

*Significance
of Tests and
Properties of*

Concrete and Concrete-Making Materials

*Paul Klieger and
Joseph F. Lamond
editors*



STP 169C

STP 169C

Significance of Tests and Properties of Concrete and Concrete-Making Materials

**Paul Klieger and Joseph F. Lamond,
editors**

ASTM Publication Code Number (PCN)
04-169030-07



ASTM
1916 Race Street
Philadelphia, PA 19103
Printed in the U.S.A.

Library of Congress Cataloging-in-Publication Data

Significance of tests and properties of concrete and concrete-making materials / Paul Klieger and Joseph F. Lamond, editors. —4th ed.

(STP ; 169c)

"ASTM publication code number (PCN) 04-169030-07."

Includes bibliographical references and index.

ISBN 0-8031-2053-2

1. Concrete—Testing. I. Klieger, Paul. II. Lamond, Joseph F., 1933- . III. Series: ASTM special technical publication; 169c.

TA440.S556 1994

620.1'36'0287—dc20

94-16746

CIP

Copyright © 1994 AMERICAN SOCIETY FOR TESTING AND MATERIALS, Philadelphia, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

Photocopy Rights

Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by the AMERICAN SOCIETY FOR TESTING AND MATERIALS for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$2.50 per copy, plus \$0.50 per page is paid directly to CCC, 222 Rosewood Dr., Danvers, MA 01923; Phone: (508) 750-8400; Fax: (508) 750-4744. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Service is 0-8031-2053-2/94 \$2.50 + .50.

Peer Review Policy

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

Printed in Fredericksburg, VA
August 1994

Foreword

This publication is a revision and expansion of *Significance of Tests and Properties of Concrete and Concrete-Making Materials (STP 169B)* published in 1978. That publication in turn replaced editions of *Report on Significance of Tests of Concrete and Concrete Aggregates* published in 1935, 1943, 1956, and 1966. The present publication includes a number of new materials and test methods which have been developed, or materials which have increased in importance since the 1978 edition. A most useful addition is the inclusion of two new chapters on cement prepared by authors who are members of ASTM Committee C1 on Cement. Previous editions did not contain chapters specifically devoted to cement.

As in the previous publications, chapters have been authored by individuals selected on the basis of their knowledge of their subject areas, and in most cases because of their participation in the development of pertinent specifications and test methods by ASTM Committee C9, and in some cases by ASTM Committee C1. Authors developed their chapters in conformance with general guidelines only. Each chapter has been reviewed and, where necessary, coordinated with chapters where overlap of subject matter might occur.

This latest edition, has been developed under the direction of the Executive Committee of ASTM Committee C9 on Concrete and Aggregates by coeditors Paul Klieger, Consultant on Concrete and Concrete Materials, and Joseph F. Lamond, Consulting Engineer, both members of ASTM Committee C9.

Contents

CHAPTER 1—Introduction—PAUL KIEGER AND JOSEPH F. LAMOND	1
PART I	
GENERAL	
CHAPTER 2—The Nature of Concrete—RICHARD A. HELMUTH	5
CHAPTER 3—Techniques, Procedures, and Practices of Sampling of Concrete and Concrete-Making Materials— EDWARD A. ABDUN-NUR AND TOY S. POOLE	15
CHAPTER 4—Statistical Considerations in Sampling and Testing— GARLAND W. STEELE	23
CHAPTER 5—Variability of Concrete-Making Materials— ANTHONY E. FIORATO	31
CHAPTER 6—The Role of Cement and Concrete Testing Laboratories—JAMES H. PIELERT	38
CHAPTER 7—Research Needs—W. L. DOLCH	42
PART II	
FRESHLY MIXED CONCRETE	
CHAPTER 8—Factors Influencing Concrete Workability— JOHN M. SCANLON	49
CHAPTER 9—Air Content, Temperature, Unit Weight, and Yield— LAWRENCE R. ROBERTS	65
CHAPTER 10—Making and Curing Concrete Specimens— JOSEPH F. LAMOND	71
CHAPTER 11—Time of Setting—VANCE H. DODSON	77
CHAPTER 12—Bleeding—STEVEN H. KOSMATKA	88
CHAPTER 13—Cement and Water Content of Fresh Concrete— DEBORAH J. LAWRENCE	112
PART III	
HARDENED CONCRETE	
CHAPTER 14—Concrete Strength Testing—PEGGY M. CARRASQUILLO	123
CHAPTER 15—Prediction of Potential Concrete Strength at Later Ages—NICHOLAS J. CARINO	140
CHAPTER 16—Freezing and Thawing—HOWARD NEWLON, JR., AND TERRY M. MITCHELL	153
CHAPTER 17—Corrosion of Reinforcing Steel—WILLIAM F. PERENCHIO	164
CHAPTER 18—Embedded Metals and Materials Other Than Reinforcing Steel—BERNARD ERLIN	173
CHAPTER 19—Abrasion Resistance—TONY C. LIU	182
CHAPTER 20—Elastic Properties and Creep—ROBERT E. PHILLO	192
CHAPTER 21—Bond with Reinforcing Steel—LEROY A. LUTZ	202
CHAPTER 22—Petrographic Examination—BERNARD ERLIN	210
CHAPTER 23—Volume Change—P. KUMAR MEHTA	219
CHAPTER 24—Thermal Properties—JOHN M. SCANLON AND JAMES E. MCDONALD	229

CHAPTER 25—Pore Structure and Permeability— NATALIYA HEARN, R. DOUGLAS HOOTON, AND RONALD H. MILLS	240
CHAPTER 26—Chemical Resistance of Concrete— G. W. DEPUY	263
CHAPTER 27—Resistance to Fire and High Temperature— PETER SMITH	282
CHAPTER 28—Air Content and Unit Weight of Hardened Concrete— KENNETH C. HOVER	296
CHAPTER 29—Analyses for Cement and Other Materials in Hardened Concrete— WILLIAM G. HIME	315
CHAPTER 30—Nondestructive Tests— V. MOHAN MALHOTRA	320

PART IV

CONCRETE AGGREGATES

CHAPTER 31—Petrographic Evaluation of Concrete Aggregated— RICHARD C. MIELENZ	341
CHAPTER 32—Alkali-Silica Reactions in Concrete— DAVID STARK	365
CHAPTER 33—Alkali-Carbonate Rock Reaction— MICHAEL A. OZOL	372
CHAPTER 34—Degradation Resistance, Strength, and Related Properties— RICHARD C. MEININGER	388
CHAPTER 35—Grading, Shape, and Surface Properties— JOSEPH E. GALLOWAY, JR.	401
CHAPTER 36—Soundness, Deleterious Substances, and Coatings— STEPHEN W. FORSTER	411
CHAPTER 37—Unit Weight, Specific Gravity, Absorption, and Surface Moisture— ROBERT LANDGREN	421
CHAPTER 38—The Pore System of Coarse Aggregates— DOUGLAS WINSLOW	429
CHAPTER 39—Thermal Properties of Aggregated— D. STEPHEN LANE	438

PART V

OTHER CONCRETE MAKING MATERIALS

CHAPTER 40—Hydraulic Cements—Physical Properties— LESLIE STRUBLE AND PETER HAWKINS	449
CHAPTER 41—Hydraulic Cement—Chemical Properties— SHARON M. DEHAYES	462
CHAPTER 42—Mixing and Curing Water for Concrete— JAMES S. PIERCE	473
CHAPTER 43—Curing and Curing Materials— EPHRAIM SENBETTA	478
CHAPTER 44—Air-Entraining Admixtures— PAUL KIEGER	484
CHAPTER 45—Chemical Admixtures— BRYANT MATHER	491
CHAPTER 46—Mineral Admixtures— CRAIG J. CAIN	500

PART VI

SPECIALIZED CONCRETES

CHAPTER 47—Ready Mixed Concrete— RICHARD D. GAYNOR	511
CHAPTER 48—Lightweight Concrete and Aggregates— THOMAS A. HOLM	522
CHAPTER 49—Cellular Concrete— LEO A. LEGATSKI	533
CHAPTER 50—Concrete for Radiation Shielding— DOUGLAS E. VOLKMAN	540
CHAPTER 51—Fiber-Reinforced Concrete— COLIN D. JOHNSTON	547
CHAPTER 52—Preplaced Aggregate Concrete— RAYMOND E. DAVIS, JR.	562
CHAPTER 53—Roller-Compacted Concrete (RCC)— KENNETH L. SAUCIER	567
CHAPTER 54—Polymer-Modified Concrete and Mortar— LOU A. KUHLMANN AND MICHAEL O'BRIEN	577
CHAPTER 55—Shotcrete— I. LEON GLASSGOLD	589
CHAPTER 56—Organic Materials for Bonding, Patching, and Sealing Concrete— RAYMOND J. SCHUTZ	599
CHAPTER 57—Packaged, Dry, Cementitious Mixtures— OWEN BROWN	604

INDEXES

Subject Index	611
----------------------	-----



Paul Klieger

Before establishing his own consulting firm in 1986, Paul Klieger was employed by the Portland Cement Association (PCA) for forty five years. Mr. Klieger received a BS degree in Civil Engineering from the University of Wisconsin at Madison. He is a registered Professional Engineer in the state of Illinois.

While at PCA, he accomplished research and development work relative to the properties of materials used in concrete and their influence on the strength and performance of concrete in a variety of environments. Special emphasis was placed on durability in severe environments such as freezing and thawing, sulfate soils and waters, and seawater. Other assignments dealt with problems associated with corrosion of reinforcing steel in concrete and possible deleterious reactions between cement alkalis and certain siliceous and carbonate aggregates.

While with the Construction Technology Laboratories, Inc. division of PCA, he managed and conducted contract research, development, and consulting activities related to evaluation of the performance of concrete and masonry in field structures, including laboratory studies required to resolve performance problems. His research included the suitability of cements, admixtures, and aggregates; sulfate attack; alkali-aggregate reactions; corrosion of reinforcing steel; seawater exposure; freezing and thawing, and deicer scaling; and the use of fly ashes, ground slags, and silica fume in concretes.

Mr. Klieger is a Fellow and Honorary Member of the American Concrete Institute, a Fellow of the American Society for Testing and Materials, and an Honorary Member of ASTM Committee C-9 on Concrete and Concrete Aggregates. He is also active with the Prestressed Concrete Institute and the Transportation Research Board.

Mr. Klieger continues his interests as a Consultant on concrete and concrete materials and serves as an expert witness in litigation.



Joseph F. Lamond

Since 1990, Joe Lamond has been a Consulting Engineer in Springfield, Virginia specializing in the field of concrete, concrete materials, and concrete construction. He received his Civil Engineering degree from the University of Massachusetts at Dartmouth and is a Registered Professional

Engineer in the Commonwealth of Massachusetts.

Mr. Lamond was employed by the U.S. Army Corps of Engineers and was involved in the design and construction of concrete materials for the Army, Air Force, and Civil Works projects. There he developed guide specifications and design criteria for mass concrete, roller-compacted and structural concrete for the construction of dams and flood protection concrete structures and rehabilitation of existing structures. He retired in May 1989 as Chief Materials Engineer.

Mr. Lamond was also Engineering Director for the Pyrament Division of Lone Star Industries, Inc. He was project manager for the structures program on chloride-induced corrosion in bridges for the Strategic Highway Research Program.

Mr. Lamond is a Fellow of the American Concrete Institute and served on the Board of Direction from 1989-1992. He is Chairman of the Fellows Nominating Committee and actively serves on five technical committees. As a member of the American Society for Testing and Materials he serves on seven subcommittees and is Chairman of the Subcommittee on Testing Concrete for Strength. Mr. Lamond is also a member of the Transportation Research Board, the International Concrete Repair Institute, and is listed in *Who's Who in Science and Engineering*.