Geotechnical Characterization, Field Measurement, and Laboratory Testing of **Municipal Solid Waste**



Proceedings of the 2008 International Symposium on Waste Mechanics

Geotechnical Special Publication No. 209

ASCE

Edited by
Dimitrios Zekkos, Ph.D., P.E.

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GEOTECHNICAL CHARACTERIZATION, FIELD MEASUREMENT, AND LABORATORY TESTING OF MUNICIPAL SOLID WASTE

PROCEEDINGS OF THE 2008 INTERNATIONAL SYMPOSIUM
ON WASTE MECHANICS

March 13, 2008
New Orleans, Louisiana

SPONSORED BY
The Geo-Institute of the American Society of Civil Engineers

EDITED BY
Dimitrios Zekkos, Ph.D., P.E

Published by the American Society of Civil Engineers

Cataloging-in-Publication Data on file with the Library of Congress.

American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4400

www.pubs.asce.org

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ISBN 978-0-7844-1146-9
Manufactured in the United States of America.

ABOUT THE WASTE MECHANICS SYMPOSIUM

In March 2008, an International Symposium on Waste Mechanics was held in New Orleans. The Symposium provided a unique opportunity for researchers and engineers practicing in the field of waste mechanics to present recent research findings and case histories, as well as interact and exchange ideas. The Symposium's objectives were the following:

1. Develop consensus on procedures and guidelines for waste characterization, field testing, and laboratory testing of Municipal Solid Waste;
2. Summarize the state of knowledge on waste properties for use in research and engineering practice; and
3. Identify research needs in waste mechanics.

The Symposium included the following activities:

- Three paper presentation sessions that were part of the main program of the Geo-Institute Geoenvironmental Congress on Tuesday and Wednesday March 11-12, 2008;
- An international panel discussion on research needs that was held on Wednesday March 12, 2008 also as part of the Conference's main program; and
- A one-day workshop with break-out sessions that was held on Thursday March 13, 2008.

Paper Presentation Sessions

The three sessions included presentation of 16 papers that were reviewed by two or three reviewers. These papers can be found in the Geocongress 2008 volume on "Geotechnics of Waste Management and Remediation" (GSP No. 177). A list of the papers that were presented in the sessions as part of the Symposium is provided below:

Session I: "Waste shear response and stability"

- Towhata, I., Uno, M., "*Laboratory Tests on Creep and Shear Behavior of Municipal Solid Waste and Mitigation of Its Long-Term Subsidence*".
- Reddy, K. R., Gangathulasi, J., Hettiarachchi, H., Bogner, J., "*Geotechnical Properties of Municipal Solid Waste Subjected to Leachate Recirculation*".
- Zekkos, D., Bray, J. D., Stokoe, K., Kavazanjian, E., Rathje, E., Athanasopoulos, G. A., Riemer, M., Matasovic, N., Lee, J. J., Seos, B., "*Recent findings on the static and dynamic properties of Municipal Solid Waste*".
- Athanasopoulos, G., Grizi, A., Zekkos, D., Founta, P., Zisimatou, E., "*Municipal Solid Waste as a Reinforced Soil: Investigation Using Synthetic Waste*".
- Chen, Y., Zhan, T.L.T., Ling, W., "*Mechanical properties of municipal solid waste from Suzhou landfill in China*".

Session II: "Waste Compressibility, degradation and time effects"

- McDougall, J., "*Geomechanics and Long-term Landfill Settlement*".
- Singh, M.K., Fleming, I.R., "*Estimation of the mechanical properties of MSW during degradation in a laboratory compression cell*".
- Castelli, F., Maugeri, M., "*Experimental analysis of waste compressibility*".

- Hossain, M.D.H, Gabr, M. A., Haque, M.A., "*Deformation of MSW Bioreactor Landfills: Properties and Analysis Approach*"
- Kavazanjian, E., "*The impact of degradation on MSW shear strength*".

Session III: "Waste characterization and hydraulic properties"
- Powrie, W., Beaven, R., Hudson, A., "*The influence of landfill gas on the hydraulic conductivity of waste*".
- Borgatto, A.V.A., Izzo, R.L.S., Mahler, C. F., "*Application of a Morphologic Classification of Brazilian MSW*".
- Zhan, T.L.T., Ling, D., Zhang, W., Chen, Y. "*Hydrogeological characterization of Suzhou landfill of municipal solid wastes*".
- Dixon, N., Langer, U., "*Relationship Between Classification and Shear Behavior of MSW*".
- Izzo, R.L., Mahler, C.F., Munnich, K., Bauer, J., "*MBT Waste Used as a Capillary Barrier in a Sanitary Landfill*".
- Stoltz, G., Gourc, J.P., "*Variation of fluid conductivity with settlement of domestic waste*".

Panel Discussion

An international panel discussion on research needs in waste mechanics was also held. Panel members from different countries were invited to submit an opinion paper prior to the conference and made a 5-minute presentation on research needs. A discussion among participants followed. The opinion papers are included in this volume.

One-day workshop

A one-day workshop was held and included plenary and break-out sessions. Morning plenary and breakout sessions focused on procedures and guidelines for waste characterization, laboratory testing and field measurements. Afternoon plenary and breakout sessions focused on a review of the state of understanding on waste properties with emphasis on shear strength, settlement behavior, hydraulic properties and dynamic properties of Municipal Solid Waste.

Organization and Participants

The Symposium was organized by:
- Jonathan Bray, Professor, University of California at Berkeley
- Susan Burns, Associate Professor, Georgia Institute of Technology
- Jeff Dunn, PhD, Kleinfelder
- Edward Kavazanjian, Professor, Arizona State University
- Ellen Rathje, Professor, University of Texas at Austin
- Dimitrios Zekkos, PhD, (Chair), Assistant Professor, University of Michigan at Ann Arbor

Attendance to the paper presentation sessions and the panel discussions was generally unrestricted, whereas participation to the one-day workshop required pre-registration at no cost to the participant. A total of 31 researchers and practicing engineers from 9 countries

participated in the Symposium. The names of the participants (alphabetically) and their affiliation is listed below.

Name	*Affiliation*
Mohamed Arab	Arizona State University, Arizona, USA
George Athanasopoulos	University of Patras, Greece
Adda Athanasopoulos-Zekkos	University of Michigan at Ann Arbor, USA
Christopher Bareither	Univ. of Wisconsin-Madison, Wisconsin, USA
Richard Beaven	University of Southampton, UK
Jonathan Bray	Univ. of California at Berkeley, California, USA
Susan Burns	Georgia Institute of Technology, Georgia, USA
Young Min Cho	University of Florida, Florida, USA
Neil Dixon	Loughborough University, UK
Jeff Dunn	Kleinfelder, California, USA
Rami El-Sherbiny	Cairo University, Cairo, Egypt
Jeffrey B. Fassett	Golder Associates, Texas, USA
Ian Fleming	University of Saskatchewan, Canada
Patrick Fox	Ohio State University, Ohio, USA
Jean-Pierre Gourc	Grenoble University, France
Beth Gross	Geosyntec Consultants, Texas, USA
Edward Kavazanjian	Arizona State University, USA
Milind Khire	Michigan State University, Michigan, USA
Claudio Mahler	Federal University of Rio de Janeiro, Brazil
Mario Manassero	Politecnico di Torino, Italy
Neven Matasovic	Geosyntec Consultants, California, USA
Michelle Maugeri	University of Catania, Italy
John McDougall	Napier University, UK
Scott Merry	Kleinfelder, Arizona, USA
Marina Pantazidou	National Technical University of Athens, Greece
Krishna Reddy	University of Illinois - Chicago, Illinois, USA
Janardhanan Ganga Thulasi	University of Illinois - Chicago, Illinois, USA
James Tinjum	CH2M Hill, Pennsylvania, USA
Ikuo Towhata	University of Tokyo, Japan
Dimitrios Zekkos	University of Michigan at Ann Arbor, USA

The Symposium was held under the auspices of the ASCE Geoinstitute Geoenvironmental Engineering Technical Committee, and was funded by the ASCE Geo-Institute, Kleinfelder Inc, and Geoengineer.org. The Symposium's website is available online by Geoengineer.org at the following address: http://wastesymposium.geoengineer.org. The Symposium's website includes additional information on the symposium as well as Powerpoint slides from the 1-day workshop

ABOUT THIS VOLUME

The field of waste mechanics has advanced significantly since the early admirable attempts in the 1980s and early 1990s with many of the scientific contributions in the field made by practicing engineers who needed to address the serious issues associated with solid waste disposal. Many of these issues, such as containment, stability, settlement, gas generation and leachate management, are common worldwide. Subsequent research efforts focused on providing a scientific understanding of the complexities of waste behavior. From a geotechnical perspective, municipal solid waste is a very interesting and challenging material. It is heterogeneous in nature consisting of distinctly different organic and inorganic constituents that vary significantly with depth as well as laterally, and has compressibility that is comparable to peaty soils. It is also highly anisotropic and many of its constituents contribute a fibrous reinforcement that only now we begin to understand. It is also degradable and in that process generates gas that impacts its hydraulic and mechanical behavior. This volume attempts to integrate our understanding of the MSW and provide guidance to researchers and practicing engineers who confront issues related to waste behavior.

The three paper presentation sessions and the panel discussion of the international waste mechanics symposium provided an excellent opportunity for interaction and exchange of ideas among researchers and practitioners in the field of waste mechanics worldwide. The one-day workshop attempted to review and integrate the state of the art and practice in the field of waste mechanics as well as reach some consensus among waste mechanics experts on some of the aspects of laboratory testing, field measurements and characterization of MSW.

This volume consists of three parts:

In part 1, a review of the state of the art in some of the most critical properties of Municipal Solid Waste is provided: Chapter 1 focuses on the saturated and unsaturated hydraulic properties of MSW; Chapter 2 summarizes the stress-strain response and shear strength of MSW; Chapter 3 addresses our understanding of the settlement behavior and compressibility of MSW landfills and; Chapter 4 summarizes the dynamic properties of MSW. It is important to note that although, extensive references are made to numerous previous studies, an exhaustive review of the available literature was not the objective and was not attempted in all cases. However, the literature is reviewed critically and the reader will benefit from the extensive treatment of each topic.

In part 2, an attempt to reach some consensus or provide some minimum requirements or recommended procedures for waste characterization (Chapter 5), field measurements (Chapter 6) and laboratory testing (Chapter 7) is made. A review of the available literature is also presented, but the objective is not the comprehensive review of the subject. The chapters are intended to be a first step forward in providing some systematic guidance on the characterization and testing of MSW.

The chapters presented in part 2 essentially mirror the themes of the break-out sessions of the one-day workshop. Leaders of each break-out session had been identified prior to the symposium. Each leader prepared a set of slides that were used during the break-out session by the participants as a basis for discussion. In many cases amendments were made by the participants. After the workshop, the leaders prepared each chapter and asked the members of

the break-out session to review it and provide feedback. In certain cases, depending on the participants' feedback, participants were included as co-authors of the chapter. Because significant effort was expended in preparation for the symposium discussions, most of the chapter content is limited to contributions published up to 2008, although in some cases, some more recent contributions have been included too.

Part 3 includes five opinion papers submitted by the invited panelists of the panel session titled "International perspectives on Research Needs". The five papers are authored by participants from the United Kingdom, Brazil, Canada, Japan and the United States. All papers were submitted prior to the panel discussion and are included in this volume to stimulate the interest of researchers.

This volume includes the results of a systematic effort to integrate our understanding of waste behavior and provide some guidance to researchers and practitioners in the field of waste mechanics. The authors of these chapters deserve to be complemented for the significant level of effort that they expended to make this volume a reality. I would also like to thank the Past and Present Chairs of the Geoenvironmental Engineering Technical Committee, Prof. Susan Burns from Georgia Tech and Prof. Krishna Reddy from the University of Illinois, Chicago, respectively, as well as the members of the Geoenvironmental Technical Committee for their support to the symposium and this volume. I would also like to thank, Anna Kathleen James, undergraduate student in the Department of Civil and Environmental Engineering of the University of Michigan, for her valuable assistance in the final states of the preparation of this volume.

In reviewing this volume and its content, one realizes that, indeed, a lot of progress has been made, but there is still much to be learned. An improved understanding of waste mechanics will allow our Profession to make a valuable contribution to society by improving our waste disposal practices nationally and worldwide.

Dimitrios Zekkos
Editor
Assistant Professor
Dept. of Civil and Environmental Engineering
University of Michigan
Ann Arbor
July 2010

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