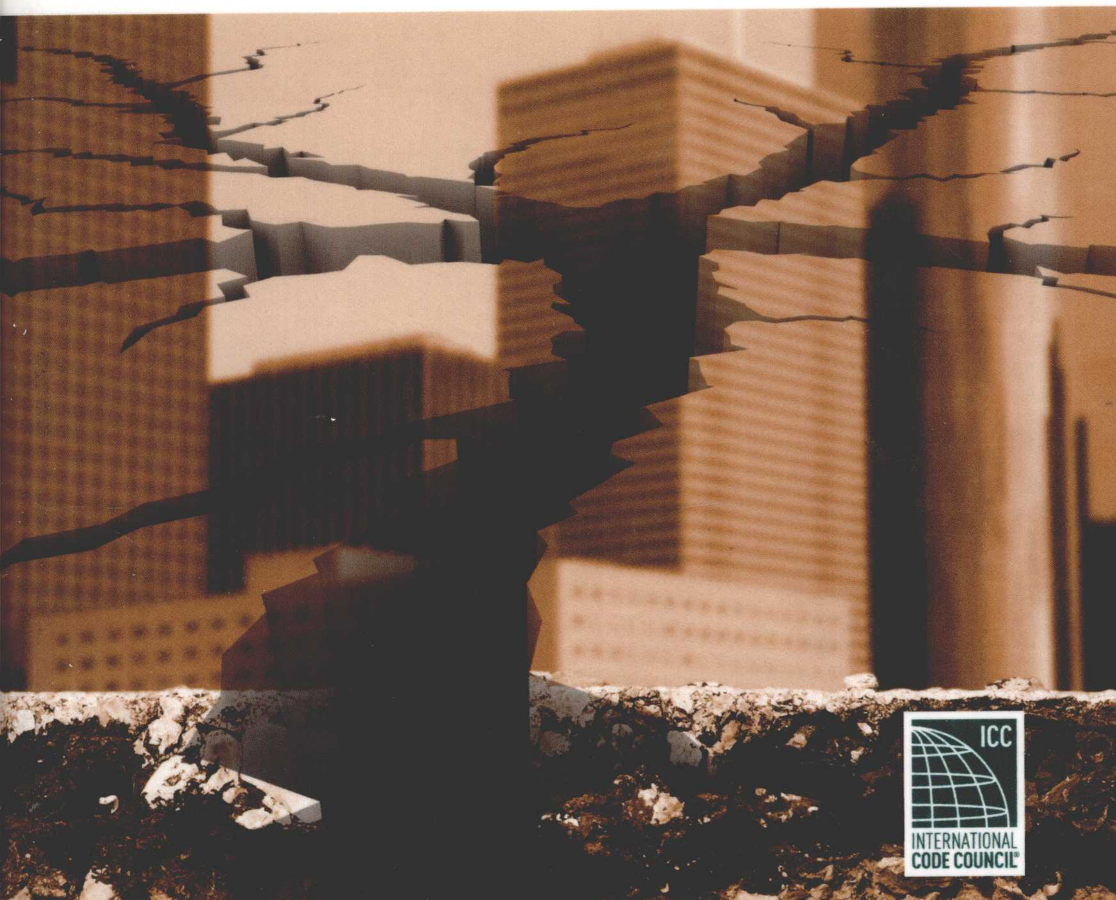
ROBERT W. DAY

GEOTECHNICAL EARTHQUAKE ENGINEERING HANDBOOK

Second Edition

WITH THE 2012 INTERNATIONAL BUILDING CODE



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GEOTECHNICAL EARTHQUAKE ENGINEERING HANDBOOK

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Robert W. Day is a leading geotechnical engineer and the principal engineer at American Geotechnical in San Diego, California. He is the author of more than 200 published technical papers and several books, including two editions of *Foundation Engineering Handbook*, *Forensic Geotechnical and Foundation Engineering*, and *Geotechnical Engineer's Portable Handbook*.

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Dedicated with love to my wife, Deborah

PREFACE

The purpose of this book is to present the practical aspects of geotechnical earthquake engineering. Because of the assumptions and uncertainties associated with geotechnical engineering, it is often described as an "art" rather than exact science. Geotechnical earthquake engineering is even more challenging because of the inherent unknowns associated with earthquakes. Because of these uncertainties in earthquake engineering, simple analyses are prominent in this book, with complex and theoretical evaluations kept to an essential minimum.

The book is divided into four separate parts. Part 1 (Chaps. 2 to 4) provides a discussion of basic earthquake principles, common earthquake effects, and typical structural damage caused by the seismic shaking. Part 2 (Chaps. 5 to 11) deals with earthquake computations for conditions commonly encountered by the design engineer, such as liquefaction, settlement, bearing capacity, and slope stability. Part 3 (Chaps. 12 and 13) discusses site improvement methods that can be used to mitigate the effects of the earthquake on the structure. Part 4 (Chaps. 14 and 15) deals with building codes and a summary chapter.

The book contains practical analyses for geotechnical earthquake engineering. There may be local building codes, government regulations, or other special project requirements that are more rigorous than the procedures outlined in this book. The analyses presented here should not replace experience and professional judgment. Every project is different, and the engineering analyses described in this book may not be applicable for all circumstances.

This second edition includes new material such as Chap. 14 dealing with the geotechnical earthquake engineering regulations from the 2012 *International Building Code*. Chapter 15, Summary of Geotechnical Earthquake Engineering, has been added. Other chapters have been updated, and more problems and solutions are included in this second edition.

Robert W. Day

ACKNOWLEDGMENTS

I am grateful for the contributions of the many people who helped make this book. Special thanks are also due to the International Code Conference (ICC), who sponsored the author's work. The continued support of Mark Johnson at ICC is greatly appreciated, as well as the effort of Sandra Hyde, ICC Staff Engineer, for her review and comments concerning Chap. 14. I would also like to thank Maurice Power, principal engineer at AMEC, for his help with the IBC regulations regarding the maximum considered earthquake peak ground acceleration. I would also like to thank the following individuals for their contributions:

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- Thomas Blake, who provided assistance in the use and understanding of his EQSEARCH, EQFAULT, and FRISKSP computer programs.
- Professor Robert Ratay, who reviewed the proposed content of the book and provided many helpful suggestions during its initial preparation.
- Professor Charles C. Ladd, Massachusetts Institute of Technology, who reviewed the draft of the author's book titled *Geotechnical and Foundation Engineering: Design and Construction*, portions of which have been reproduced in this book.

I am also indebted to Gregory Axten, president of American Geotechnical, for his support and encouragement during the development of the book. I would also like to thank Tom Marsh for his invaluable assistance during the preparation of the book, Rick Walsh for his help with the engineering analyses, and Eric Lind for supplying some of the deep foundation photographs.

Tables and figures taken from other sources are acknowledged where they occur in the text. Finally, I wish to thank Larry Hager, David Fogarty, Pamela Pelton, and others on the McGraw-Hill editorial staff and the editorial staff at Neuetype, who made this book possible and refined my rough draft into this finished product.

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CHAPTER 1
INTRODUCTION

1.1 GEOTECHNICAL EARTHQUAKE ENGINEERING

Geotechnical earthquake engineering can be defined as that subspecialty within the field of geotechnical engineering which deals with the design and construction of projects in order to resist the effects of earthquakes. Geotechnical earthquake engineering requires an understanding of basic geotechnical principles as well as geology, seismology, and earthquake engineering. In a broad sense, *seismology* can be defined as the study of earthquakes. This would include the internal behavior of the earth and the nature of seismic waves generated by the earthquake.

The first step in geotechnical earthquake engineering is often to determine the dynamic loading from the anticipated earthquake (the anticipated earthquake is also known as the *design earthquake*). For the analysis of earthquakes, the types of activities that may need to be performed by the geotechnical engineer include the following:

- Investigating the possibility of liquefaction at the site (Chap. 6). Liquefaction can cause a complete loss of the soil's shear strength, which could result in a bearing capacity failure, excessive settlement, or slope movement.
- Calculating the settlement of the structure caused by the anticipated earthquake (Chap. 7).
- Checking the design parameters for the foundation, such as the bearing capacity and allowable soil bearing pressures, to make sure that the foundation does not suffer a bearing capacity failure during the anticipated earthquake (Chap. 8).
- Investigating the stability of slopes for the additional forces imposed during the design earthquake. In addition, the lateral deformation of the slope during the anticipated earthquake may need to be calculated (Chap. 9).
- Evaluating the effect of the design earthquake on the stability of retaining walls (Chap. 10).
- Analyzing other possible earthquake effects, such as surface faulting and resonance of the structure (Chap. 11).
- Developing site improvement techniques to mitigate the effects of the anticipated earthquake. Examples include ground stabilization and groundwater control (Chap. 12).
- Determining the type of foundation, such as a shallow or deep foundation, that is best suited for resisting the effects of the design earthquake (Chap. 13).
- Assisting the structural engineer by investigating the effects of ground movement due to seismic forces on the structure and by providing design parameters or suitable structural systems to accommodate the anticipated displacement (Chap. 13).