# **Expansive Soils**

Recent advances in characterization and treatment

#### Editors

## Amer Ali Al-Rawas

Department of Civil and Architectural Engineering, College of Engineering, Sultan Qaboos University, Sultanate of Oman

## Mattheus F.A. Goosen

School of Science and Technology, University of Turabo, Puerto Rico, USA

© 2006 Taylor & Francis Group, London, UK

Typeset in Times New Roman by Newgen Imaging Systems (P) Ltd, Chennai, India Printed and bound in Great Britain by TJ International, Padstow, Cornwall

All rights reserved. No part of this publication or the information contained herein may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic or mechanical, by photocopying, recording or otherwise, without written prior permission from the publishers.

Although all care is taken to ensure integrity and the quality of this publication and the information herein, no responsibility is assumed by the publishers nor the author for any damage to property or persons as a result of operation or use of this publication and/or the information contained herein.

Published by: Taylor & Francis/Balkema

P.O. Box 447, 2300 AK Leiden, The Netherlands

e-mail: Pub.NL@tandf.co.uk

www.balkema.nl, www.tandf.co.uk, www.crcpress.com

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

Library of Congress Cataloging in Publication Data

Expansive soils: recent advances in characterization and treatment / editors: Amer Ali Al-Rawas, Mattheus F. A. Goosen.

p. cm.

Includes index.

1. Soil consolidation. 2. Swelling soils. 1. Al-Rawas, Amer Ali,

II. Goosen, Mattheus F.A.

TE210.4.E96 2006 624.1'5136-dc22

2005035532

ISBN 10 0-415-39681-6 ISBN 13 978-0-415-39681-3

## Contents

	List of contributors	ix
	Preface	хi
	RT I	
	ature, identification, and classification of pansive soils	I
1	Geology, classification, and distribution of expansive soils and rocks: a case study from the Arabian Gulf	3
	AMER A. AL-RAWAS, MATTHEUS F.A. GOOSEN, AND GHAZI A. AL-RAWAS	
2	Identification and classification of expansive soils SUDHAKAR M. RAO	15
3	Prediction and classification of expansive clay soils  AGUS SETYO MUNTOHAR	25
4	Overview of mineralogy of bentonites: genesis, physicochemical properties, industrial uses, and world production RICHARD PŘÍKRYL	37
5	Swelling in non-vertisolic soils: its causes and importance MIGUEL ANGEL TABOADA AND RAÜL SILVIO LAVADO	55
PA	RT 2	
Vo	olume change characteristics	79
6	hydration/dehydration cycles	81
	JOELLE DUPLAY, GERMAN MONTES-HERNANDEZ, AND LUIS MARTINEZ	

7	Large-scale odometer for assessing swelling and consolidation behavior of Al-Qatif clay SHAHID AZAM	85
	SHAHID AZAM	
8	Water sorption and dilatation of bentonites and montmorillonite-rich clays	101
	RADEK HANUS, IRENA KOLAŘÍKOVÁ, AND RICHARD PŘÍKRYL	
	RT 3	
Sw	relling potential measurement	115
9	ESEM-DIA method to estimate swelling-shrinkage of raw	
	and cation-saturated bentonite	117
	GERMAN MONTES-HERNANDEZ	
10	Effect of remolding techniques on soil swelling and shear	
	strength properties	127
	MOUSA F. ATTOM, MAJED M. ABU-ZREIG, AND	
	MOHAMMED TALEB OBAIDAT	
11	Swelling rate of expansive clay soils	139
	ROSLAN HASHIM AND AGUS SETYO MUNTOHAR	
12	Swelling behavior of Ankara Clay: predictive techniques,	
	damage details, and swelling maps	149
	ZEYNAL ABIDDIN ERGULER AND RESAT ULUSAY	
13	Prediction of swelling characteristics with free swell index	173
	BHYRAVAJJULA R. PHANIKUMAR	
	RT 4	
Ad	vanced techniques for swelling potential assessment	185
14	Remote sensing of expansive soils: use of hyperspectral methodology	
	for clay mapping and hazard assessment	187
	SABINE CHABRILLAT AND ALEXANDER F.H. GOETZ	
15	Speatroscopy as a tool for studying availing and	muloV
15	Spectroscopy as a tool for studying swelling soils PATRICK CHEGE KARIUKI, KEITH SHEPHERD, AND	211
	FREEK VAN DER MEER	
	street a free surprise new transaction and the surprise a	Liter
16	Finite element analysis of piers in expansive soils	231
	YAHIA EA. MOHAMEDZEIN	

17	Prediction of swelling pressure of expansive soils using Neural Networks	245
	YAHIA EA. MOHAMEDZEIN, RABAB IBRAHIM, AND ASSIM ALSANOSI	
18	Shrinkage strain characterization of expansive soils using digital imaging technology	257
	ANAND J. PUPPALA, SIVA PATHIVADA, VENKAT BHADRIRAJU, AND LAUREANO R. HOYOS	
PA	RT 5	
Sit	te characterization	271
19	Swelling behavior of expansive shale: a case study from Saudi Arabia	273
	ABDULLAH I. AL-MHAIDIB	
20	Volume change characteristics of compacted Ankara clay	289
21	Influence of trees on expansive soils in southern Australia DONALD A. CAMERON, MARK B. JAKSA, WAYNE POTTER, AND	295
	AARON O'MALLEY	
PA	RT 6	
	me stabilization	315
22	Stabilization of expansive Ankara Clay with lime MEHMET CELAL TONOZ, CANDAN GOKCEOGLU, AND RESAT ULUSAY	317
23	Lime stabilization of expansive clay ZALIHE NALBANTOGLU	341
24	Combined lime and polypropylene fiber stabilization for modification of expansive soils	349
	ANAND J. PUPPALA, EKARIN WATTANASANTICHAROEN, AND ALI PORBAHA	
PA	RT 7	
C	ement-stabilization	369
25	Assessment of anisotropic behavior of swelling soils on ground and construction work	371
	EVANGELOS I. STAVRIDAKIS	

viii Conte	nts
------------	-----

26	Stabilization of problematic soils using cement and lime EVANGELOS 1. STAVRIDAKIS	385
27	Influence of sand content on strength and durability of cement-acrylic resin treated soil	399
	COSTAS A. ANAGNOSTOPOULOS	
28	Physical and engineering properties of cement stabilized soft soil treated with acrylic resin additive COSTAS A. ANAGNOSTOPOULOS	405
PA	RT 8	
Ot	her treatment methods	417
29	Pozzolanic stabilization of expansive soils P.V. SIVAPULLAIAH	419
30	Swelling characteristics and improvement of expansive soil with rice husk ash AGUS SETYO MUNTOHAR	435
31	Effects of addition of fly ash on swell potential of an expansive soil  DEVRIM TURKER AND ERDAL COKCA	453
32	Dynamic characterization of chemically modified expansive soil LAUREANO R. HOYOS. PHONLAWUT CHAINUWAT, AND ANAND J. PUPPALA	465
33	Assessment of seasonal effects on engineering behavior of chemically treated sulfate-rich expansive clay LAUREANO R. HOYOS, ARTHIT LAIKRAM, AND ANAND J. PUPPALA	483
	RT 9	505
<u>_</u> 0	nstruction techniques and remedial measures	505
34	Granular pile-anchors: an innovative foundation technique for expansive soils BHYRAVAJJULA R. PHANIKUMAR AND RADHEY S. SHARMA	507
	Index	523

#### Contributors

Abdullah I. Al-Mhaidib, King Saud University, Riyadh, Saudi Arabia Amer Ali Al-Rawas, Sultan Qaboos University, Al-Khoud, Sultanate of Oman Ghazi A. Al-Rawas, Sultan Qaboos University, Sultanate of Oman Assim Alsanosi, University of Khartoum, Khartoum, Sudan Costas A. Anagnostopoulos, Aristotle University of Thessaloniki, Thessalonica, Greece Mousa F. Attom, Jordan University of Science and Technology, Irbid, Jordan Shahid Azam, University of British Columbia, Vancouver, Canada Venkat Bhadriraju, University of Texas at Arlington, USA Donald A. Cameron, University of South Australia, Australia Sabine Chabrillat, GeoForschungsZentrum (GFZ) Potsdam, Germany Phonlawut Chainuwat, PSA Engineering, Texas, USA Erdal Cokca, Middle East Technical University, Ankara, Turkey Ozlem Cora, Middle East Technical University, Ankara, Turkey Joelle Duplay, Centre de Géochimie de la Surface, Strasbourg, France Zeynal Abiddin Erguler, Hacettepe University, Ankara, Turkey Alexander F.H. Goetz, University of Colorado, USA Candan Gokceoglu, Hacettepe University, Ankara, Turkey Mattheus F.A. Goosen, University of Turabo, Gurabo, Puerto Rico Radek Hanus, Charles University, Prague, Czech Republic Roslan Hashim, University of Malaya, Kuala Lumpur, Malaysia Laureano R. Hovos, University of Texas at Arlington, USA Rabab Ibrahim, Al-Amin Engineering Company, Khartoum, Sudan Mark B. Jaksa, University of Adelaide, Australia

Majed M. Abuzreig, Jordan University of Science and Technology, Irbid, Jordan