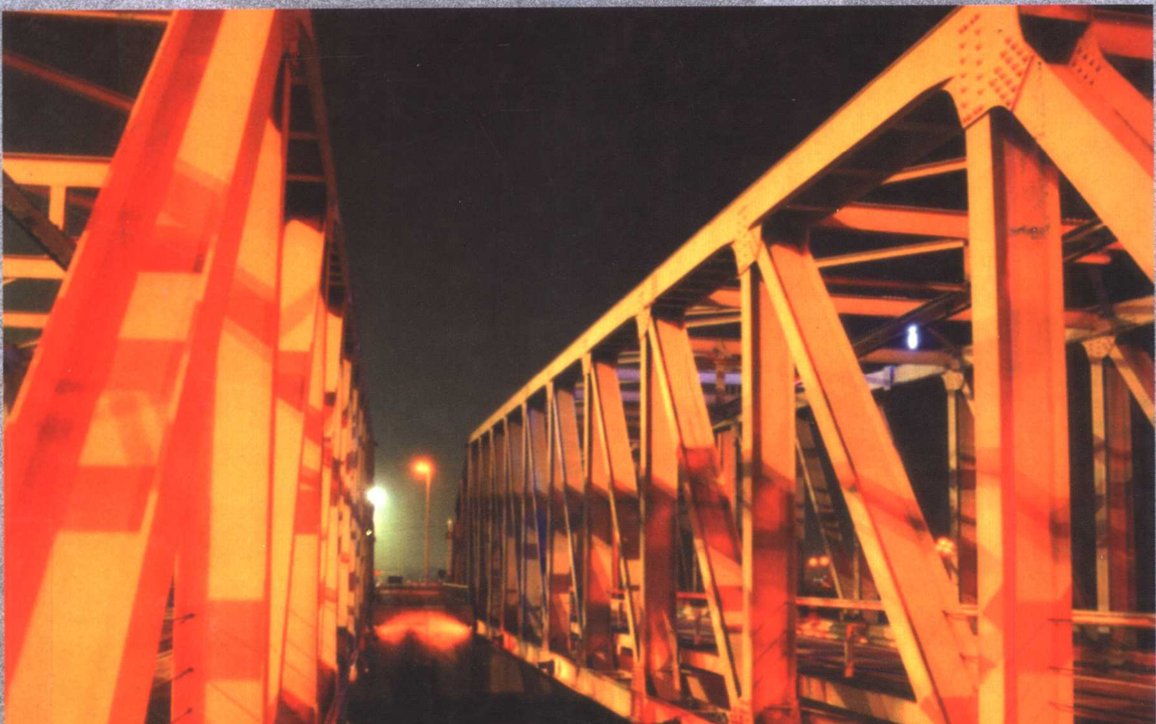
高等学校双语教学系列教材

结构分析

（英文版）

Structural Analysis

[美] R.C.Hibbeler 著



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出 版 说 明

教育部于2001年出台了《关于加强高等学校本科教学工作提高教学质量的若干意见》，明确了高等学校要积极开展双语教学工作。目前各高校根据教育部的要求，陆续开设了双语教学课程。

为了配合建筑院校的双语教学，满足双语教学的需要，我社策划引进了这套《高等学校双语教学系列教材》。通过本系列教材的学习，可以使学生有效提高外语水平，了解和掌握学科专业及其前沿内容。该套丛书中，我们率先引进了《结构分析》（Structural Analysis）、《土木工程材料科学与技术》（The Science and Civil Engineering Materials）、《工程项目管理》（Construction Project Management）和《建设合同商务与法律原理》（Construction Contracting）四册，根据教学需求，我们将会陆续引进其他专业课程英语原版教材。为了更好地适应我国双语教学的专业特点，我们分别邀请了北京工业大学建筑工程学院的高向宇老师审阅了《结构分析》分册、李悦老师审阅了《土木工程材料科学与技术》分册、章慧蓉老师审阅了《工程项目管理》和《建设合同商务与法律原理》分册，他们对不符合我国建筑行业标准和教学内容的章节进行了删节，同时保持了原版教材的特点。

《结构分析》一书工程背景强，附有大量例题、习题和综合训练。《土木工程材料科学与技术》内容全面翔实、深入浅出、细节清晰。《工程项目管理》涵盖面广，包括了施工管理、招投标和合同法规等方面的内容。《建设合同商务与法律原理》侧重于商务和法律原理，理论性强，内容严谨系统，每章都有问题与训练。本套丛书可作为建筑院校本科生的双语专业教材使用。

本书为《高等学校双语教学系列教材》之《结构分析》分册，可供土木工程、建筑学、工程管理专业的双语教学使用，也可供相关专业师生、工作人员学习参考。

《高等学校双语教学系列教材》是我们进行双语教学教材工作的一种尝试，在引进和编辑过程中难免会有不足之处，敬请广大读者批评指正。

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2005 年 12 月

Preface

This book is intended to provide the student with a clear and thorough presentation of the theory and application of structural analysis as it applies to trusses, beams, and frames. Emphasis is placed on developing the student's ability to both model and analyze a structure and to provide realistic applications encountered in professional practice.

Organization and Approach

The contents of each chapter are arranged into sections with specific topics categorized by title headings. Discussions relevant to a particular theory are succinct, yet thorough. In most cases, this is followed by a "procedure for analysis" guide, which provides the student with a summary of the important concepts and a systematic approach for applying the theory. The example problems are solved using this outlined method in order to clarify its numerical application. Problems are given at the end of each chapter and are arranged to cover the material in sequential order; moreover, for any topic they are arranged in approximate order of increasing difficulty.

During recent years there has been a growing emphasis on using computers to analyze structures by matrix analysis. These developments are most welcome, because they relieve the engineer of the often lengthy calculations required when large or complicated structures are analyzed using classical methods. Although matrix methods are more efficient for a structural analysis, it is the author's opinion that students taking a first course in this subject should also be well versed in the classicial methods. Practice in applying these methods will develop a deeper understanding of the basic engineering sciences of statics and mechanics of materials. Also, problem-solving skills are further developed when the various techniques are thought out and applied in a clear and orderly way. By experience, one can better grasp the way loads are transmitted through structures and obtain a more complete understanding of the way structures deform under load. Finally, the classicial methods provide a means of checking computer results rather than simply relying on the generated output.

Homework Problems

Most of the problems in the book depict realistic situations encountered in practice. It is hoped that this realism will both stimulate the student's interest in structural analysis and develop the skill to reduce any such problem from its physical description to a model or symbolic representation to which the appropriate theory can be applied. Throughout the book there is an approximate balance of problems using either SI or FPS units. The intent has been to develop problems that test the student's ability to apply the theory, keeping in mind that those problems requiring tedious calculations can be relegated to computer analysis. Using the STRAN computer program, included with this book, the student also has a means of checking the solutions to many of these problems, and can thereby be encouraged to apply a computer analysis throughout the course. The answers to selected problems are listed in the back of the book.

Contents

This book is divided into three parts. The first part consists of seven chapters that cover the classical methods of analysis for statically determinate structures. Chapter 1 provides a discussion of the various types of structural forms and loads. The analysis of statically determinate structures is covered in the next six chapters. Chapter 2 discusses the determination of forces at a structure's supports and connections. The analysis of various types of statically determinate trusses is given in Chapter 3, and shear and bending-moment functions and diagrams for beams and frames are presented in Chapter 4. In Chapter 5, the analysis of simple cable and arch systems is presented, and in Chapter 6 influence lines for beams, girders, and trusses are discussed. Finally, in Chapter 7 several common techniques for the approximate analysis of statically indeterminate structures are considered.

In the second part of the book, the analysis of statically indeterminate structures is covered in five chapters. Both geometrical and energy methods for computing deflections are discussed in Chapter 8. Chapter 9 covers the analysis of statically indeterminate structures using the force method of analysis, in addition to a discussion of influence lines for beams. Then the displacement methods consisting of the slope-deflection method in Chapter 10 and moment distribution in Chapter 11 are discussed. Finally, beams and frames having nonprismatic members are considered in Chapter 12.

The third part of the book treats the analysis of structures using the stiffness method. Trusses are discussed in Chapter 13, beams in Chapter 14, and frames in Chapter 15. A review of matrix algebra is given in Appendix A.

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Many of my colleagues in the teaching profession and my students have made constructive criticisms that have helped in the development of this revision, and I would like to hereby acknowledge all of their valuable suggestions and comments. I personally would like to thank the reviewers contracted by my editor:

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Finally, I would like to acknowledge the help I received from my wife Conny (Cornelie), who has always been very supportive and helpful in preparing the manuscript for publication.

I would greatly appreciate hearing from you if at any time you have any comments or suggestions regarding the contents of this edition.

Russell Charles Hibbeler
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Contents

The diamond-patterned framework on this high-rise building is used to resist earthquake loadings. *(Photo courtesy of Bethlehem Steel Corporation.)*

1 Types of Structures and Loads

This chapter provides a discussion of some of the preliminary aspects of structural analysis. The phases of activity necessary to produce a structure are presented first, followed by an introduction to the basic types of structures, their components, and supports. Finally, a brief explanation is given of the various types of loads that must be considered for an appropriate analysis and design.

1.1 Introduction

A *structure* refers to a system of connected parts used to support a load. Important examples related to civil engineering include buildings, bridges, and towers; and in other branches of engineering, ship and aircraft frames, tanks, pressure vessels, mechanical systems, and electrical supporting structures are important.

When designing a structure to serve a specified function for public use, the engineer must account for its safety, esthetics, and serviceability, while taking into consideration economic and environmental constraints. Often this requires several independent studies of different solutions before final judgment can be made as to which structural form is most appropriate. This design process is both creative and technical and requires a fundamental knowledge of material properties and the laws of mechanics which govern material response. Once a preliminary design of a structure is proposed, the structure must then be *analyzed* to ensure that it has its required strength and rigidity. To analyze a structure properly, certain idealizations must be made as to how the members are supported and connected together. The loadings are determined from codes and local specifications, and the forces in the members and their displacements are found using the theory of structural analysis, which is the subject matter of this text. The results of this analysis then can be used to redesign the structure, accounting for a more accurate determination of the weight of the members and their size. Structural design, therefore, follows a series of successive approximations in which every cycle requires a structural analysis. In this book, the structural analysis is applied to civil engineering structures; however, the method of analysis described can also be used for structures related to other fields of engineering.

1.2 Classification of Structures

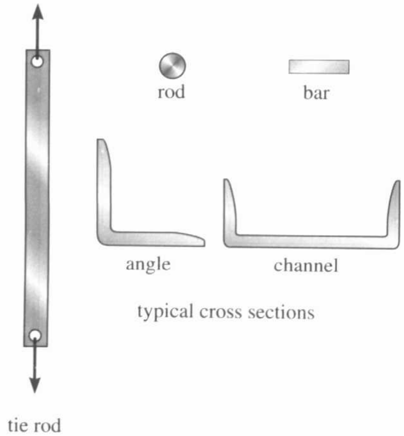


Fig. 1–1

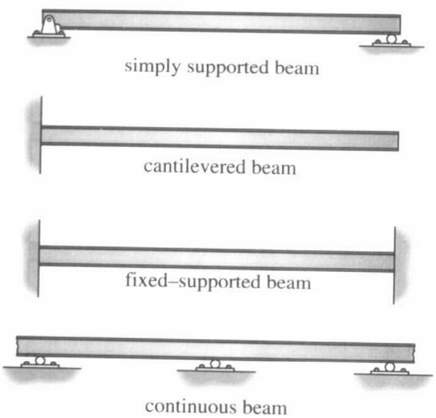


Fig. 1–2

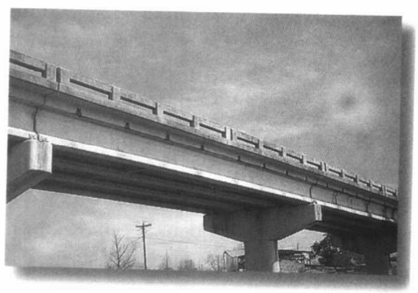
It is important for a structural engineer to recognize the various types of elements composing a structure and to be able to classify structures as to their form and function. We will introduce some of these aspects now and expand on them at appropriate points throughout the text.

Structural Elements. Some of the more common elements from which structures are composed are as follows.

Tie Rods. Structural members subjected to a *tensile force* are often referred to as *tie rods* or *bracing struts.* Due to the nature of this load, these members are rather slender, and are often chosen from rods, bars, angles, or channels, Fig. 1–1.

Beams. Beams are usually straight horizontal members used primarily to carry vertical loads. Quite often they are classified according to the way they are supported, as indicated in Fig. 1–2. In particular, when the cross section varies the beam is referred to as tapered or haunched as shown in the photo below. Beam cross sections may also be "built up" by adding plates to their top and bottom.

Beams are primarily designed to resist bending moment; however, if they are short and carry large loads, the internal shear force may become quite large and this force may govern their design. When the material used for a beam is a metal such as steel or aluminum, the cross section is most efficient when it is shaped as shown in Fig. 1–3. Here the forces developed in the top and bottom *flanges* of the beam form the necessary couple used to resist the applied moment **M,** whereas the *web* is effective in resisting the applied shear **V.** This cross section is commonly referred to as a "wide flange," and it is normally formed as a single unit in a rolling mill in lengths up to 75 ft (23 m). If shorter lengths are needed, a cross section having tapered flanges is sometimes selected. When the beam is required to have a very large span and the loads applied are rather large, the cross section may take the form of a *plate girder.* This member is fabricated by using a large plate for the web and welding or bolting plates to its ends for flanges. The girder is often transported to the field in segments, and the segments are designed to be spliced or joined together at points where the girder carries a small internal moment.



The precast concrete girders are simply supported and are used for this highway bridge. Also, note the tapered beams used to support these girders.