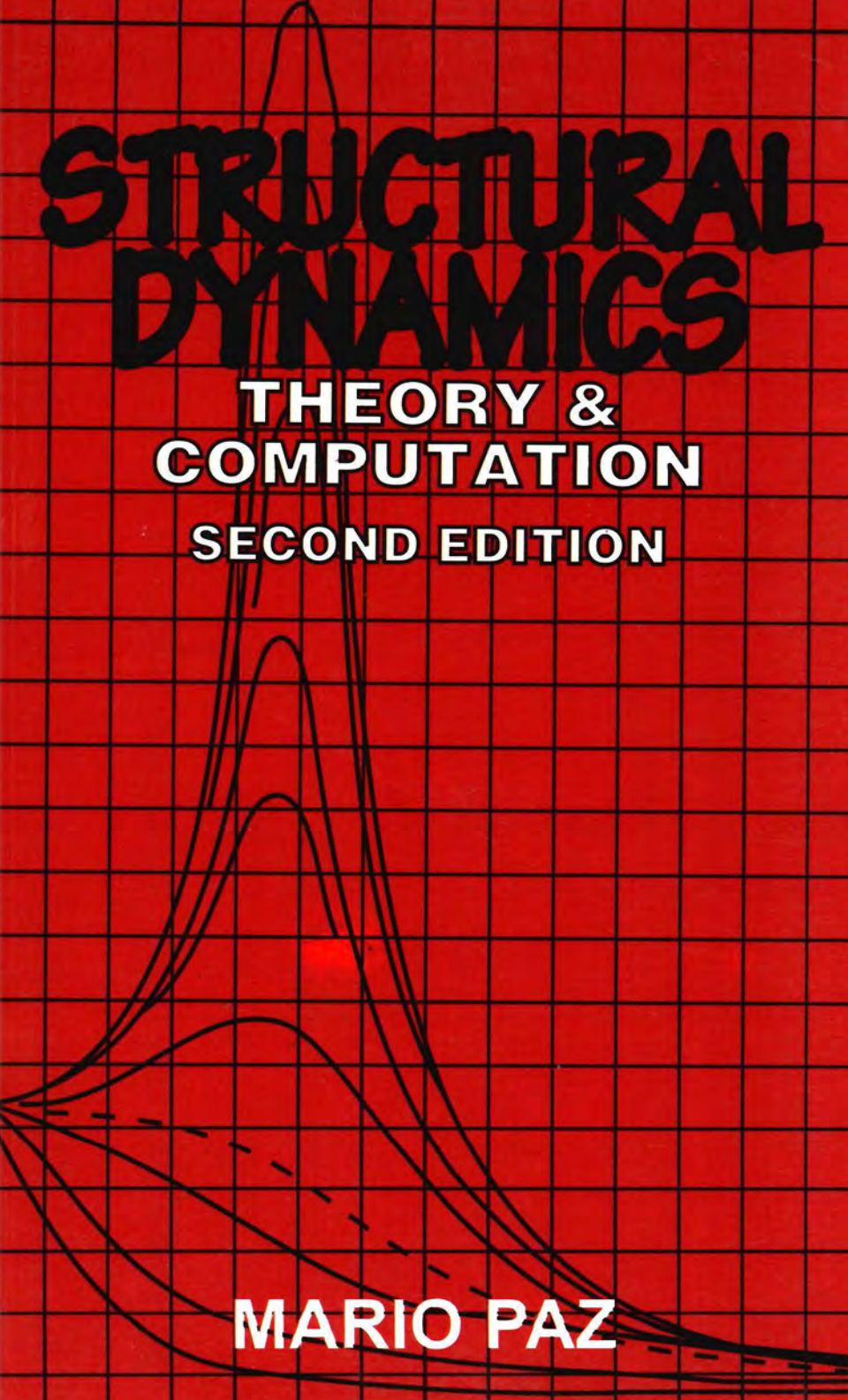
STRUCTURAL DYNAMICS

THEORY & COMPUTATION

SECOND EDITION



MARIO PAZ

STRUCTURAL DYNAMICS

THEORY AND COMPUTATION

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THEORY AND COMPUTATION

MARIO PAZ

Professor of Civil Engineering
University of Louisville

Second Edition

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TO MY CHILDREN
BRENDA
NOEMI
SELMA
BENJAMIN

Foreword

In the Latin world, particularly in France, there is a hallowed tradition by which a young author upon the impendent appearance in print of his first book seeks out an older person, who has worked in the same field a generation earlier, and who (in France) usually has reached a ripe age and the dignity of a "Member of the Academy," with the request to write a foreword or preface, wishing the new book well on the beginning of its career. Such forewords (being a generation out of date by definition) rarely are worth reading, but they are intended to pay a compliment to the older man for his past work.

Although we do not live in the Latin world and we have no tradition, hallowed or otherwise, in this respect, Mario Paz (who originally hails from Chile in the Latin world) has still paid me the compliment with the request that I write a foreword and I am very much pleased of course.

I have known Mario in this country for some 15 years and during that time have worked with him on a number of practical vibration problems; both of us as consultants to the Vibrating Equipment Division of Rexnord Inc., makers of vibrating conveyors. I have formed a high opinion of his abilities.

The book gives a thorough and comprehensive discussion of various "structures," which are the stock in trade of the civil engineer. However, the mechanical

engineer in the background has the habit of messing up these nice structures by putting unbalanced rotors and other devilish devices on them which cause "harmonic responses." These harmonic responses in the structure are discussed through the whole gamut of increasing complication: from single degree-of-freedom idealizations, to discrete systems, and to systems with distributed inertia. If the reader is willing to admit to his "structure" the presence of rotating or reciprocating structural elements the whole book also gives the methods of attack for the truly mechanical engineering problems of rotor dynamics.

This text is important and timely because it bridges the gap between the differential (or other) equations and the ultimate practical numerical solution of a computer program. In so doing the author has indeed advanced a generation on my own youthful text on vibration (1934–1956).

The present book of Mario Paz is clearly written; it should and hopefully will be appreciated by engineering students and practicing engineers, civil or mechanical. I wish the author and his new book a good career!

J. P. DEN HARTOG

Preface to the second edition

The basic structure of the first edition is maintained here, although numerous revisions and additions have been introduced. Rayleigh's method for the rapid calculation of the natural frequencies, which was omitted in the first edition, is now presented in ample detail. The *dynamic condensation method* which has recently been developed by the author for the reduction of eigenproblems is incorporated in Chapter 13. This method of reduction provides a virtually exact solution for each mode in the reduced system. A new chapter on random vibration introduces the reader to this fascinating topic in structural dynamics from an engineering application point of view.

Several sections of the book have been rewritten in an effort to clarify the presentation, and numerous problems have been added to various chapters of the book. The computer programs presented in Appendix I have been revised, more comment statements being included to facilitate program usage. Finally, two new appendices have been added to the book; one providing the answers to the problems proposed as exercises in Part 1, and the other presenting a glossary of basic definitions and concepts employed in the field of structural dynamics.

The author is indebted to the many students, colleagues, and practicing pro-

fessionals who have suggested improvements, identified typographical errors, and recommended additional topics for inclusion. All these suggestions were carefully considered and have been included in this second edition whenever possible. The author is especially appreciative of the many suggestions made by Mr. Herbert Saunders of the General Electric Company who wrote a very complimentary review of the first edition which appeared in *Nuclear Engineering and Design* (No. 71, 1982, p. 259).

Furthermore, it is most appropriate to give special recognition to my former student, Professor Carlos Malpartida of Cusco University, Peru, who with great dedication and talent, collaborated in the development of the dynamic condensation method introduced in the current edition. A special note of appreciation is also extended to Dr. Melvin J. Maron, a colleague at the University of Louisville, for carefully reading the final draft of Chapter 13 and making editorial improvements.

To those people whom I recognized in the first edition for their help, I again express wholehearted appreciation.

MARIO PAZ

Preface to the first edition

Natural phenomena and human activities impose forces of time-dependent variability on structures as simple as a concrete beam or a steel pile, or as complex as a multistory building or a nuclear power plant constructed from different materials. Analysis and design of such structures subjected to dynamic loads involve consideration of time-dependent inertial forces. The resistance to displacement exhibited by a structure may include forces which are functions of the displacement and the velocity. As a consequence, the governing equations of motion of the dynamic system are generally nonlinear partial differential equations which are extremely difficult to solve in mathematical terms. Nevertheless, recent developments in the field of structural dynamics enable such analysis and design to be accomplished in a practical and efficient manner. This work is facilitated through the use of simplifying assumptions and mathematical models, and of matrix methods and modern computational techniques.

In the process of teaching courses on the subject of structural dynamics, the author came to the realization that there was a definite need for a text which would be suitable for the advanced undergraduate or the beginning graduate engineering student being introduced to this subject. The author is familiar with the existence of several excellent texts of an advanced nature but generally these

texts are, in his view, beyond the expected comprehension of the student. Consequently, it was his principal aim in writing this book to incorporate modern methods of analysis and techniques adaptable to computer programming in a manner as clear and easy as the subject permits. He felt that computer programs should be included in the book in order to assist the student in the application of modern methods associated with computer usage. In addition, the author hopes that this text will serve the practicing engineer for purposes of self-study and as a reference source.

In writing this text, the author also had in mind the use of the book as a possible source for research topics in structural dynamics for students working towards an advanced degree in engineering who are required to write a thesis. At Speed Scientific School, University of Louisville, most engineering students complete a fifth year of study with a thesis requirement leading to a Master in Engineering degree. The author's experience as a thesis advisor leads him to believe that this book may well serve the students in their search and selection of topics in subjects currently under investigation in structural dynamics.

The subjects in this text are organized in four parts. Part I deals with structures modeled as single degree-of-freedom systems. It introduces basic concepts and presents important methods for the solution of such dynamic systems. Part II introduces important concepts and methodology for multidegree-of-freedom systems through the use of structures modeled as *shear buildings*. Part III describes methods for the dynamic analysis of framed structures modeled as discrete systems with many degrees of freedom. Finally, Part IV presents the mathematical solution for some simple structures modeled as systems with distributed properties, thus having an infinite number of degrees of freedom. Part IV also shows mathematically the relation between the exact method of solution of continuous systems and the approximate method of solution of structures modeled as discrete systems. The listing of 16 computer programs is given in the Appendix. These programs are discussed in the appropriate chapters throughout the text. They are not highly sophisticated programs which can solve a large variety of problems with optimal efficiency nor are they intended to compete with commercially developed programs. These computer programs are intended mainly for instructional purposes. The programs have been tested through simple problems solved by hand calculation. As a final note, the author would like to assure the user that these programs are "bug-free." Unfortunately, experience demonstrates the high risk involved in such assurances. Instead, the author will be grateful that any error found in the programs be called to his attention.

Should the text fulfill the expectations of the author in some measure, particularly the elucidation of this subject, he will then feel rewarded for his efforts in the preparation and development of the material in this book.

MARIO PAZ

December, 1979

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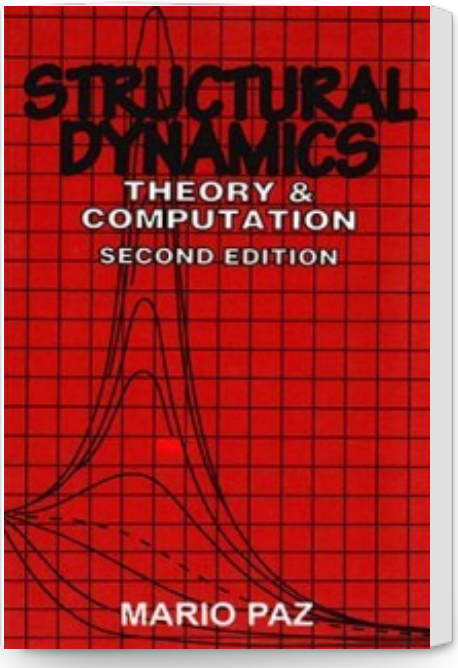
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