高等学校土建类教材英文版

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1982年9月，获得天津大学结构工程专业工学学士学位；1986年3月和1989年3月，分别获得日本九州大学工学硕士和工学博士学位；1990年3月至1994年5月，在美国加州大学圣迭哥分校任研究员；自1994年6月起，在美国南加州大学土木系任教；自2001年10月起，被评为教育部长江学者，担任湖南大学特聘教授。

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◇ 钢筋混凝土结构，钢结构，竹、木结构及组合结构的抗震性能和设计；

◇ 高性能新材料在结构中的应用等。

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1957年至1962年，在密执安大学学习，获工学学士学位和硕士学位；1965年至1969年，在加州大学伯克利分校学习，获哲学博士学位；自1974年起，在美国南加州大学土木系任教。

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◇ 建筑钢结构的抗震设计；

◇ 结构动力分析。

代　　序

为使国内大学的本科生和研究生，科研人员和设计、施工技术人员能够对国外的钢结构设计方法有初步了解，作者按照美国钢结构规范 AISC 进行本书的编写，内容仍与国内大学本科钢结构课程基本一致，注重基本原理的讨论，并辅以中美规范对比。因此，本书的目的是使读者不仅对钢结构设计的基本理论和美国规范有所掌握，还能了解中美钢结构设计上的异同，从而有助于读者提高对钢结构的认识。

本书共有十章。第一章为绪论。第二章至第八章分别讲述钢结构的力学性能，钢结构的设计原则及设计方法，焊缝连接和螺栓连接及钢结构的三大基本构件（轴心受力构件，受弯构件和拉弯、压弯构件）的性能和计算。第二章主要介绍钢材性能，中美常用结构钢类型；第三章和第四章分别介绍了轴心受拉和轴心受压构件的性能和设计；第五章和第六章分别介绍了受弯构件和压弯构件的受力性能和设计方法；第七章和第八章分别介绍了简单受力节点和偏心受力节点的性能、设计要求和设计方法；第九章专题介绍了美国规范针对深梁的设计；第十章为钢框架体系的抗震设计及有关要求。关于构件设计的各章节的讨论，如压杆、受弯构件和压弯构件，其中稳定问题是理解掌握内容的关键。因此，作者在选材时先辅以有关稳定理论的介绍，从而可以把理论和实际设计联系起来。

书中例题是使学生得以用所学理论和方法解决工程实际问题的最好练习，因而书中列举了一定数量的例题。例题内容偏重设计，少量为验算。例题中物理量的单位大都采用国际单位制单位，少量的英制单位和国际单位制单位并用。大多数例题对比了中美规范的不同设计方法。

本书除可用作大学本科土木工程专业的“钢结构”英语教学或双语教学教材外，也可供研究生和设计人员参考。

Prof. Xiliang Liu，Tianjin University

2006 年 4 月

PREFACE

The authors intend to present this book as a basic textbook in structural steel design for undergraduate students. The objectives of this textbook are to introduce the fundamental structural design process and provide a detailed discussion on the design of steel structures.

As a design textbook, it is impossible to discuss the subjects without referencing design codes or specifications. The design procedures discussed in this textbook are primarily based on the Load and Resistance Factor Design (LRFD), which is a modern design method widely used in the North America. However, the book places significant emphasis on the theoretical background and general design considerations, common in most modern design codes. Particularly for the Chinese readers, the Chinese National Steel Structure Design Standards (GB 50017—2003) requirements are also discussed and compared in correlation with the LRFD design procedure, wherever necessary and possible in the textbook. This special feature of the book may also be useful as a reference source for those non-Chinese engineers who are involved in design projects in China.

The book is suitable for readers who have had a good understanding of behavior and analysis of materials and structures through courses such as Strength of Materials and Structural Analysis. Though the book is intended primarily as the textbook for Chinese undergraduate students to learn design subjects in English, practicing engineers may also find it useful as a reference of steel design written in English.

The book starts with an introduction of general and fundamental structural design procedures, with laying out the framework of the LRFD design and the Chinese design standards. Chapter 2 reviews the basic material behavior of steel and provides general introduction to construction and manufacturing methods of steel. The subsequent Chapter 3 to Chapter 6 discuss different structural components, namely, tension members, columns, beams, and beam-columns. The design methods for simple and eccentric connections are treated in Chapter 7 and Chapter 8, respectively. The last two chapters deal with two special topics, girders in Chapter 9 and requirements for seismic design in Chapter 10.

The book was written based on the lecture notes of the authors (Xiao: Chapter 1—9; Anderson: Chapter 10) in teaching courses at both the University of Southern California and the Hunan University. The authors and the publisher have taken special care to reduce errors to a minimum, however cannot hope for perfection in such a book, essentially first in its kind. Both the authors and the publisher will welcome notification of errors and suggestions for improvement. The corresponding author can be contacted at yanxiao@usc.edu, or, cipres@hnu.cn.

The authors would like to thank the following persons for their helps in various stages of preparing the manuscript: Mr. Yuntian Wu, Ph. D. candidate, and Mr. Andrew Jacobs, undergraduate student, University of Southern California; Mr. Tao Zhou; Mr. Xian Li; Mr. Guowang Huang, Ms. Ying Tao, graduate research assistants, Hunan University. The authors would like to thank Prof. Xiliang Liu, Tianjin University, and Dr. Jingsi Huo, Hunan University, for providing careful reviews of the manuscript. Special thanks are due to Ms. Xianghui Zhao for her kind encouragement and efficient work in publishing this book.

The authors would like to thank their families for their encouragements and endurance throughout the lengthy process of preparing this book.

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University of Southern California

May 2006
At Hunan University, Yuelu Mountain

郑重声明

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 Structural Design

Within the framework of Civil Engineering, structural engineering is the discipline that creates the structural forms that serve to provide shelter, electrical power, and transportation etc. for the population. It is often said that structural design is a combination of art and science. The experience and intuitive feeling of the engineer relative to the structure being built reflect the artistic aspects of structural design. The scientific aspects of structural design rely on knowledge of mechanics, material behavior and construction technology etc. However, the two aspects are not separated since a good structural design requires a highly creative work based on engineering judgments and scientific principles.

Generally, the layout and overall dimensions of a structure are designed by architects, owners or other professionals who are responsible for the functionality of the structure. Once the size and function of a structure is determined, the structural design is initiated by a consideration of the various structural systems that might be utilized and the alternative types and disposition of structural members and materials. This is followed by the preparation of preliminary design drawings. Before the preliminary design can be accomplished, it is necessary to make a reasonable estimate of the loads that will be applied to the structure during its service life. These loads will produce strength and stiffness demands on the structure that must be satisfied by the strength and stiffness supplied by the selected members. The basic concept of a successful design is that the Demand of the applied loads (also including deformation demands) must be less than the Supply of strength and stiffness (also including deformability) provided by the structural members.

Following the preliminary design, a final determination of the member sizes and types is made along with the details of the connections. A detailed computer analysis is then conducted to verify the adequacy of the design which then becomes the final design that includes detailed drawings and notes that facilitate fabrication and construction of the structural framework.

The emphasis of this book is on the Supply side of the design task. One must first learn to design the individual structural members and their connections before they can plan and execute the design of the whole structural system. Hence the objective is to study the methods that can be used to calculate the strength and displacement capacities of typical structural steel members and their connections under different loading conditions. These include tension members, compression members (columns), beam-columns, simple and eccentric connections, etc.

1.2 General Design Process

The role of structural design in the general process of a construction project can be demonstrated by the flow chart in Figure 1.1.

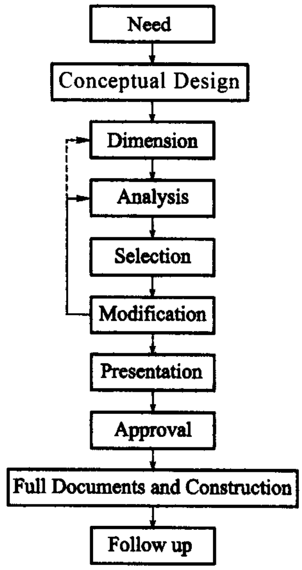

Figure 1.1 Design process

Need

A construction project starts with the establishment of certain basic needs, such as to provide shelter, contain water, provide for transportation, provide electrical power and its transmission among others. The owner of the project can be either private or government entity and is the client of the designers and the contractors.

Conceptual design

Based on the proposed function, constraints, experience, aesthetic expression, the initial idealization of structural types and forms are established.

Dimension

The overall dimension of the structural space is typically selected and designed by the architect.

Analysis

Based on the functional need and dimension, structural engineers estimate the design loads and calculate the member forces. Computer programs are typically used in this process.

Selection (sizing)

Selection of member sizes and connection details need to be determined.

Modification

Due to the limitations in material and member shapes, and coordination with other members of the design team such as architects, electrical, mechanical and environmental engineers, modification of the initial design may be required.

Presentation

The design work is put into clear construction drawings.

Approval

Client and governing agencies need to verify the structure's satisfaction of function and safety needs and approve the design. If not satisfied, additional modification is needed.

Full documents and construction

The full documents of a project include all the technical drawings, reports, approval certificates and permits. Then typically through a bidding process, a contractor or a group of contractors is selected to execute the construction according to the design documents. During the construction process, the design engineers are often needed to oversee the construction to ensure the structure is built according to the design specifications and to solve problems arriving from changes of construction or other matters.

Follow up

Once a project is completed and the structure has been built and placed into operation, monitoring and maintenance are needed to ensure the structure to function according to the design. Occasionally, performance tests can be conducted to determine if the structure is functioning according to the design and analysis. When a potential problem is determined following construction, retrofit measures may need to be considered. If the structure is damaged during its service life, repair work needs to be carried out. All of these involve a certain degree of design work.

1.3 Requirements

Functionality

The engineer should choose the suitable structural type for meeting the client's needs.

Serviceability

The structure has to be designed to function properly during its anticipated service life. This usually means that excessive deformations and undesired vibrations should not occur. During this period, the structure should function in the elastic range with no permanent deformations.

Safety

The structure must be designed with sufficient strength and stiffness to resist the design loads and have enough reserve deformation capacity to maintain life safety under possible extreme loads. This can be attained by a combination of good design, good workmanship and good construction methods.

Constructability

The structure should be designed with simple forms and field connections that can be built within the skill level of the local work force so that high quality can be attained subject to an acceptable time schedule.

Economics

A good design results in both low initial cost and low maintenance cost.

Presentations

The design work should be documented in clear and well-drafted format, which is easy to follow and can be readily understandable by third parties.

Among the above requirements, the requirements for safety and most serviceability issues are the structural engineer's responsibility and potential liability.

1.4 Building Codes and Specifications

1.4.1 Building Codes

Structures built in modern societies are designed based on compliance with a legal document that is called a building code. A building code is a broad based document that provides a framework of minimum requirements for building design and construction. Building codes generally address all facets relating to occupant safety such as structural design, architectural details, fire protection, heating and air conditioning, plumbing and sanitation, and lighting. In the North American, although some large cities have their own building codes, most municipalities either adopt a regional "model" code or modify a "model" code to suit the particular needs of their regions of jurisdiction. Many societal entities such as professional organizations, industrial trade groups, and academic sectors have an interest in the model codes and contribute to their development. Currently there are three model codes that include the following: Uniform Building Code (International Conference of Building Officials, 1997), Standard Building Code (Southern Building Code Congress International, 1999), and the BOCA National Building Code (Building Officials and Code Administrators International, 1999). The Uniform Building Code was first written in 1927 and is widely used in the West. The Standard Building Code has been in existence since 1945 and is widely used in the South and Southeast. The BOCA National Building Code was initiated in 1950 and has been extensively used in the Northeast and North-Central states. It is of particular importance to note that the codes regulate the minimum design loads, to which the structure is to be designed. However, engineers should be aware such minimum standards are by no means the worst case and are encouraged to investigate the actual loading conditions in a design work.

The adoption of different codes in various parts of the country has created inconsistencies, inconveniences and even legal challenges. Toward the end of last century, the three code organizations (UBC, BOCA and the SBCCI) worked together to merge the three codes into a single code. The result was the development of the International Building Code (International Code Council, 2000). As of today, there has only been partial success for the IBC code to be adopted by the various municipalities. However, the trend is to move towards a uniform code in the United States.

In China, building codes are typically developed and enforced by the governmental sectors. However, in the U. S., the code that is adopted and approved by a government entity (such as state, city etc.) has the status of law and is enforced by the government over its jurisdictional territory.

1.4.2 Specifications

A specification is usually developed by a group of experts in the field of research and design and gives specific guidance for the design of structural members and connections. There are a variety of specifications that have been developed for both materials and structures. The design of steel buildings in the United States is based primarily on the specifications of the AISC (American Institute of Steel Construction). The AISC is an organization comprised of steel fabricators and manufacturing companies, but also includes individual members interested in the design and research of steel buildings. Hence the Specification reflects the combined judgment of practicing engineers and researchers and incorporates years of experience gained through actual structural usage. It is intended to guide the designer in producing a safe and economical structure. From time to time the specifications are either modified or rewritten to reflect recent developments. In the above-mentioned codes, various reference standards and specifications are adopted with minimum modifications. The current specifications are Specification for Structural Steel Buildings 1989— Allowable Stress Design and Plastic Design and the 2001 Load and Resistance Factor Design Specification for Structural Steel Buildings. It should be pointed out that many model codes include both the AISC ASD and the AISC LRFD specifications.

The word "specifications" may also refer to a group of rules set forth by the architect or engineer that pertain to only one particular building during construction. Once the building official of the municipality approves these specifications, they become legally binding documents.

The design of steel bridges and other special structures are typically treated separately from buildings. In the US, bridges are designed based on the specifications of the AASHTO (American Association of State Highway Transportation Officials). The AISC Specifications are reflected in the steel design chapter of the AASHTO code.

Steel railroad bridges are designed in accordance with the specifications adopted by the AREA (American Railway Engineering Association). In this case the railroads have the responsibility for safety and through their own organization adopt the rules to insure safe designs.

Loads on structures

Demands are placed on the members of the structural system by the loads (forces) that must be transferred to the base (foundation). The self weight of the members must be estimated initially but can be calculated accurately following the preliminary design. Included with the self-weight are the weights of permanently attached partitions and equipment, ceilings and finish flooring. These loads are termed the "dead load" since they are fixed with regard to both position and magnitude. Occupancy loads are considered to be "live loads" since both their magnitude and location are uncertain. These include vehicle traffic, human occupants, furnitures, movable partitions and storage. Due to concern for public safety, minimum live loads to