



Applied Mineralogy

Technische Mineralogie

Edited by
Herausgegeben von

V. D. Fréchet, Alfred, N. Y.

H. Kirsch, Essen

L. B. Sand, Worcester, Mass.

F. Trojer, Leoben

9

Springer-Verlag
Wien New York 1976



W. E. Brownell

Structural Clay Products

Springer-Verlag
Wien New York 1976



WAYNE ERNEST BROWNELL, B. S., M. S., Ph. D.
Professor of Ceramic Science
New York State College of Ceramics at Alfred University
Alfred, N. Y., U. S. A.

With 120 partly colored Figures

This work is subject to copyright.

All rights are reserved, whether the whole or part
of the material is concerned, specifically those of translation,
reprinting, re-use of illustrations, broadcasting,
reproduction by photocopying machine or similar means,
and storage in data banks.

© 1976 by Springer-Verlag/Wien

Softcover reprint of the hardcover 1st edition 1976

Library of Congress Cataloging in Publication Data. Brownell, Wayne E. Structural clay products. (Applied mineralogy; v. 9.) Includes bibliographies and index. 1. Ceramics. 2. Ceramic materials. I. Title. TP825.B76. 666. 76-40216

ISBN-13:978-3-7091-8451-6

e-ISBN-13:978-3-7091-8449-3

DOI: 10.1007/978-3-7091-8449-3

Preface

Structural clay products have had a place in the history of civilization like bread and cloth. Probably because the industry has been so commonplace in the lives of people, little has been written about it; even the history of its development is sketchy. There is no other book quite like this in publication at present, and it is prompted now because much general scientific knowledge can be, and is, applied to the manufacture of structural clay products. This book is an attempt to bring together in one place the basic sciences that can be useful in all of the processes and experiences of the clayworker.

This volume was written primarily as a text to be used in courses for third and fourth year college students; however, there will be a broader interest in it by industrial foremen, engineers, architects, and scientists employed in the manufacture, research and use of structural clay products. It will also be a source of general information for those interested in entering the field. The treatment of the basic principles of clay products manufacturing and use is so general that even those interested in refractories, whitewares, and pottery may find many parts useful to them.

Structural Clay Products organizes and applies scientific and engineering principles to each production step in the order of its occurrence. It starts with the selection of raw materials and ends with in-service problems and a survey of the present state of the industry in the United States of America. The mathematics introduced has been kept to a minimum and only employed where it can actually be used to solve practical problems or to assist in understanding the scientific principles involved in the various processes. As one goes through this book, it will become obvious that the basic principles of mineralogy are extremely important in the production of high-quality clay products.

I am indebted to many people and organizations for direct contributions to this volume and/or advice, criticism, and encouragement in its preparation. First, I would like to thank my wife, Vivian, for reading and questioning the manuscript; then I must acknowledge the assistance of my technical editor, Dr. Van Derck Fr chet te, who made this volume easier to understand and more readable. During the industrial survey at the start of this project, all persons extended to me the greatest hospitality, assistance, and encouragement. The structural clay products industry in the United States is operated by some of the finest people in the world. The following organizations were particularly helpful:

American Olean Tile Company

The Belden Brick Company

The Bonnot Company
Can-Tex Industries, Division of Harsco Corp.
The Fate-Root-Heath Company
General Shale Products Corporation
Glen-Gery Corporation
J. C. Steele and Sons
K-F Brick Company
Merry Companies
National Clay Pipe Institute
National Sewer Pipe Limited
North American Manufacturing Company
Robinson Industries
Swindell-Dressler Company

Alfred, September 1976

WAYNE E. BROWNELL

Contents

| | |
|--|----|
| 1. History and Classification | 1 |
| 1.1. Early History | 1 |
| 1.2. Industrial Revolution | 6 |
| 1.3. Scientific Revolution | 12 |
| 1.4. Classification of Structural Clay Products | 18 |
| References | 22 |
| 2. Mineralogical Composition of Structural Clay Products | 24 |
| 2.1. Structure of Disilicate Minerals | 24 |
| 2.2. Classification of Disilicate Minerals | 30 |
| 2.3. Essential Minerals | 36 |
| 2.4. Nonessential Minerals | 37 |
| 2.5. Typical Compositions | 39 |
| References | 41 |
| 3. Raw Materials and Processing | 43 |
| 3.1. Mining | 43 |
| 3.1.1. Exploration for Raw Materials | 43 |
| 3.1.2. Testing and Evaluation of Deposits | 45 |
| 3.1.3. Mining Procedures | 47 |
| 3.1.4. Mining Pollution Controls | 50 |
| 3.2. Raw Material Processing | 50 |
| 3.3. Particle-Size Distribution | 55 |
| 3.4. Dust Pollution Controls | 60 |
| 3.5. Blending and Additives | 61 |
| References | 62 |
| 4. Forming of Structural Clay Products | 63 |
| 4.1. Structure and Properties of Water | 63 |
| 4.2. Clay-Water Interaction | 69 |
| 4.3. Plasticity of Clays | 74 |
| 4.4. Plastic Forming Methods | 82 |

| | | |
|------------|---|-----|
| 4.4.1. | Plasticity in Forming | 82 |
| 4.4.2. | Soft-Mud Process | 83 |
| 4.4.3. | Stiff-Mud Process | 85 |
| 4.4.4. | Plastic Pressing | 95 |
| 4.4.5. | Cutting of Extruded Columns | 95 |
| 4.4.6. | Automatic Hacking of Bricks | 97 |
| 4.4.7. | Dry-Press Forming | 98 |
| References | | 99 |
| 5. | Drying Process | 101 |
| 5.1. | Fundamentals of Drying Clay Bodies | 101 |
| 5.2. | Shrinkage, Stresses, and Strength | 109 |
| 5.3. | Practical Drying Schedules | 112 |
| 5.4. | Types of Dryers and Energy Sources | 115 |
| 5.4.1. | Periodic and Continuous Dryers | 115 |
| 5.4.2. | Energy Sources | 117 |
| 5.5. | Heat Balance in Dryers | 119 |
| 5.6. | Scum Development | 121 |
| References | | 124 |
| 6. | Firing Process | 126 |
| 6.1. | High-Temperature Reactions in Disilicate Minerals | 126 |
| 6.2. | Reactions in Typical Clay Bodies | 132 |
| 6.3. | Influences of Kiln Atmospheres | 142 |
| 6.3.1. | Kiln Atmospheres | 142 |
| 6.3.2. | Oxidation-Reduction | 144 |
| 6.3.3. | Oxidation of Carbon and Pyrite | 145 |
| 6.3.4. | Color Development and Control | 149 |
| 6.4. | Types of Kilns | 150 |
| 6.5. | Kiln Firing | 154 |
| 6.6. | Burner Systems | 156 |
| 6.7. | Cooling Stresses | 160 |
| References | | 162 |
| 7. | Decoration, Panels, and Packaging | 165 |
| 7.1. | Sanded Surfaces | 165 |
| 7.2. | Texturing of Extruded Bricks | 166 |
| 7.3. | Coating Decorations | 171 |
| 7.3.1. | Engobes and Slurries | 171 |
| 7.3.2. | Glazes | 173 |
| 7.4. | Panelling | 175 |
| 7.5. | Packaging | 176 |
| References | | 177 |

| | |
|--|-----|
| 8. Jointing of Vitrified Clay Sewer Pipe | 178 |
| 8.1. Factory Installed Jointing Units | 178 |
| 8.2. Requirements for Good Joints | 178 |
| 8.3. Types of Compression Joints | 179 |
| 8.3.1. Polyvinyl Chloride Joints | 179 |
| 8.3.2. Polyester Joints | 181 |
| 8.3.3. Polyurethane Joints | 184 |
| 8.3.4. Jointing of Plain-End Pipes | 185 |
| 8.4. Specifications and Tests for Vitrified Clay Pipe Joints | 187 |
| References | 187 |
| 9. Quality Control | 188 |
| 9.1. Philosophy | 188 |
| 9.2. Nature of the Quality-Control Program | 189 |
| 9.3. Procedure | 190 |
| 9.4. Statistical Approach | 191 |
| References | 192 |
| 10. Plant Layout and Design | 193 |
| 10.1. Predesign Planning | 193 |
| 10.2. Factors Affecting Plant Design | 194 |
| 10.3. Planning for Starting the Plant | 197 |
| References | 197 |
| 11. Serviceability and Durability | 198 |
| 11.1. Serviceability of Structural Clay Products | 198 |
| 11.2. Durability of Bricks and Roofing Tiles | 198 |
| 11.3. Durability of Sewer Pipes | 203 |
| 11.4. Moisture Expansion | 203 |
| 11.5. Bonding of Mortar to Bricks and Tiles | 205 |
| 11.6. Efflorescence and Staining of Brickwork | 206 |
| 11.7. Cleaning Brickwork | 209 |
| References | 210 |
| 12. Future Trends | 212 |
| 12.1. Production | 212 |
| 12.2. Technical Changes | 216 |
| 12.3. Research of the Future | 218 |
| 12.4. Summary | 219 |
| References | 220 |
| Subject Index | 221 |