Fundamentals of
REINFORCED CONCRETE DESIGN
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To
The Society
To whom we owe a lot
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The book is primarily designed to be an applied text to cater to the class-room or self-study needs of students at undergraduate level in Civil Engineering. It covers all the basic topics of reinforced concrete design generally taught in first course in Civil Engineering curriculum in Indian Universities. It presents, in simple terms, the basic principles of reinforced concrete design, a thorough knowledge of which is essential for proper understanding of current design practices and code provisions. It conforms to the limit states design method as given in the latest revision of IS:456. The traditional working stress design method is given in the appendix for the use in investigation of limit states of serviceability and for design in the situations where the use of limit states design approach is not convenient.

In writing this text I have mainly drawn on my lecture notes developed while teaching the subject and on the experience accumulated over the years as a result of both research and consultancy. Considerable effort has been devoted to the detailed discussion of basic concepts, behaviour of various structural components under loads, and development of fundamental expressions for analysis and design. The emphasis is on clarity of concept and development of structural sense needed for proper detailing. The text presents efficient and systematic procedures for solving design problems. In addition to the discussion of basis for design calculations, a large number of worked-out practical design examples based on the appropriate codes and current design practices have been included to illustrate salient features of reinforced concrete design. A wide variety of well-labelled diagrams are provided throughout the text to help the reader to develop sound judgement in practical design. Review questions and tutorial problems are included at the end of each chapter for class-room or self-study to facilitate thorough comprehension of the fundamentals.
In Chapter 1, a concise discussion on the properties of concrete and steel has been included to give the reader a feel for constituent materials of total structural system. Chapter 2 compares various design approaches to reinforced concrete design and discusses the codal recommendations. Chapters 3 to 6 deal with limit states of collapse in flexure; shear, bond, and torsion; compression, and limit state of serviceability. In Chapter 7, the application of basic principles discussed in preceding chapters to the design of key building components has been given to enable the reader to undertake the practical design of a common range of structures. Chapter 8 on detailing the structures describes good detailing and construction practices. The detailing of steel is considered to be an art and is carried out according to the stipulations given in approved manuals for integrated action in various parts of the structure. The durability and serviceability aspects have been given due consideration for an efficient reinforced concrete design.

Time saving analysis and design aids in the form of tables and charts have been developed for use in the design office. The relevant algorithms used in development of design aids are explained in details. The design aids would prove extremely useful to the practicing engineers engaged in actual practice. There has been conscious effort to present results in non-dimensional form to facilitate the application to different materials and cross-sectional dimensions. A large amount of practical data in tabular form is given in the appendix for the use in design office.

Extensive reference is made to IS code provisions, but care is taken to avoid overdependence on the code to enable the reader to rationally assess the design situation rather than blindly follow the code provisions. However, to maximize the benefits, the readers are advised to use IS:456, SP:16 and SP:34 along with the text keeping in mind that the code stipulations should be used as a guide only. A structural engineer must use his/her judgement in addition to calculations in interpretation of various provisions of the code to obtain an efficient and economical structure.

The subject matter, its format and presentation sequence has been class tested. It is hoped that the text will prove to be a dependable companion for teachers and practicing engineers.

I am thankful to the Bureau of Indian Standards for their published material to which references are made at numerous places in the text. I thank all those who have assisted in various ways in preparation of the text. Particularly I wish to acknowledge the assistance rendered by Dr. Puneet Gambhir in preparation of the manuscript. I am extremely grateful to my wife, Ms. Saroj Gambhir for the patience she has shown while I was busy completing the job. I express my gratitude to Ms. Neha Gambhir who has developed design aids and contributed in making the text possible.

I welcome suggestions from the readers for improvement in the subject matter in any manner.

M.L. GAMBHIR
CHAPTER 1

Introduction to Reinforced Concrete

1.1 INTRODUCTION

Concrete is the most widely used material for construction. It consists of a binding medium of cement and water called cement paste, and particles of relatively inert filler called aggregate (and sometimes admixture). The mixture, when placed in forms and allowed to cure, becomes hard like stone. The hardening is caused by chemical reaction between water and the cement, which continues for a long time, and consequently the concrete grows stronger with age.

The popularity of the concrete is due to the fact that from the common ingredients, it is possible to tailor the properties of concrete to meet the demands of any particular situation. The advances in concrete technology have paved the way to make the best use of locally available materials by judicious mix proportioning and proper workmanship, so as to produce concrete satisfying performance requirements.

The finished product (hardened concrete) has high compressive strength, but its tensile strength is very low—approximately one-tenth of its compressive strength. In situations where tensile stresses are developed the concrete is strengthened by steel bars forming a composite construction called reinforced cement concrete. The concrete without reinforcement is called plain concrete or simply concrete.

Thus, concrete making is not just a matter of mixing ingredients to produce a plastic mass, but good concrete has to satisfy the performance requirements in plastic or green state and also in the hardened state. In the plastic state the concrete should be workable and free from segregation and bleeding. Segregation is the separation of coarse aggregate, and bleeding is the separation of cement paste from the main mass. In its hardened state concrete should be strong,
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