Third Edition

PAVEMENT ENGINEERING

Principles and Practice

Edited by
Rajib B. Mallick and Tahar El-Korchi

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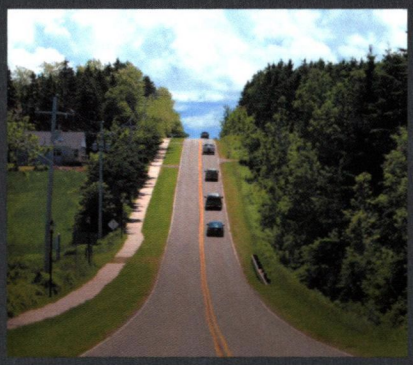
CIVIL ENGINEERING

Third Edition

PAVEMENT ENGINEERING

Principles and Practice



"This book is, in my opinion, the best and most easily structured text to teach pavement structural engineering to undergraduate engineering students. It strikes a good balance between fundamentals and practice and helps guide undergraduate students to see how the two are connected. The core content I use to teach my course is here, and information on other aspects of pavement engineering less related to direct structural design of pavements is there as well."
—Shane Underwood, Arizona State University, Tempe, Arizona, USA

"We have happily used this book for the past five years in our pavement design course. It expertly covers the important topics in pavements in sufficient detail: structural design, mix design, traffic, distresses, maintenance, etc. No other textbook summarizes such a wide range of topics."
—Christopher Senseney, United States Air Force Academy, Colorado, USA

"The most valuable resource, of which I am aware, for the education of road, runway, and port engineers."
—John Yeaman, University of the Sunshine Coast, Queensland, Australia

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Pavements are an important part of everyday life, transportation, and commerce and trade. In order for these engineered structures to perform as expected, they must be designed, constructed, maintained, and managed properly. Providing a comprehensive overview of the subject, ***Pavement Engineering: Principles and Practice, Third Edition*** covers a wide range of topics in asphalt and concrete pavements, from soil preparation to structural design and construction.

This new edition presents a comprehensive overview of pavement analysis, design, and construction. It includes new concepts and methods that have been developed and extended recently, such as topics related to highway and airport pavement design and testing and sustainable pavement design and construction. Additional new topics include pavement surface characteristics, standards in pavement design, test methods for both asphalt binder and mixes, and new construction practices, such as the use of precast concrete pavements. Relevant information from the recently completed US National Cooperative Highway Research Program (NCHRP) projects as well as the Strategic Highway Research Program (SHRP) II have been included.

The text describes the significance of standards and examines traffic, drainage, concrete mixes, asphalt binders, distress and performance in concrete and asphalt pavements, and pavement maintenance and rehabilitation. The authors explore key concepts and techniques for economic analysis and computing life-cycle cost, instrumentation for acquiring test data, and specialty applications of asphalt and concrete. It also contains extensive references, including online resources for extending knowledge of the principles and practices of pavement engineering.

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Pavement Engineering

Preface

Significant advances have been made in the field of pavement engineering in the years since the publication of our second edition in 2013. New research has given way to implementation in different areas such as new concepts, new tests, and more comprehensive definitions and frameworks for sustainable pavements. One such example is the completion of the Strategic Highway Research Program (SGRP) 2 in the United States.

In this edition we have tried to incorporate new materials as much as possible while retaining the very important basics of pavement engineering and directed readers to appropriate websites for further information. Specifically, we have added one chapter on pavement surface characteristics, completely rewritten the chapter on sustainable pavements, made several relevant additions to the different chapters, and corrected errors in the second edition.

As always, it has been a challenge to balance basics with advanced concepts, specifically because we have tried to present this book for undergraduates and beginning graduate students, practitioners, and consultants. We have tried to maintain a balance between theory and practice since pavement engineering is a much applied branch of civil engineering. However, we did try to include the latest information, including key figures, from relevant US National Cooperative Highway Research Projects (NCHRP) and have indicated appropriate websites for further information.

We hope the readers will find the book useful and interesting. We thank them for their acceptance of this book and request them to provide feedback to us on ways to improve it. Finally, we wish them the very best in their quest for knowledge in this very noble profession!

Acknowledgments

For the third edition we would like to acknowledge the help of Professor Mingjiang Tao, who has contributed to Chapter 18 on Pavement Surface Characteristics, and Mr. James Scherocman, who has spent a considerable amount of his valuable time on reading the previous edition and making numerous valuable suggestions.

We are fortunate to have a number of colleagues who have provided valuable feedback on the book, and we are greatly thankful to them: Mr. Richard (Rick) L. Bradbury of Maine Department of Transportation; Professor A. Veeraragavan, IIT Madras; Professor Sivakumar Babu, IISc, Bangalore; Professor Soheil Nazarian, University of Texas, El Paso; Professor Jorge Prozzi, University of Texas, Austin; Professor Linbing Wang, Virginia Tech; Professor Okan Sirin, Qatar University; Professor Kevin Hall, University of Arkansas; and Professor Elie Y. Hajj, University of Nevada, Reno.

We have tried to present in this book what we have learned in courses from teachers, from students, from colleagues, and from our academic, research, and consulting experiences. There are some people, though, without whom this book would not have been possible, and we thank them from the bottom of our hearts: Dr. Ray Brown; Prithvi Kandhal; Dr. Frazier Parker; Dr. Dan Brown of Auburn University; Dale Peabody, Brian Marquis, Derek Nener-Plante, and Wade McClay of the Maine Department of Transportation; Sudhansu Bhattacharjee, consultant; Robert Pelland of the Massachusetts Port Authority (Massport); Mike Marshall of Wirtgen GmbH; Ed Kearney of Wouter Gulden of the American Concrete Pavement Association (ACPA–SE Chapter); Robert Otto Rasmussen of the Transtec Group, Inc.; Maureen Kestler of the US Forest Service; and Marylou Horanzy, Cindy Bergeron, Dr. Martins Zaumanis, Russ Lang, and Don Pellegrino of Worcester Polytechnic Institute. We greatly appreciate the help of Robert (Bob) Frank of Compliance Monitoring and RAP Technologies for procuring a number of photographs.

We could write this book only with the support and encouragement of our families. Special thanks go to Sumita and Urmila and to Marya, Miriam, and Youssef for their patience, help, and encouragement. This book would not have been possible without the blessings of our parents, Bimalangshu Kumar Basu Mallick and Monika Basu Mallick, and M'hamed El-Korchi and Bahija El-Bouchti El-Korchi.

We thank the helpful staff of the Taylor & Francis Group and codeMantra group for making this publication possible: Joe Clements, acquiring/contact editor, Ariel Crockett, senior editorial assistant, and Mathi Ganesan. It has been a pleasure to work with them.

Authors

Rajib Mallick has extensive experience in the study of asphalt materials, mixture design, construction, pavement design, recycling, and nondestructive testing. From 1992 to 1998, he worked as a research assistant and as a senior research associate at the National Center for Asphalt Technology (NCAT) and is currently the Ralph White Family Distinguished Professor of Civil and Environmental Engineering at Worcester Polytechnic Institute (WPI). He has completed numerous research projects for several departments of transportation, the Federal Highway Administration (FHWA), the Massachusetts Port Authority (Massport), the National Science Foundation (NSF), the Federal Aviation Administration (FAA), and several private practitioner organizations. Dr. Mallick has coauthored more than 100 papers for journals and conference proceedings as well as several practical reports, manuals, and state-of-the-practice reports for federal, state, and local highway agencies. He has taught professional courses on asphalt technology, presented courses on recycling for the FHWA, and lectured in the national workshops at the Indian Institute of Technology (IIT) at Kanpur, Kharagpur, and Madras in India. He has presented a series of seminars on hot mix asphalt paving for the Baystate Roads Programs for the Massachusetts Highway Department. He has also introduced many innovations in his courses and has received several awards from the NSF. He is a member of several professional organizations and a registered professional engineer (PE) in Massachusetts. Dr. Mallick has served as a consultant in several projects for practitioner organizations, worked at the University of Peradeniya, Sri Lanka as a Fulbright Fellow and has served IIT Madras as a professor of civil engineering for 1 year.

Tahar El-Korchi is a professor and head of civil and environmental engineering at Worcester Polytechnic Institute. He has been at WPI since 1987. He does research and teaches courses on pavement analysis, design and management, construction materials testing and evaluation, cement and concrete materials and construction processes, structural analysis and design, and high-performance structural materials at the undergraduate and graduate level. He has published more than 80 publications and presentations and has served at numerous WPI global project centers including Puerto Rico, Washington DC, Morocco, Costa Rica, and Panama. Dr. El-Korchi was granted the prestigious Presidential Young Investigator Award by the National Science Foundation in 1991. His research funding has been generated from federal and state sources including the National Science Foundation, the U.S. Army Waterways Experiment Station (WES), the U.S. Geological Survey's Columbia River Research Laboratory (CRRL), the Small Business Innovation Research (SBIR), the Federal Highway Administration, National Institute of Standards and Technology (NIST), the New England Transportation Consortium, the Massachusetts Highway Department, and numerous industries. He was an invited scientist at the Turner Fairbanks Highway Research Center (Federal Highway Administration), Washington, DC (1993–1994). He was also an advisor to the Mass Highway QC/QA Implementation Program, the LTPP Expert Technical Group, and the FHWA LSPEC. Dr. El-Korchi is also a consultant to several major corporations. He provides recommendations for the design and evaluation of pavements, materials, and structures.

Contributors

Suzanne LePage holds an MS in civil engineering from Worcester Polytechnic Institute (WPI), has nearly 15 years of experience as a regional planner, and has been teaching a variety of urban and environmental planning courses at WPI for 10 years. She is responsible for developing course materials, delivering lectures, and encouraging student learning for classes in urban and environmental planning, land use, site development, hydrology, and traffic engineering. LePage also advises 15–20 undergraduate students each year in a variety of interdisciplinary projects and civil engineering capstone design projects. These are student team projects on topics including alternative energy, sustainable development, stormwater management, food systems planning, community planning for recreation facilities and trails development, and transportation planning and design. In addition to her appointment at WPI, LePage owns and operates a sustainable farm-to-table and field-to-glass brewpub in Sturbridge, MA.

Mingjiang Tao earned a BS in civil engineering at Fuzhou University, China, in 1997 and an MS in geotechnical engineering at Tongji University, China, in 2000, and a PhD in civil engineering at Case Western Reserve University, USA, in 2003, respectively. He joined Worcester Polytechnic Institute in 2007, where he is an associate professor of civil engineering. His research is in the interdisciplinary aspects of highway infrastructure engineering, with the current research focusing on bridging the linkage between chemistry and mechanical properties of various construction materials. He is the author of more than 40 papers on alternative cementitious binders, asphalt concrete, granular materials, and characterization of construction materials at nano- and marco-scales. Professor Tao is a member of the American Society of Civil Engineers and the Chemical and Mechanical Stabilization Committee (AFS90), Engineering Behavior of Unsaturated Soils Committee, and Physicochemical and Biological Processes in Soils (AFP40) of the Transportation Research Board.

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