Construction Materials

土木工程材料

Zongjin Li, Yamei Zhang, Chris Leung, Yunsheng Zhang, Huisu Chen

李宗津　张亚梅　梁坚凝　张云升　陈惠苏

中国建筑工业出版社
CHINA ARCHITECTURE & BUILDING PRESS

Construction Materials

土木工程材料

Zongjin Li, Yamei Zhang, Chris Leung,
Yunsheng Zhang, Huisu Chen

李宗津　张亚梅　梁坚凝　张云升　陈惠苏

中国建筑工业出版社

China g Press

图书在版编目(CIP)数据

Construction Materials 土木工程材料/李宗津等.
—北京：中国建筑工业出版社，2014.8
ISBN 978-7-112-17053-1

Ⅰ.①土… Ⅱ.①李… Ⅲ.①土木工程-建筑材料-英文 Ⅳ.①TU5

中国版本图书馆CIP数据核字(2014)第150232号

责任编辑：刘 江 万 李
责任设计：董建平
责任校对：陈晶晶 刘梦然

Construction Materials
土木工程材料
Zongjin Li，Yamei Zhang，Chris Leung，
Yunsheng Zhang，Huisu Chen
李宗津 张亚梅 梁坚凝 张云升 陈惠苏
*
中国建筑工业出版社出版、发行(北京西郊百万庄)
各地新华书店、建筑书店经销
北京红光制版公司制版
北京同文印刷有限责任公司印刷
*
开本：787×1092毫米 1/16 印张：22½ 字数：560千字
2014年8月第一版 2014年8月第一次印刷
定价：**49.00**元
ISBN 978-7-112-17053-1
(25247)

PREFACE

Construction materials are the most widely used materials in the world. They are used to construct different infrastructure and private buildings, for both structural and non-structural applications. Understanding the composition, processing methods, mechanical properties and general performance of construction materials are essential for civil engineering students to meet the need in professional careers. Due to the rapid development in construction materials, the content of conventional text book in construction materials field needs to be updated. The motivation to write this book is try to fill in the vacancy by introducing new types of materials, new processing methodologies, new testing methods for property assessment, and innovative developments in technology. The unique features of this book include the introduction of basic mechanical behavior of the materials, emphasized fundamental exploration of materials composition and microstructure, and state of art of construction materials development and innovations. This book provides more comprehensive knowledge on construction materials technology including the systematic introduction of fibrous composite materials and functional cement-based materials.

The book is divided into ten chapters. Chapter 1 gives a brief introduction of construction materials, including its historic development, structural materials definition, materials physical and chemical properties, and new development trend of the construction materials. Chapter 2 provides the knowledge of mechanical behavior of construction materials, covering elastic, plastic, creep, fracture and fatigue. Chapter 3 discusses the properties of aggregates, focusing on grading and moisture content. Chapter 4 focuses on the binding materials such as non-hydraulic and hydraulic cement. Emphases are on the Portland cement. Chapter 5 covers the contents of concrete, the most important construction material. The chapter discusses the properties of concrete in both fresh and hardened stage. New testing method of noncontact resistivity measurement is introduced. Chapter 6 provides updated knowledge on steel, including corrosion protection and steel recycling. Chapter 7 introduces the basic knowledge of fibrous composites from their composition, mechanics to the application. It is new content for construction materials. Chapter 8 covers the essential knowledge of wood on its properties and applications. In chapter 9, the pavement materials have been introduced with the emphases on the asphalt concrete. Finally, chapter 10 discusses the non-structural materials, in which the functional materials are new in a book of construction materials.

The book is designed and written primarily to meet the teaching needs for undergraduate students in civil engineering and materials engineering. However, it can serve as a reference or a guide for professional civil engineers in their practice.

In the process of writing this book, the authors received enthusiastic help and invaluable assistance from many people, which are deeply appreciated. The authors would like to express their special thanks to Dr. Yu Zhu, Miss Yu Cheng and for their help in editing the book draft. Mr. Mike Pomfret is acknowledged for his professional page proof reading.

The support from China Basic Research Grant, Basic Research on Environmentally Friendly Contemporary Concrete (2009CB623200) is greatly acknowledged.

Zongjin Li , Yamei Zhang, Chris Leung, Yunsheng Zhang, Huisu Chen

Content

Chapter 1 Introduction

1.1 Historic development

The earth is composed of various materials. Materials science and engineering serves as the base for all technology branches such as electronics, energy, communication, environment, and health engineering. Construction materials are the most widely used materials and their usage is the largest in terms of tonnage in the world.

Through the history of human civilization, many materials such as clay, brick, rock, concrete, wood and steel have been used in the construction of buildings, bridges, roads and other structures. According to their load-carrying function in structures, construction materials can be divided into structural materials and non-structural materials. Structural materials carry not only their own self-weight, but also loads being transferred from other components of buildings or infrastructures. On the other hand, non-structural materials only carry their own weight. Non-structural materials include floor and wall coverings, tiles, glass, insulation materials, sealants and paint or coatings. Most of them are specified for protection, aesthetic and architectural purposes by the architect or the interior designer.

The focus of this book is on modern structural materials including concrete, steel, wood, bituminous materials as well as polymers and fibrous composites. Among these materials, concrete will receive the most attention for two reasons. First, the civil engineer is responsible for designing the concrete he/she uses and for ensuring its long term performance. It should be pointed out that steel and wood products are designed by material and mechanical engineers, who supply them to civil engineers according to their specifications. Second, concrete (reinforced concrete) is the most widely-used construction material in the world.

Besides concrete, steel and wood are the other two most commonly-used construction materials in the world. In the US, for example, most residential houses are built with wood and over half of the office buildings are constructed with steel. This is due to the abundant supply of both materials, making them economical. Steel, besides its use as structural members on its own, is also used as reinforcements or prestressed tendons for concrete structures. Understanding steel behavior is hence an important component in the study of reinforced concrete and prestressed concrete design. Bituminous materials are used all over the world in the construction of road pavements. In recent years, polymers and polymeric composites have been gaining popularity in the construction industry, due to their light weight and good durability. Polymers have been used in pipes, fabrics for roofing as well as geotextiles for slope protection. Reinforcing bars and grids have been made with fiber reinforced composites to replace metals in corrosive environments. Moreover, structural renovation in concrete utilizes more and more fibrous composites.

Soil is also an important construction material. Masonry (bricks and blocks) are widely used in building walls. Since they are not the primary load carrying components, they are not discussed in this book.

1.2 Structural materials and structural design

Structural materials and structural design are two closely related fields and have mutual influence on each other. To design a building or a bridge, we often start with a given structural form based on an architectural design. Once the loading on the structure is determined, structural analysis allows us to obtain the axial forces, moments and shear forces in each of the members. In this stage, materials properties are only needed for statically indeterminate structures (structures with redundant restraints). We then choose member sizes to ensure that failure or excessive deflection will not occur. Moreover, in case failure occurs, we want it to be gradual, rather than sudden and without warning. In order to perform this task, two issues need to be addressed. First, how can one relate the maximum stress and deflection of a member to the applied moment and shear as well as the member size and material stiffness. This issue involves materials properties and theories in the mechanics of materials. Second, what is the strength (or maximum stress capacity) and stiffness of the material, and what is its failure mode. This involves the study of the behavior of structural materials, and is best presented in terms of the stress-strain diagram (or constitutive relation) of the material (Figure 1-1).

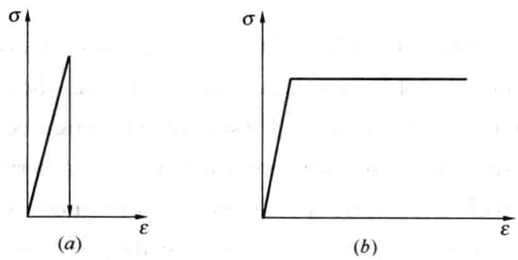

Figure 1-1 Stress-Strain Diagrams

(*a*) Brittle; (*b*) Ductile Materials

Figure 1-1 shows the stress-strain relationship for typical brittle and ductile materials. The stress is obtained by dividing the force by the area it acts on $\left(\sigma = \frac{F}{A}\right)$ and the strain is obtained by dividing the elongation to its original length $\left(\varepsilon = \frac{\Delta l}{l_0}\right)$. The initial slope of the stress-strain diagram reflects the stiffness of the material. The higher the slope, the more difficult it is to deform the material. If a structural member is made with a stiffer material, its deflection will be reduced. Figure 1-1(*a*) shows the stress-strain relation for a brittle material such as glass.

Once a critical stress value (the strength) is reached, failure will occur suddenly with no warning. The stress-strain relation shown in Figure 1-1 (*b*) represents that of mild steel (up to a certain strain level). After the yield value is reached, the material can still carry stress on further deformation. This deformation capability is called ductility. The implication is that the structural member will undergo significant deflection before failure occurs, providing a warning to people in and around the structure.

In the above discussion, we start with the structure form, and then consider the relevance of the material stress-strain relation in choosing the member size. In reality, the stress-strain relation of a material often determines the structural form. For example, due to the high compressive strength but low tensile strength of natural stone, historical stone bridges are built in the arch form. With the development of high strength steel, cable suspended and cable stayed bridges can be designed. The fact that structural form is affected by material behaviour is usually taken for granted, since we have sufficient experience with materials like concrete, wood and steel to prescribe the structural form. When new materials (such as fiber reinforced composites) are introduced, civil engineers need to come up with new structural forms which take full advantage of the materials.

In recent years, due to the infrastructure decay problem in many developed countries, the long term performance of structures has become an important concern. In other words, we are interested in knowing how the stress-strain relation may change with time. For example, under chemical attack and repeated loading from traffic, would the strength of concrete or steel be reduced over time? Under sustained loading over many years, would the stiffness of polymers become much lower, hence leading to excessive deflection? These are important issues to be addressed and are some of the major foci of discussion throughout the course.

Mechanical properties of various materials, including strength, stress, strain, elastic modulus, viscosity, creep, shrinkage etc, are present in chapter 2. Besides the mechanical properties, physical properties and chemical properties of construction materials are also important. For instance, the weight of the materials governs the dead load on a structure. Its porosity governs water and gas penetration that affects material durability. The chemical properties govern the likelihood of chemical reaction and deterioration under various environments, and are clearly important in the study of the long term performance of materials.

1.3 Physical properties

Physical properties are properties of matter that can be observed without changing the chemical composition. The physical properties of matter may include, but are not limited to, color, density, porosity, conductivity, ductility, brittleness, dielectrics, melting point, permeability, specific heat, resistivity, viscosity, thermal expansion, texture, etc.

In this section, the following physical properties of substance are of concerned: