45 Geotechnical Testing Journal

TECHNICAL EDITOR

Dr. Vincent P. Drnevich University of Kentucky Department of Civil Engineering 212 Anderson Hall Lexington, KY 40506 606-257-1958

EDITORIAL BOARD

Dr. Gualtiero Baldi I.S.M.E.S. Viale Giulio Cesare 29 24100 Bergamo, Italy

Dr. Stephen F. Brown University of Nottingham Dept. of Civil Engineering University Park. Nottingham United Kingdom NG7 2RD

Mr. Willard L. De Groff, *Test Tips Ed.* McClelland Engineers, Inc. Box 740010 Houston, TX 77274

Dr. Charles J. Haas Professor of Mining Engineering Rock Mechanics and Explosives Research Center University of Missouri—Rolla Rolla, MO 65401

Mr. Paul C. Knodel U.S. Bureau of Reclamation Box 25007, Denver Federal Ctr. Denver, CO 80225

Dr. Suzanne Lacasse Norwegian Geotechnical Institute P.O. Box 40, Taasen Oslo 8, Norway

Dr. W. Allen Marr GEOCOMP Corporation 342 Sudbury Road Concord, MA 01742

Dr. K. Rainer Massarsch Franki International Rue Gretry 196 B-4020 Liege, Belgium Dr. Paul W. Mayne Law Engineering Testing Company P.O. Box Drawer QQ McClean, VA 22101

Dr. Syd S. Peng College of Mineral and Energy Resources West Virginia University Morgantown, WV 26506

Dr. John F. Peters, Book Review Ed., Soil Mechanics U.S. Army Corps of Engineers Waterways Exp. Sta. P.O. Box 631 Vicksburg, MS 39180 Dr. Harry C. Poulos Sydney University School of Civil and Mining Engineering Sydney NSW. Australia 2006

Dr. Steve J. Poulos Geotechnical Engineers, Inc. 1017 Main St. Winchester, MA 01890

Dr. Ernest T. Selig, Past Technical Editor University of Massachusetts Marston Hall 235 Amherst, MA 01003

Mr. Woodland G. Shockley Chairman of Committee D-18 326 Lakehill Drive Vicksburg, MS 39180

Dr. Vincent Silvestri Ecole Polytechnique, Montreal Univ. P.O. Box 6079 A Montreal, Quebec, Canada H3C 3A7

Dr. Stein Sture Dept. of Civil Engineering University of Colorado at Boulder Boulder, CO 80309

Mr. L. David Suits, *D-35 News Ed.* New York State Dept. of Transportation 1220 Washington Avenue Albany, NY 12232

Dr. Fumio Tatsuoka
Assoc. Prof. of Geotechnical Engineering
University of Tokyo
22-1, Roppongi 7 Chome
Minato-ku, Tokyo 106, Japan
Mr. Carl D. Tockstein, *D-18 News Ed.*Supervisor Geotechnical Engineering Sec.
Tennessee Valley Authority
400 W. Summit Hill Drive

Dr. Shou-I Tsien Institute of Mechanics Chinese Academy of Sciences Beijing, People's Republic of China

Knoxville, TN 37902

Purpose and Scope

The purpose of the Geotechnical Testing Journal is (1) to provide a publication of quality that informs the profession of new developments in soil and rock testing and related fields; (2) to provide a forum for the exchange of information, particularly that which leads to the development of new test procedures or improves existing procedures; and (3) to stimulate active participation of the profession in the work of ASTM Committee D-18 on Soil and Rock.

The editorial scope of this journal includes papers, technical notes, letters to the editor, discussions of previously published papers, and book reviews that deal with test methods for soil and rock for engineering purposes. Similar material covering sampling, nomenclature, and practices relating to the determination of properties and behavior of soil and rock for engineering purposes will be included. Topics of interest include new testing equipment, apparatus, and procedures for both field and laboratory applications, evaluation of existing ASTM standards and recommendations for new standards for apparatus or test procedures, and test results that give insights into test procedures and techniques. Topics must be related to soil and rock, but can include highway materials testing, such as aggregate properties or pavement performance measurement, and geophysical exploration.

The American Society for Testing and Materials is not responsible, as a body, for the statements and opinions advanced in this publication.

Geotechnical Testing Journal (ISSN 0149-6115) is published quarterly by ASTM as part of the Testing and Evaluation Series, which includes the *Journal of Testing and Evaluation* (published bimonthly) and *Cement. Concrete*, and *Aggregates* (published semiannually). Publication at the Headquarters of the Society. 1916 Race St., Philadelphia, PA 19103

Subscriptions: United States and Canada for 1 year \$38.00 (members \$28.00), for 2 years \$66.00 (members \$48.00), for 3 years \$87.00 (members \$60.00). Foreign for 1 year \$43.00 (members \$28.00), for 2 years \$76.00 (members \$56.00), for 3 years \$102.00 (members \$72.00). Single copies are \$14.00. To subscribe, please send prepaid order to ASTM. Subscription Dept.—GTJ, 1916 Race St., Philadelphia, PA 19103. The Geotechnical Testing Journal is indexed regularly by Engineering Index, Inc., and is available on microfilm from University Microfilms, a Xerox company. Ann Arbor, MI. Copyright 1986 by the American Society for Testing and Materials.

Permission to Copy: The appearance of the code at the bottom of the first page of an article in this journal indicates the copyright owner's consent that copies of the article may be made for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition, however, that the copier pay the stated per-copy fee through the Copyright Clearance Center, Inc., Operations Office, P.O. Box 765, Schenectady, NY 12301, for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law. (The per copy fee appears as the last four digits of the code at the bottom of the first page of each article.) This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale. Further information may be obtained from the Copyright Clearance Center's Administrative Office, 310 Madison Ave., New York, NY 10017 (212/697-2525).

Change of Address: Please return entire addressing label on wrapper to ASTM, Subscription Dept.—GTJ, 1916 Race St., Philadelphia, PA 19103.

ASTM

Editorial Staff

Susan L. Gebremedhin, Senior Assistant Editor
Bette Grugan, Secretary, Acquisition & Review
Kathy Greene, Manager, Acquisition & Review
Bill Benzing, Manager, Editorial
Janet R. Schroeder, Managing Editor
M. Bruce Vieth, Manager of Production
Robert L. Meltzer, Vice-President, Publications and Marketing

Officers

Gladys B. Berchtold, *Chairman*Robert Baboian, *Vice-Chairman*W. DeWayne France, Jr., *Vice-Chairman*David M. Greason, *Treasurer*Joseph G. O'Grady, *President*

DIRECTORS

Kenneth E. Benson John F. McLaughlin John A. Blair John A. Millane Jack A. Bono Thomas D. Moreland F. Greg Clarke Donald M. Preiss Howard I. Forman Theodore P. Pritsker Kenneth L. Reifsnider John A. Gilligan John A. Heslip Peter E. Schilling John W. Lyons Richard A. Stimson Robert W. Macdonald Conrad J. J. Zellweger

PAST CHAIRMEN DIRECTORS

Robert J. Redelfs Lendell E. Steele

Committee on Publications

Robert C. Deen, Chairman
Kenneth L. Reifsnider,
Vice-Chairman
John M. Barsom
Edward P. Bartkus,
Ex-officio
Shéldon W. Dean
William G. Dukek
Richard Kimerle
Edwin L. Lewis
Leonard Mordfin
James S. Perrin
Clifford G. Scott
Pamela G. Sullivan

Robert E. White

Information for Authors

Contributions to the *Geotechnical Testing Journal* are subject to peer review, in accordance with the policy established by the ASTM Committee on Publications. The paper must either contribute to the permanent literature or be of immediate interest to ASTM membership. The subject matter must not be of a speculative nature and the contents must not include materials of an advertising nature. The paper must not be seriously defective as to literary form and structure, continuity of thought, and clarity of expression. The substance of the paper should not have been published previously in the open literature.

Authors preparing papers for submittal should observe the conventions of style explained in the ASTM Style Manual. Since the journal does not request page charges, the author is expected to conform to these standard conventions for style. SI units are to be used throughout; if data were not measured in SI units, a note should appear to that effect and the original units should be included in parentheses after the SI units. Key words should be chosen in accordance with the latest edition of ASTM D 3584. Recommended Practice for Indexing Papers and Reports on Soil and Rock for Engineering Purposes.

The original manuscript and four clear copies, including original illustrations, should be submitted to Kathy Greene, Manager, Acquisitions and Review, ASTM, 1916 Race St., Philadelphia, PA 19103. Papers are eligible for the following ASTM awards: the C. A. Hogentogler Award (papers on soils for engineering purposes), the Sanford E. Thompson Award (papers on concrete and concrete aggregates), and the Richard L. Templin Award (papers on new and useful testing procedures and apparatus).

General

This publication is one of many issued by ASTM in connection with its work in promoting knowledge of the properties and performance of materials, products, systems, and services, as well as in developing standard specifications and test measurement techniques to establish their value. Much of the information results from the voluntary contributions of many of the country's leading technical authorities from industry, scientific agencies, and government. A list of publications and information on the work of ASTM will be furnished on request.

In Appreciation

The high quality of the papers that appear in this publication is a tribute not only to the obvious efforts of the authors represented but to the unheralded, though essential, efforts of their reviewers. It is to the reviewers' dedication to upholding the high standards of their profession that this note pays tribute. On behalf of ASTM and the authors as well, we acknowledge with appreciation their important contribution to the success of this journal.