CONCRETE STRUCTURAL FUNDAMENTALS

Editor in Chief Zhao Chuanzhi
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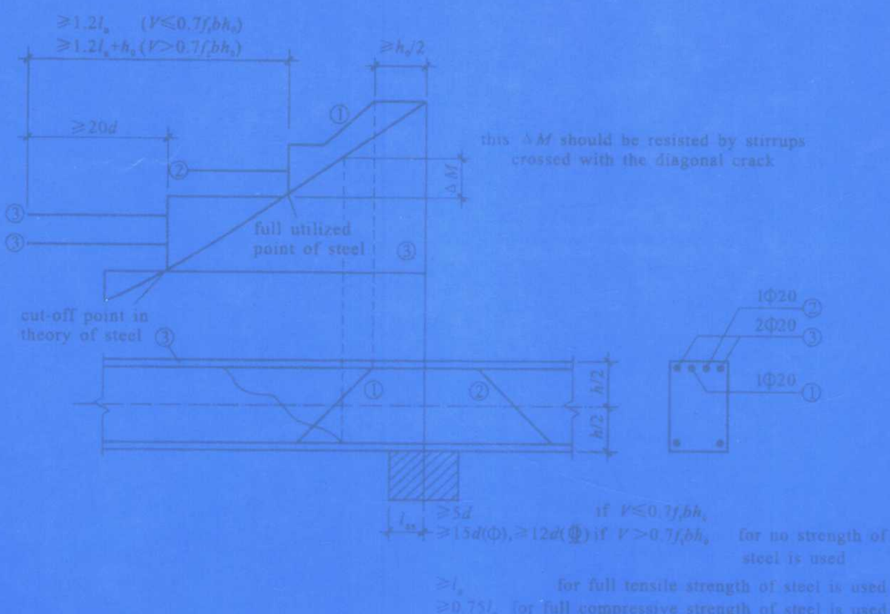

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高等学校双语教学试用教材

CONCRETE STRUCTURAL FUNDAMENTALS

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混凝土结构基本原理

英文版

（按新规范 GB50010—2002 编写）

主　编　　赵传智

副主编　　俞　晓

Wuhan University of Technology Press

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·武　汉·

Summary

This book is based on the new code in China "Code for Design of Concrete Structures" (GB50010—2002) and the teaching program for civil and structural engineering. Contents in the book are: materials of reinforced concrete structures; design principles for concrete structures; failure modes, calculating equations and detailing requirements for members with flexure, shear, compression, tension and torsion; basic concepts and calculations of prestressed concrete.

The book can serve as textbook for university and college students, the textbook of specialism English and the reference for techanicians, researchers and foreign students.

Editor in Chief:

Zhao Chuanzhi Professor of Civil Engineering of Wuhan University of Science and Technology. First class registered engineer of PRC.

【内容简介】

本书是根据《混凝土结构设计规范》(GB50010—2002)及全国高等学校土木工程专业教学指导委员会制订的本科培养方案及教学要求编写而成。内容包括：钢筋混凝土结构的材料，可靠度设计原理，受弯、剪、压、拉等基本构件的破坏形式、计算公式与构造细则，预应力结构的基本概念、设计原则与杆件的计算。

本书除作为高等学校双语教学的教材外，还可作为土木工程专业的"专业外语"教材使用；也可供研究生、外籍生、工程技术人员及科研人员阅读参考。

主编：赵传智 武汉科技大学城市建设学院教授，国家一级注册结构工程师。

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Preface to Second Edition

I have engaged in teaching and researching "Concrete Structures" for several decades. During my time of learning in university we had some textbooks in English. It has favoured me a great deal. Nowadays, the English lesson in university is neither combined into the specialism nor continued in the high class. It is not favourable for English learning and it is the motive for me to write this textbook "Concrete Strüctural Fundamentals". It is based on the teaching program for civil and structural engineering. It is designed to be easy to read for university and college students. It can serve as the reference for technicians, researchers and foreign students.

There are eight chapters in the book: 1. Mechanical properties of reinforced concrete materials; 2. Basic principles for the design of concrete structures; 3. Flexural strength of members with flexure and shear; 4. Shear strength of members with flexure and shear; 5. Strength of members with compression; 6. Strength of members with tension and members with torsion; 7. Check of deformation and crack of reinforced concrete members; 8. Prestressed concrete.

Since and before the publication of this book it has been used as the textbook of "specialism English "or "bilingular teaching" in universities and colleges for many times and several years. It is welcome.

I am indebted to many friends and colleagues. This book was greatly improved by comments or suggestions from them.

Readers in the past have been most cooperative in reporting any errors they notice and these comments permit errors to be corrected in this second edition.

The following major changes have been made in this second edition:

1. Modernigation to conform to the new code "Code for Design of Concrete Structures" (GB50010-2002).

2. Recognition of very significient changes in code notation "Standard for Terminology and Symbols Used in Design of Building Structures" (GB/T50083-97).

3. Many materials are inducted to induce this textbook which can also serve as the bilingual textbook in universities or colleges. Such as the calculation of prestressed members with flexure has been induces in Chapter 8.

4. Problems of exercise are induced for the selection of students.

Many colleagues have been taken part in this second edition work. They are Zhao Chuanzhi(Editor in chief, chapter 0,1,2), Yu Xiao(Associate- editor, chapter 3,4).

Assistant editor: Guo Zailin(chapter 5), Wan Shengwu(chapter 6), Yue Honghui(chapter 7), Wu Xiaochun(chapter 8).

Sincere thanks are due to the various authors whose figures in publications are quoted and to my daughter Zhao Aiwu for the faultless typing of the manuscript.

Finally, I would be grateful to any constructive comments or criticisms that readers may have and for notification of any errors that they will inevitably detect.

Wuhan University of Science & Technology

Zhao Chuanzhi

12.2002

修订版前言

本人在高等院校从事土木工程专业“混凝土结构”教学、科研工作数十年。早在大学读书时代，曾有几门课程采用的就是英文原版教材，本人得益匪浅。目前，在大学本科的英语教学中，既不结合专业，且到高年级又往往断线，对人才的培养颇为不利。为此，我们编写了这本英文版教材 Concrete Structural Fundamentals（混凝土结构基本原理）。本教材是根据全国高等学校土木工程专业教学指导委员会制订的本科培养方案及教学要求编写的，内容精炼，文字简洁，便于学生阅读。本书也可供研究生、外籍学生、工程技术人员及科研人员阅读参考。

本书内容共 8 章。第 1 章：钢筋混凝土材料的力学性能；第 2 章：混凝土结构的基本设计原理；第 3 章：受弯、剪构件的抗弯强度；第 4 章：受弯、剪构件的抗剪强度；第 5 章：受压构件的强度；第 6 章：受拉与受扭构件的强度；第 7 章：钢筋混凝土构件的变形与裂缝验算；第 8 章：预应力混凝土结构。

本书在出版前后，即曾在有关院校中作为土木工程专业本科生的“专业外语”或“双语教学”的试用教材使用过多遍，颇受欢迎。很多同行与好友曾对本书的出版提出过许多宝贵意见并给予无私的帮助，很多读者还对本书第 1 版第 1 次印刷中存在的一些问题曾细心指出，使之能在这次修订工作中得以改正，特此致谢。

在本书的修订版中，主要对有关内容作了如下的修订：

1. 所有计算公式及构造规定均根据我国最新颁布的《混凝土结构设计规范》(GB50010—2002)进行修订。

2. 专用英文名词、术语及符号均采用《建筑结构设计术语和符号标准》(GB/T50083—97)的有关规定。

3. 进一步充实了部分章节的有关内容，使本书既可作为高等学校土木工程专业双语教学的教材，又可兼作本专业的“专业英语”教材使用。

4. 增加了部分习题内容，便于教学工作中选用。

本书由赵传智担任主编，俞晓担任副主编，具体参加本书修订版编写工作的人员及分工如下：

赵传智（第 0、1、2 章），俞晓（第 3、4 章），郭在林（第 5 章），万胜武（第 6 章），岳宏辉（第 7 章），吴晓春（第 8 章）。

因作者水平有限，书中难免还有疏漏或不妥之处，敬请读者批评指正。

武汉科技大学
赵传智
2002 年 12 月

Contents

0 Introduction

0.1 Basic Concepts and Characteristics of Reinforced Concrete

Reinforced concrete is a composite material composed of two different materials, concrete and steel reinforcement.

Concrete behaves very well when it is subjected to compressive force, but ruptures suddenly when small tensile force is applied. The tensile strength of concrete is only about 10% of its compressive strength.

$$\text{C20} \quad f_c = 9.6\text{N/mm}^2 \quad f_t = 1.1\text{N/mm}^2 \quad \text{ratio} = \frac{1.1}{9.6} = 11\%$$

Reinforcement behaves very well both in compression and tension.

$$\text{Grade HRB235} \quad f_y = f_y' = 300\text{N/mm}^2$$

For example, the bearing capacity of a concrete beam shown in Fig. 0.1 (*a*) is only 1.37kN/m while the bearing capacity of the same beam with two steel bars 2Φ16 is 9.31kN/m, which is 6.8 times of the former.

For the concrete beam:

$$M_c = \frac{\gamma f_{ct} bh^2}{6} = \frac{1.55 \times 0.61 \times 200 \times 400^2}{6}$$

$$= 5.04 \times 10^6 \text{N} \cdot \text{mm} = 5.04\text{kN} \cdot \text{m}$$

$$q_c = \frac{8M_c}{l^2} = \frac{8 \times 5.04}{6^2} = 1.12\text{kN/m}$$

For the reinforced concrete beam:

$$\zeta = \frac{A_s f_y}{\alpha_1 f_c b h_0} = \frac{402 \times 300}{1 \times 9.6 \times 200 \times 365} = 0.172 \rightarrow \alpha_s = 0.157$$

$$M = \alpha_s \alpha_1 f_c b h_0^2 = 0.157 \times 1 \times 9.6 \times 200 \times 365^2 = 40.2\text{kN} \cdot \text{m}$$

$$q = \frac{8M}{l^2} = \frac{8 \times 40.2}{6^2} = 8.93\text{kN/m}$$

Therefore, in order to utilize these materials effectively, concrete is usually utilized to resist compressive forces and reinforcement the tensile forces in structural members.

Besides, in order to minify the cross-section of members with axial load steel reinforcement is also used to assist the concrete to resist compressive forces.

For example, the bearing capacities of the two sections of columns shown in Fig. 0.2 are the same. But the area of section of the reinforced concrete column is only 79 percent

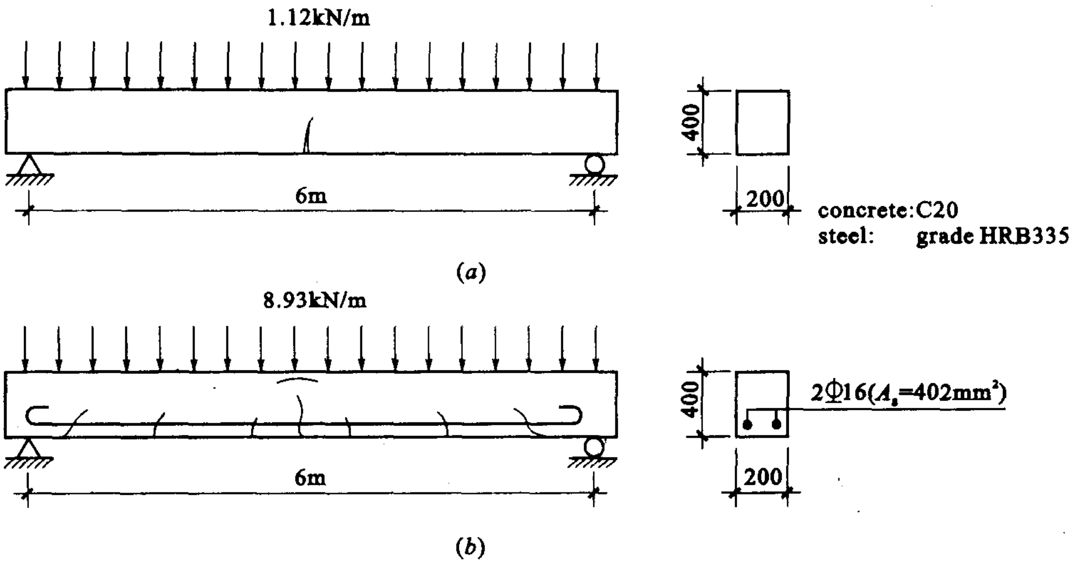

Fig. 0. 1 A comparison of concrete beam with reinforced beam

of the concrete column.

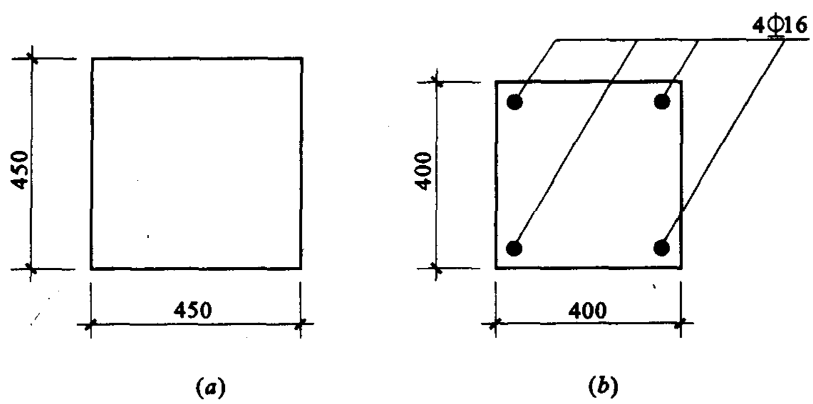

Fig. 0. 2 A comparison of concrete column with reinforced concrete column

(*a*) concrete column; (*b*) reinforced concrete column

Concrete and reinforcement can work together because there is a sufficiently strong bond between the two materials to ensure that no relative movements of the steel bars and the surrounding concrete occur before cracking of concrete while the thermal expansion coefficients of the two materials, about 1.2×10^{-5} for steel versus, $1.0\times10^{-5}\sim1.5\times10^{-5}$ for concrete, are sufficiently close to forestall cracking and other undesirable effects of differential thermal deformations.

Advantages of reinforeed concrete:

(1) Durability

The reinforced concrete has good durability because the concrete strength increases with its age within twenty to thirty years while the concrete which surrounds the steel reinforcement provides excellent corrosion protection to the steel reinforcement.

(2) Fire resistance

Both concrete and steel are not the ignitible material. They are not really affected by fire until about 200℃ of temperature while a moderate amount of concrete cover provides sufficient thermal insulation for the embedded reinforcement.

(3) Monolith, earthquake resistant

In comparison with masonry structures the reinforced concrete structures have better earthquake resistant quality because of its monolith and higher strength.

(4) Locally available sources

It is always possible to make use of local sources of labour and a nearby source of aggregate can be found so that only the cement and reinforcement need to be brought in from a remote source.

(5) Steel saving

In comparison with steel structure, the reinforced concrete structure is more cheap and steel saving.

Shortcomings of reinforced concrete:

(1) Heavy volume weight

The use of reinforced concrete structures in civil engineering is limited by its heavy volume weight.

$$0.4 \times 0.2 \times 25 = 2\text{kN/m} \qquad \frac{2}{8.93} = 0.22 = 22\%$$

In the former example the self-weight of the reinforced concrete beam is 2kN/m, which is 22 percent of its bearing capacity. The ratio will increase to 86 percent if the span length of the beam increases to 12m.

(2) Cracking with ease

Due to the low elongation and tensile strength of concrete, the reinforced concrete structures usually work with cracks.

During the cracking of concrete the stress in tension steel σ_s is only

$$\sigma_s = \varepsilon_{cu} \times E_s = 0.0001 \times 2 \times 10^5 = 20\text{N/mm}^2$$

This is also the cause of limitation in use of this kind of structure.

(3) Construction with difficulty

The production of concrete is very complicated and time consuming. The process of concrete making is comprised of mixing, pouring and curing etc. But it can be simplified by the use of advanced technique.

0.2 Background and Application of Reinforced Concrete

Technology:

(1) High-quality concrete

It has not only high strength(C100～C200) but also high durability (over 100 years) and good workability(pour without vibration).

(2) Prestressed concrete

The disadvantage of cracking with ease of concrete can be eliminated by the use of prestressed concrete and the limitation in use can also be relaxed.

(3) Fibre reinforced concrete, light-weight concrete, steel tubular concrete ete.

It is aimed to enhance the tension resistance, bearing capacity and reduce weight of concrete.

Application:

Roof truss with span of 60m

High-rise buildings in Korea, with a height of 319.8m and 101 stories.

Theory of calculation:

Allowable stress method (1940)→Failure stage method (1955) →Limit state method (1964)→Probability based limit state design (GBJ10—89、GB50010—2002).

Structural analysis:

Elastic theory→Unelastic theory

Manual computation→Computer computation

1 Mechanical Properties of Reinforced Concrete Materials

1.1 Reinforcement

1.1.1 Types, Grades and Kinds of Reinforcement

1.1.1.1 Types

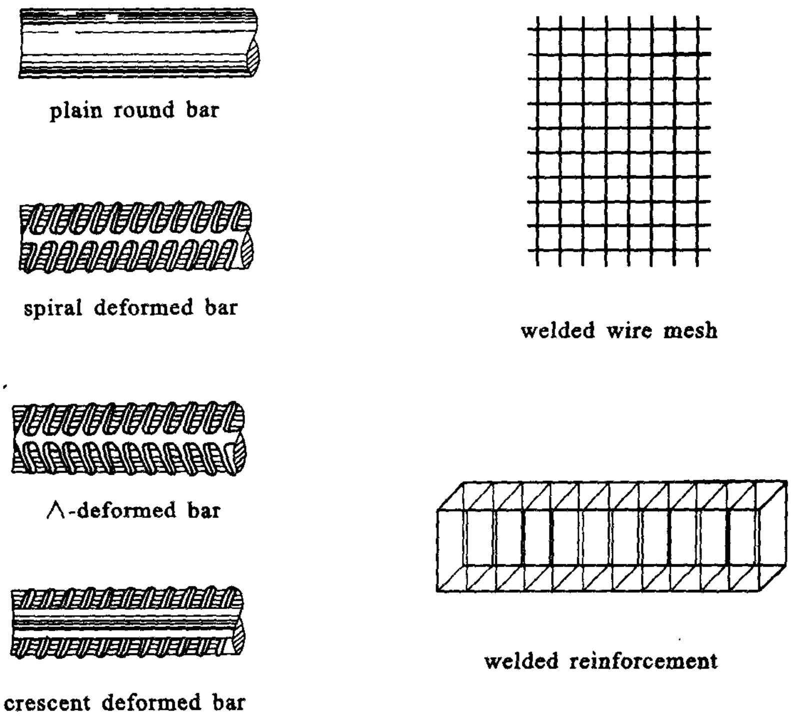

Fig. 1.1 Various types of reinforcements

1.1.1.2 Kinds and Grades

(1) Hot rolled bar (ϕ, ϕ, ϕ, ϕ^{R} for grade Ⅰ, Ⅱ, Ⅲ);

(2) Cold drawn bar (ϕ^{l}, ϕ^{l}, ϕ^{l} for grade Ⅰ, Ⅱ, Ⅲ);

(3) Heat tempering bar (ϕ^{HT});

(4) Strand (ϕ^{S});

(5) Stress deleted wire (ϕ^{P}, ϕ^{H}, ϕ^{I}).

1.1.2 Strength and Deformation of Reinforcement

Stress-strain curves:

Fig. 1.2 shows the typical stress-strain curves for various kinds of steel reinforcement loaded monotonically in tension. The curve for mild steel bar exhibits an obvious yield strength and yield plateau and a large ultimate strain, whereas the curve for hard steel wire exhibits no obvious yield plateau and yield strength and a small ultimate strain. After cold-worked the yield strength of mild steel bar has raised but the yield plateau gets shorten.

Design strength:

hot rolled bar—yield strength;

cold drawn bar—control stress(regardless of the age hardening);

Because in structures, members fail in bending, shear, compression, tension or torsion soon after the yielding of steel.

strand
stress deleted wire } —specified yield strength.
heat tempering bar

It is because the hard steel has no obvious yield point.

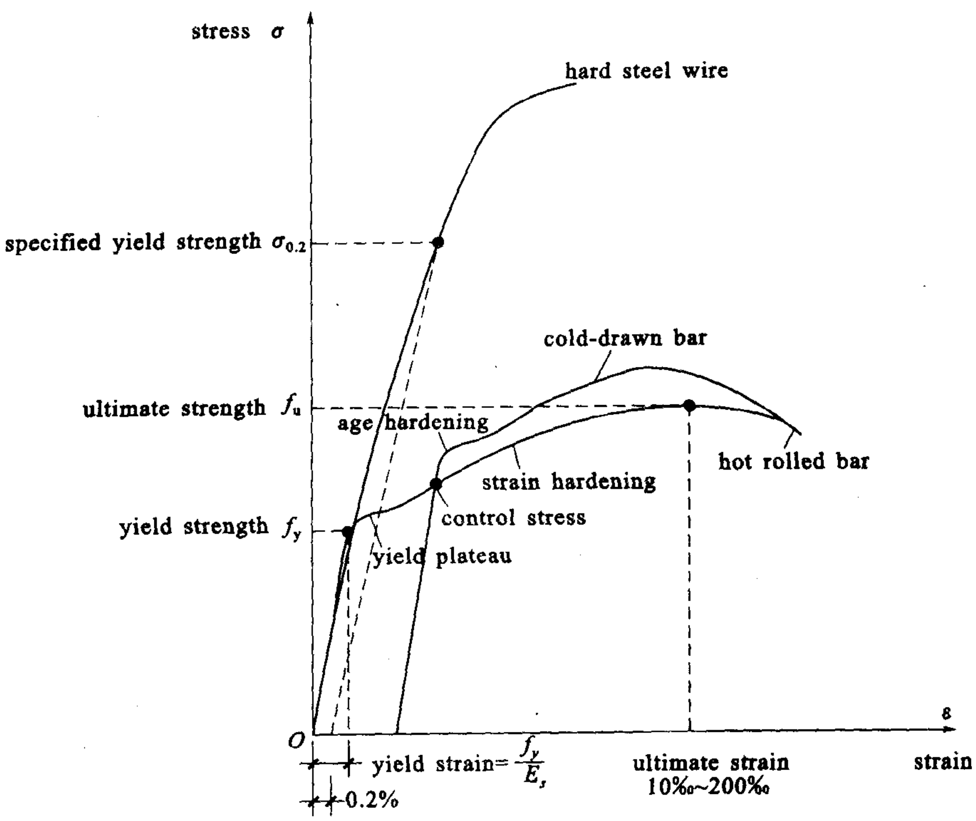

Fig. 1. 2 Typical stress-strain curves for reinforcement

Modulus of elasticity:

$$E_s = \tan\alpha$$

$E_s = 2.1 \times 10^5 \text{N/mm}^2$ for grade HPB235;

$E_s = 2 \times 10^5 \text{N/mm}^2$ for grade HRB335, HRB400, RRB400;

$E_s = 1.95 \times 10^5 \text{N/mm}^2$ for strand;