



Geotechnical Aspects of Landfill Design and Construction

By Xuede Qian, Robert M. Koerner, Donald H. Gray

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Focuses on actual, state-of-the-art design/construction procedures as opposed to a discussion of solid waste management issues and to general descriptions and/or conceptual designs. Provides an integrated package of analytical tools, design equations, and step-by-step construction procedures for all elements of a landfill, giving the reader a better sense of the necessary site investigation, planning, analysis, and organization that go into a landfill design and construction project. The characteristics of landfill containment envelopes and their design/construction are treated in detail. Physico-chemical and engineering properties of solid waste that are relevant and important to landfill design and construction are tabulated and described. Includes explanation of how to evaluate and assess potential problems that affect landfill performance such as sideslope stability, settlement, containment effectiveness, and erosion control. Discusses vertical landfill expansion; how leachate moves across a liner or barrier under both advection and diffusion; compares the containment effectiveness of different liner systems to the combined advective-diffusive transport of dissolved leachate solutes. Includes a detailed explanation with numerical examples and calculations of how to design a gas collection and piping system in a landfill—including the collection and handling of condensate in the gas. Detailed installation and inspection guidelines are provided for both earthen and geosynthetic liner/cover systems—comparing the relative advantages and limitations of each. For professional training courses in Geotechnical and Geoenvironmental Engineering.

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Editorial Review

From the Back Cover

This book, intended for professionals or students taking a course on geoenvironmental engineering, addresses landfill design and construction issues in a comprehensive manner. It does this by focusing on all elements of a landfill, from design to completion. The book also looks at actual, state-of-the-art construction procedures in a step-by-step manner, including carefully selected design equations and examples, diagrams, tables, and homework problems.

- Provides hundreds of useful design equations, specific guidance and protocols for design of a landfill envelope, leachate collection and removal system, and gas collection and control systems.
- Explains how to evaluate and assess potential problems that affect landfill performance including contaminant transport through landfill liners, landfill stability waste settlement, containment effectiveness, vertical expansions, bioreactor landfills, erosion control, and postclosure uses.
- Presents students and professionals with extensive coverage on potential problems that affect landfill performance; and provides decisionmaking and problem-solving techniques.

About the Author

Xuede Qian is currently a statewide Geotechnical Engineering Specialist with the Waste Management Division, Michigan Department of Environmental Quality. He received the B.S. and M.S. degrees in hydraulic and geotechnical engineering from Hohai University Nanjing, China, and the Ph.D. degree in geotechnical engineering from the University of Michigan, Ann Arbor. He is also an adjunct faculty member with the Department of Civil and Environmental Engineering, University of Michigan, with responsibility for teaching a senior/graduate level course on landfill design and construction. He has been actively involved in landfill engineering research and has participated in many landfill design, construction, and remediation projects during the past decade. Dr. Qian has authored numerous technical papers in the geotechnical and geoenvironmental fields. His professional experiences include work for universities, regulatory agencies, and consulting firms.

Robert M. Koerner is currently an H. L. Bowman Professor of Civil Engineering with Drexel University, Philadelphia, PA. He received the B.S. and M.S. degrees in civil engineering from Drexel University and the Ph.D. degree in geotechnical engineering from Duke University. He is an Honorary Member of the ASCE and a member of the National Academy of Engineering. Dr. Koerner is the co-author of the first book on geotextiles and has authored or coauthored more than 300 papers on geosynthetics in major engineering journals and for national and international conference proceedings. His latest effort is the fourth edition of the textbook entitled *Designing with Geosynthetics*. As Director of the Geosynthetic Research Institute, his activities involve all aspects of waste disposal, but focus particularly on the liner and cover containment systems.

Donald H. Gray is a Professor Emeritus of Civil and Environmental Engineering with the University of Michigan, Ann Arbor. He received the B.S. and M.S. degrees and the Ph.D. degree in geological and civil engineering from the University of California at Berkeley. His areas of expertise include slope stability and erosion control, engineering properties of solid waste materials, the transport of leachate through landfill liners (under combined advection/diffusion), and containment strategies for landfilled wastes. He has

authored numerous technical papers and lectured extensively at training workshops and short courses dealing with geotechnical aspects of waste disposal in the ground. He has served as the organizer and chairman of two ASCE specialty conferences on geotechnical engineering of land disposal. Dr. Gray is also the principal author of two well-regarded reference books on biotechnical and soil bioengineering slope stabilization.

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Preface

The United States produces about 300 million tons of solid waste per year. Up to 75 percent of the solid waste continues to be landfilled—in spite of vigorous efforts aimed at waste reduction, recycling, and re-use. A modern, well-constructed landfill can be characterized as an engineered structure that consists primarily of a composite liner, leachate collection and removal system, gas collection and control system, and final cover. A landfill also behaves as a giant in-situ bioreactor whose contents undergo complex biochemical reactions. The production of landfill gas is a major byproduct of waste decomposition processes. The adoption of suitable design and construction methods is essential not only to reduce design and construction costs, but also to minimize long term operation, maintenance, and monitoring expenses.

Geotechnical Aspects of Landfill Design and Construction addresses landfill siting, design, and construction issues in a comprehensive manner. The characteristics of landfill containment envelopes and their design/construction are treated in detail. The attributes and advantages of composite liners relative to conventional compacted clay liners are examined carefully. The book discusses both the material properties and engineering design of geosynthetic components (e.g., geomembranes, geotextiles, geocomposites, and geosynthetic clay liners) that are used in modern landfill construction. Methods of estimating landfill leachate quantities and gas generation in addition to the design of leachate and gas collection systems are also described in detail. We include other important topics as well—such as vertical expansion and bioreactor concepts—that are ways of increasing capacity at existing landfills.

Several chapters in the book are devoted to the measurement and determination of landfill performance. These performance considerations include settlement estimates, mass stability, liner leakage rates (by both hydraulic convection and chemical diffusion), envelope durability, leachate and gas collection, and drainage efficiency. Final cover design to limit rainfall infiltration, frost problems, and erosion is addressed as well.

Geotechnical Aspects of Landfill Design and Construction focuses on actual design and construction procedures, as opposed to a discussion of solid waste management issues and to general descriptions and/or conceptual designs. We present the reader with a complete, integrated package of analytical tools, design equations, and construction procedures for all elements of a landfill. The purpose of the book is to show the reader how to design and construct a real landfill step by step. To this end, we provide in the book not only design equations, but also specific guidelines and procedures, and calculation examples for constructing various elements of a modern landfill.

Since landfill design and construction in the United States uses English Computational units almost exclusively (and there is no end in sight of this practice), we have complied by using these units as primary. Worldwide, however, SI units are the norm and we have accompanied the U.S. units with SI computational units in parentheses. The conversion to SI units is "soft." The notable exception to this is hydraulic conductivity where we have used in the traditional metric unit of "cm/sec."

Geotechnical Aspects of Landfill Design and Construction is intended as (i) a reference book for practicing professionals, (ii) an agency training manual, and (iii) university textbook. A draft manuscript of the book has been used and tested by the principal author in a geoenvironmental graduate course at the University of Michigan since 1995. Carefully selected design examples, diagrams, and tables are incorporated into the

book. These give the reader a better sense of the necessary site investigation, planning, analysis, and organization that go into a landfill design and construction project. In addition to worked design examples we have also included homework problems and an extensive reference list at the end of every chapter.

The authors wish to express their appreciation to the following individuals for their encouragement and support throughout the preparation of the manuscript: Professors Richard D. Woods and E. Benjamin Wylie, University of Michigan; and Jim J. Sygo, Kenneth J. Burda, Delores M. Montgomery, and Elizabeth M. Browne, Michigan Department of Environmental Quality.

The authors also would like to acknowledge and thank the following individuals for sharing their knowledge and ideas during the course of many discussions about the book: Stephen R. Blayer, V Wesley Sherman, Jr., and Carolyn B. Parker, Michigan Department of Environmental Quality; Dr. Gary R. Schmertmann, Geosyntec Consultants; Dr. Te-Yang Soong, Earth Tech, Inc.; Dr. Jengwa Lyang, NTH Consultants, Ltd.; and Scott R Lockhart, Hull and Associates, Inc. XUEDE (DAN) QIAN
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