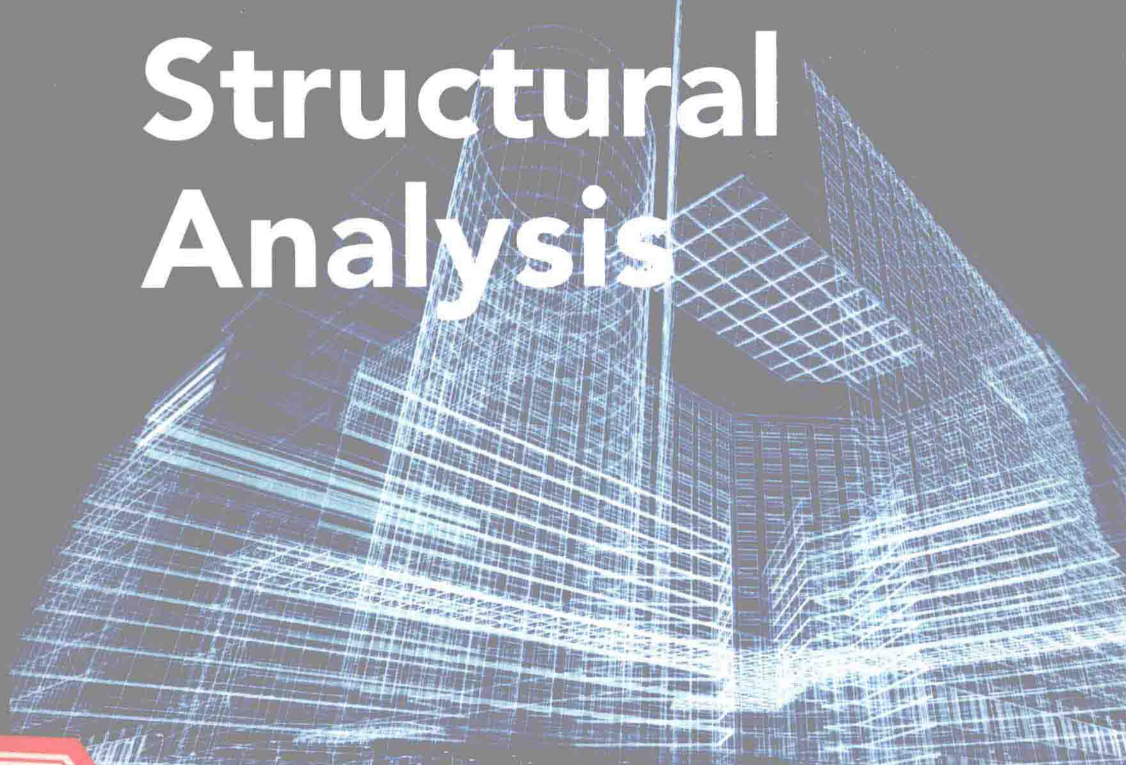
SUSTAINABLE STRUCTURAL SYSTEMS COLLECTION
Mohammad Noori, *Editor*

Numerical Structural Analysis



Steven O'Hara
Carisa H. Ramming

MOMENTUM PRESS ENGINEERING

NUMERICAL STRUCTURAL ANALYSIS

STEVEN E. O'HARA
CARISA H. RAMMING

MOMENTUM PRESS

MOMENTUM PRESS, LLC, NEW YORK

Numerical Structural Analysis

Copyright © Momentum Press®, LLC, 2015.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means—electronic, mechanical, photocopy, recording, or any other—except for brief quotations, not to exceed 400 words, without the prior permission of the publisher.

First published by Momentum Press®, LLC
222 East 46th Street, New York, NY 10017
www.momentumpress.net

ISBN-13: 978-1-60650-488-8 (print)
ISBN-13: 978-1-60650-489-5 (e-book)

Momentum Press Sustainable Structural Systems Collection

DOI: 10.5643/9781606504895

Cover and Interior design by Exeter Premedia Services Private Ltd., Chennai, India

10 9 8 7 6 5 4 3 2 1

Printed in the United States of America

NUMERICAL STRUCTURAL ANALYSIS

Abstract

As structural engineers move further into the age of digital computation and rely more heavily on computers to solve problems, it remains paramount that they understand the basic mathematics and engineering principles used to design and analyze building structures. The analysis of complex structural systems involves the knowledge of science, technology, engineering, and math to design and develop efficient and economical buildings and other structures. The link between the basic concepts and application to real world problems is one of the most challenging learning endeavors that structural engineers face. A thorough understanding of the analysis procedures should lead to successful structures.

The primary purpose of this book is to develop a structural engineering student's ability to solve complex structural analysis problems that they may or may not have ever encountered before. The book will cover and review numerical techniques to solve mathematical formulations. These are the theoretical math and science principles learned as prerequisites to engineering courses, but will be emphasized in numerical formulation. A basic understanding of elementary structural analysis is important and many methods will be reviewed. These formulations are necessary in developing the analysis procedures for structural engineering. Once the numerical formulations are understood, engineers can then develop structural analysis methods that use these techniques. This will be done primarily with matrix structural stiffness procedures. Both of these will supplement both numerical and computer solutions. Finally, advanced stiffness topics will be developed and presented to solve unique structural problems. These include member end releases, nonprismatic, shear, geometric, and torsional stiffness.

KEY WORDS

adjoint matrix, algebraic equations, area moment, beam deflection, carry-over factor, castigliano's theorems, cofactor matrix, column matrix,

试读结束：需要全本请在线购买： www.ertongbook.com

complex conjugate pairs, complex roots, conjugate beam, conjugate pairs, convergence, diagonal matrix, differentiation, distinct roots, distribution factor, eigenvalues, elastic stiffness, enke roots, extrapolation, flexural stiffness, geometric stiffness, homogeneous, identity matrix, integer, integration, interpolation, inverse, joint stiffness factor, linear algebraic equations, lower triangular matrix, matrix, matrix minor, member end release, member relative stiffness factor, member stiffness factor, moment-distribution, non-homogeneous, non-prismatic members, partial pivoting, pivot coefficient, pivot equation, polynomials, principal diagonal, roots, rotation, rotational stiffness, row matrix, second-order stiffness, shear stiffness, slope-deflection, sparse matrix, square matrix, stiffness matrix, structural flexibility, structural stiffness, symmetric transformation, torsional stiffness, transcendental equations, transformations, transmission, transposed matrix, triangular matrix, upper triangular matrix, virtual work, visual integration

List of Figures

List of Tables

试读结束：需要全本请在线购买： www.ertongbook.com

Acknowledgments

Our sincere thanks go to Associate Professor Christopher M. Papadopoulos, PhD, Department of Engineering Science and Materials University of Puerto Rico, Mayagüez.

We would also like to thank the ARCH 6243 – Structures: Analysis II, Spring 2014 class: Kendall Belcher, Conner Bowen, Harishma Donthineni, Gaurang Malviya, Alejandro Marco Perea, Michael Nachreiner, Sai Sankurubhuktha, Timothy Smith, Nuttapong Tanasap, Ignatius Vasant, and Lawrence Wilson.

A special thanks to Nicholas Prather for his assistance with figures.

Contents

CHAPTER 1

ROOTS OF ALGEBRAIC AND TRANSCENDENTAL EQUATIONS

In structural engineering, it is important to have a basic knowledge of how computers and calculators solve equations for unknowns. Some equations are solved simply by algebra while higher order equations will require other methods to solve for the unknowns. In this chapter, methods of finding roots to various equations are explored. The *roots* of an equation are defined as values of x where the solution of an equation is true. The most common roots are where the value of the function is zero. This would indicate where a function crosses an axis. Roots are sometimes *complex roots* where they contain both a real number and an imaginary unit.

1.1 EQUATIONS

Equations are generally grouped into two main categories, algebraic equations and transcendental equations. The first type, an *algebraic equation*, is defined as an equation that involves only powers of x. The powers of x can be any real number whether positive or negative. The following are examples of algebraic equations:

$$8x^3 - 3x^2 + 5x - 6 = 0$$

$$\frac{1}{x} + 2\sqrt{x} = 0$$

$$x^{1.25} - 3\pi = 0$$

The second type is *transcendental equations*. These are non-algebraic equations or functions that transcend, or cannot be expressed in terms of

试读结束：需要全本请在线购买： www.ertongbook.com