

MATERIALS FOR CIVIL AND CONSTRUCTION ENGINEERS



Fourth Edition



MICHAEL S. MAMLOUK
JOHN P. ZANIEWSKI

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FOURTH EDITION

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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 past 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 As a result, many of the conventional materials have either been replaced by more efficient materials or modified to improve their performance.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 past 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.

What's New in This Edition

The primary focus of the updates presented in this edition was on the sustainability of materials used in civil and construction engineering. The information on sustainability in Chapter 1 was updated and expanded to include recent information on sustainability. In addition, a section was added to Chapters 3 through 11 describing the sustainability considerations of each material. The problem set for each chapter was updated and increased to provide some fresh Exercises and to cover other topics discussed in the chapter. References were updated and increased in all chapters to provide students with additional reading on current issues related to different materials. Many figures were added and others were updated throughout the book to provide visual illustrations to students. Other specific updates to the chapters include:

- Chapter 1 now includes a more detailed section on viscoelastic material behavior and a new sample problem.
- Chapter 3 was updated with recent information about the production of steel.
- A sample problem was added to Chapter 5 about the water absorbed by aggregate in order to highlight the fact that absorbed water is not used to hydrate the cement or improve the workability of plastic concrete.
- Two new sample problems were added to Chapter 6 on the acceptable criteria of mixing water and to clarify the effect of water reducer on the properties of concrete.
- Chapter 7 was augmented with a discussion of concrete mixing water and a new sample problem. A section on pervious concrete was added to reflect the current practice on some parking lots and pedestrian walkways.
- Chapter 9 was updated with reference to the multiple stress creep recovery test, and the information about the immersion compression test was replaced with the tensile strength ratio method to reflect current practices. The selection of the binder was refined to incorporate the effect of load and speed. The section on the diametral tensile resilient modulus was removed for lack of use. The sample problem on the diametral tensile resilient modulus was also removed and replaced with a sample problem on the freeze-thaw test and the tensile strength ratio.

- Chapter 10 was updated to include more information about wood deterioration and preservation. The first two sample problems were edited to provide more accurate solutions since the shrinkage values used in wood are related to the green dimensions at or above the fiber saturation point (FSP), not the dry dimensions. The third sample problem was expanded to demonstrate how to determine the modulus of elasticity using the third-point bending test.
- Chapter 11 was updated to reflect information about the effective length of fibers and the ductility of fiber-reinforced polymers (FRP). The discussion was expanded with several new figures to incorporate fibers, fabrics, laminates, and composites used in civil engineering applications. The first sample problem was expanded to apply other concepts covered in the chapter.
- The laboratory manual in the appendix was updated to include two new experiments on creep in polymers and the effect of fiber orientation on the elastic modulus of fiber reinforced composites. The experiment on the tensile properties of composites was updated. This would allow more options to the instructor to choose from in assigning lab experiments to students.

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