

PREFACE

A basic function of civil and construction engineering is to provide and maintain the infrastructure needs of society. The infrastructure includes buildings, water treatment and distribution systems, waste water removal and processing, dams, and highway and airport bridges and pavements. Although some civil and construction engineers are involved in the planning process, most are concerned with the design, construction, and maintenance of facilities. The common denominator among these responsibilities is the need to understand the behavior and performance of materials. Although not all civil and construction engineers need to be material specialists, a basic understanding of the material selection process, and the behavior of materials, is a fundamental requirement for all civil and construction engineers performing design, construction, and maintenance.

Material requirements in civil engineering and construction facilities are different from material requirements in other engineering disciplines. Frequently, civil engineering structures require tons of materials with relatively low replications of specific designs. Generally, the materials used in civil engineering have relatively low unit costs. In many cases, civil engineering structures are formed or fabricated in the field under adverse conditions. Finally, many civil engineering structures are directly exposed to detrimental effects of the environment.

The subject of engineering materials has advanced greatly in the last few decades. As a result, many of the conventional materials have either been replaced by more efficient materials or modified to improve their performance. Civil and construction engineers have to be aware of these advances and be able to select the most cost-effective material or use the appropriate modifier for the specific application at hand.

This text is organized into three parts: (1) introduction to materials engineering, (2)

characteristics of materials used in civil and construction engineering, and (3) laboratory methods for the evaluation of materials.

The introduction to materials engineering includes information on the basic mechanistic properties of materials, environmental influences, and basic material classes. In addition, one of the responsibilities of civil and construction engineers is the inspection and quality control of materials in the construction process. This requires an understanding of material variability and testing procedures. The atomic structure of materials is covered in order to provide basic understanding of material behavior and to relate the molecular structure to the engineering response.

The second section, which represents a large portion of the book, presents the characteristics of the primary material types used in civil and construction engineering: steel, aluminum, concrete, masonry, asphalt, wood and composites. Since the discussion of concrete and asphalt materials requires a basic knowledge of aggregates, there is a chapter on aggregates. Moreover, since composites are gaining wide acceptance among engineers and are replacing many of the conventional materials, there is a chapter introducing composites.

The discussion of each type of material includes information on the following:

Basic structure of the materials

- Material production process
- Mechanistic behavior of the material and other properties
- Environmental influences
- Construction considerations
- Special topics related to the material discussed in each chapter

Finally, each chapter includes an overview of various test procedures to introduce the test

methods used with each material. However, the detailed description of the test procedures is left to the appropriate standards organizations such as the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO). These ASTM and AASHTO standards are usually available in college libraries, and students are encouraged to use them. Also, there are sample problems in most chapters, as well as selected questions and problems at the end of each chapter. Answering these questions and problems will lead to a better understanding of the subject matter.

There are volumes of information available for each of these materials. It is not possible, or desirable, to cover these materials exhaustively in an introductory single text. Instead, this book limits the information to an introductory level, concentrates on current practices, and extracts information that is relevant to the general education of civil and construction engineers.

The content of the book is intended to be covered in one academic semester, although quarter system courses can definitely use it. The instructor of the course can also change the emphasis of some topics to match the specific curriculum of the department. Furthermore, since the course usually includes a laboratory portion, a number of laboratory test methods are described. The number of laboratory tests in the book is more than what is needed in a typical semester in order to provide more flexibility to the instructor to use the available equipment. Laboratory tests should be coordinated with the topics covered in the lectures so that the students get the most benefit from the laboratory experience.

The first edition of this textbook served the needs of many universities and colleges. Therefore, the second edition was more of a refinement and updating of the book, with some notable additions. Several edits were made to the steel chapter to improve the description of heat treatments, phase diagram, and the heat-treating effects of welding. Also, a section on stainless

steel was added, and current information on the structural uses of steel was provided. The cement and concrete chapters have been augmented with sections on hydration-control admixtures, recycled wash water, silica fume, self-consolidating concrete, and flowable fill. When the first edition was published, the SuperPave mix design method was just being introduced to the industry. Now SuperPave is a well-established method that has been field tested and revised to better meet the needs of the paving community. This development required a complete revision to the asphalt chapter to accommodate the current methods and procedures for both Performance Grading of asphalt binders and the SuperPave mix design method. The chapter on wood was revised to provide information on recent manufactured wood products that became available in the last several years. Also, since fiber reinforced polymer composites have been more commonly used in retrofitting old and partially damaged structures, several examples were added in the chapter on composites. In the laboratory manual, an experiment on dry-rodded unit weight of aggregate that is used in portland cement concrete (PCC) proportioning was added and the experiment on creep of asphalt concrete was deleted for lack of use.

In addition to the technical content revisions, there are over 100 new figures to display concepts and equipment. Multiple sample problems and homework problems have been added to each chapter to allow professors to vary assignments between semesters.

New to this edition

The third edition maintains the structure of the first two editions with several refinements and enhancements.

- Chapter 1 was augmented with a discussion of sustainable design and the “Leadership in Environment and Energy Design” concept is introduced.
- Chapter 2 was edited to enhance the clarity of the presentation of some topics.

However, the basic concepts presented in this chapter have not changed so the content is similar to the second edition.

- Chapter 3 was edited and updated.
 - Discussion of the open hearth furnace was removed since they are no longer used for steel production.
 - A section on cold-formed steel was added in recognition of the increased use of this product in the industry. Inclusion of cold-formed steel provides a practical example of the use of strain hardening to increase the strength of a material.
 - Information on the marking codes used for reinforcing steel was added.
- A sample problem was added to Chapter 4 to highlight the influence of the differences in the modulus of elasticity between steel and aluminum on the behavior of structures.
- Chapter 5 edits and revisions include:
 - Terminology for aggregate sizes was consolidated and moved to the front of the chapter.
 - The consensus aggregate properties required for SuperPave are defined and the test methods are described.
 - A robust method for preparing gradation charts using a spreadsheet program is presented in a sample problem.
- Chapter 6 was carefully reviewed for content and accuracy and minor changes were incorporated but the bulk of the chapter was unaltered.
- The key alteration to Chapter 7 was to clarify the appropriate use of maximum and

- nominal maximum aggregate size for PCC mix design.
- Chapter 8 was edited for technical content. The discussion of concrete masonry units and mortar was revised to comply with current practices.
 - Chapter 9 was fully edited to reflect the most recent changes on the industry.
 - Discussion of the Hveem mix design method was removed. The Marshall method was retained since it is still being used by local agencies and internationally.
 - Determination of bulk and maximum theoretical specific gravity was enhanced.
 - Polymer modified asphalt and recycling of asphalt concrete are more fully described.
 - Warm mix asphalt is a new addition to this edition of the book.
 - Asphalt concrete production and construction are more fully described.
 - Chapter 10 was edited to ensure the content reflects current industry practices. In particular, the discussion of Fiber Saturation Point and the associated shrinkage/swell problems with moisture changes was altered.
 - Chapter 11 was edited for technical content and current industry practices. In the laboratory manual, the experiment on testing of wood was modified to include flexure testing of structural size lumber.
 - In addition to the technical content revisions, there are many new figures to display concepts and equipment. Sample problems and homework problems have been either edited or new problems added to each chapter to allow professors to vary assignments between semesters.

The authors would like to acknowledge the contributions of many people who assisted with the development of this new edition. First, a blind review of the second edition was performed by five individuals. Since the review was blind we cannot recognize the individuals by name. However, the authors wish to thank those reviewers and recognize the fact that most of their suggestions have been incorporated into the third edition. The authors sought and received technical input from experts for several of the chapters; we sincerely appreciate their efforts. In particular, Mr. Steven Kosmatka of the Portland Cement Association, Mr. Jason Thompson of the National Concrete Masonry Association, Mr. Jeff Linville of the American Institute of Timber Construction, Mr. Mark Skidmore of West Virginia University, and Dr. Mofreh Saleh of the University of Canterbury provided much useful information and comments on various chapters. The photos provided by Mr. Chris Eagon of Axim Italcementi Group and Dave Kretschmann of the Forest Products Laboratory are appreciated. Appreciation also goes to Mr. Mena Souliman of Arizona State University for his contribution in the preparation of the solutions manual.