

Preface

Recent advances in structural technology require greater accuracy, efficiency and speed in the analysis of structural systems. It is therefore not surprising that new methods have been developed for the analysis of structures with complex configurations and large number of elements.

The requirement of accuracy in analysis has been brought about by the need for demonstrating structural safety. Consequently, accurate methods of analysis had to be developed, since conventional methods, although perfectly satisfactory when used on simple structures, have been found inadequate when applied to complex and large-scale structures. Another reason why higher speed is required results from the need to have optimal design, where analysis is repeated hundred or even thousands of times.

This book can be considered as an application of discrete mathematics rather than the more usual calculus-based methods of analysis of structures and finite element methods. The subject of graph theory has become important in science and engineering through its strong links with matrix algebra and computer science. At first glance, it seems extraordinary that such abstract material should have quite practical applications. However, as the author makes clear, the early relationship between graph theory and skeletal structures and finite element models is now obvious: the structure of the mathematics is well suited to the structure of the physical problem. In fact, could there be any other way of dealing with this structural problem? The engineer studying these applications of structural analysis has either to apply the computer programs as a black box, or to become involved in graph theory, matrix algebra and sparse matrix technology. This book is addressed to those scientists and engineers, and their students, who wish to understand the theory.

The methods of analysis in this book employ matrix algebra and graph theory, which are ideally suited for modern computational mechanics. Although this text deals primarily with analysis of structural engineering systems, it should be recognised that these methods are also applicable to other types of systems such as hydraulic and electrical networks.

The author has been involved in various developments and applications of graph theory in the last four decades. The present book contains part of this research suitable for various aspects of matrix structural analysis and finite element methods, with particular attention to the finite element force method.

In Chap. 1, the most important concepts and theorems of structures and theory of graphs are briefly presented. Chapter 2 contains different efficient approaches for determining the degree of static indeterminacy of structures and provides systematic methods for studying the connectivity properties of structural models. In this chapter, force method of analysis for skeletal structures is described mostly based on the author's algorithms. Chapter 3 provides simple and efficient methods for construction of stiffness matrices. These methods are especially suitable for the formation of well-conditioned stiffness matrices. In Chaps. 4 and 5, banded, variable banded and frontal methods are investigated. Efficient methods are presented for both node and element ordering. Many new graphs are introduced for transforming the connectivity properties of finite element models onto graph models. Chapters 6 and 7 include powerful graph theory and algebraic graph theory methods for the force method of finite element meshes of low order and high order, respectively. These new methods use different graphs of the models and algebraic approaches. In Chap. 8, several partitioning algorithms are developed for solution of multi-member systems, which can be categorized as graph theory methods and algebraic graph theory approaches. In Chap. 9, an efficient method is presented for the analysis of near-regular structures which are obtained by addition or removal of some members to regular structural models. In Chap. 10, energy formulation based on the force method is derived and a new optimization algorithm called SCSS is applied to the analysis procedure. Then, using the SCSS and prescribed stress ratios, structures are analyzed and designed. In all the chapters, many examples are included to make the text easier to be understood.

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Every effort has been made to render the book error free. However, the author would appreciate any remaining errors being brought to his attention through his email-address: alikhavah@iust.ac.ir.

Tehran
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