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Twelfth Edition

SIMPLIFIED ENGINEERING for ARCHITECTS AND BUILDERS



JAMES AMBROSE

SIMPLIFIED ENGINEERING FOR ARCHITECTS AND BUILDERS

12th Edition

JAMES AMBROSE AND PATRICK TRIPENY

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SIMPLIFIED
ENGINEERING FOR
ARCHITECTS AND
BUILDERS

PREFACE TO THE TWELFTH EDITION

This book treats the topic of design of structures for buildings. As with previous editions, the material in this book has been prepared for persons lacking formal training in engineering. Mathematical work is limited mostly to simple algebra. It is thus well suited for programs in architecture and building construction.

However, as most programs in civil engineering offer little opportunity for study of the general fields of building planning and construction, this book may well be useful as a supplement to engineering texts. The emphasis here is on the development of practical design, which typically involves a relatively small effort in structural investigation and a lot of consideration for circumstantial situations relating to the existence of the building structure.

Changes that occur in reference sources and in design and construction practices make it necessary to revise the material in this book periodically. This edition has indeed received such an updating, although the reader is advised that these changes are continuous.

so that it is inevitable that some of the material present here will be outdated in a short time. However, the concentration in this work is on fundamental concepts and processes of investigation and design; thus the use of specific data is of less concern to the learning of the fundamental material. For use in any actual design work, data should be obtained from current references. A list of these references can be found in the reference section of this book.

In addition to updating, each new edition affords an opportunity to reconsider the organization, presentation, and scope of the material contained in the book. This new edition therefore offers some minor alterations of the basic content of previous editions, although just about everything contained in the previous edition is here somewhere. Some trimming has occurred, largely in order to add new material without significantly increasing the size of the book.

This textbook has an accompanying website for students. The purpose of this website is to provide study material that will aid students in learning this complex material. It is available to anyone using this text either as part of the purchase price or at a nominal cost for those obtaining it secondhand. We encourage all students to take advantage of this resource.

In recent editions it has been the practice to provide answers for all of the computational exercise problems. However, this book receives considerable use as a course text, and several teachers have requested that some problems be reserved for use without given answers. To accommodate this request in this edition, additional exercise problems have been provided, with answers given only to alternate problems. These answers are provided at the accompanying website.

For text demonstrations, as well as for the exercise problems, it is desirable to have some data sources contained in this book. We are grateful to various industry organizations for their permission to use excerpts from these data sources, acknowledgment for which is provided where data are provided.

Both personally—as the authors of this edition—and as representatives of the academic and professional communities, we must express our gratitude to John Wiley & Sons for its continued publication of this highly utilized reference source. We are truly grateful for the sympathetic and highly competent support provided by the Wiley editors and production staff.

Finally, we need to express the gratitude we have to our families. Writing work, especially when added to an already full-time occupation, is very time consuming. We thank our spouses and children for their patience, endurance, support, and encouragement in permitting us to achieve this work.

JAMES AMBROSE

PATRICK TRIPENY

PREFACE TO THE FIRST EDITION

(The following is an excerpt from Professor Parker's preface to the first edition.)

To the average young architectural draftsman or builder, the problem of selecting the proper structural member for given conditions appears to be a difficult task. Most of the numerous books on engineering which are available assume that the reader has previously acquired a knowledge of fundamental principles and, thus, are almost useless to the beginner. It is true that some engineering problems are exceedingly difficult, but it is also true that many of the problems that occur so frequently are surprisingly simple in their solution. With this in mind, and with a consciousness of the seeming difficulties in solving structural problems, this book has been written.

In order to understand the discussions of engineering problems, it is essential that the student have a thorough knowledge of the various terms which are employed. In addition, basic principles of forces in equilibrium must be understood. The first section of this book,

"Principles of Mechanics," is presented for those who wish a brief review of the subject. Following this section are structural problems involving the most commonly used building materials, wood, steel, reinforced concrete, and roof trusses. A major portion of the book is devoted to numerous problems and their solution, the purpose of which is to explain practical procedure in the design of structural members. Similar examples are given to be solved by the student. Although handbooks published by the manufacturers are necessities to the more advanced student, a great number of appropriate tables are presented herewith so that sufficient data are directly at hand to those using this book.

Care has been taken to avoid the use of advanced mathematics, a knowledge of arithmetic and high school algebra being all that is required to follow the discussions presented. The usual formulas employed in the solution of structural problems are given with explanations of the terms involved and their application, but only the most elementary of these formulas are derived. These derivations are given to show how simple they are and how the underlying principle involved is used in building up a formula that has practical application.

No attempt has been made to introduce new methods of calculation, nor have all the various methods been included. It has been the desire of the author to present to those having little or no knowledge of the subject simple solutions of everyday problems. Whereas thorough technical training is to be desired, it is hoped that this presentation of fundamentals will provide valuable working knowledge and, perhaps, open the doors to more advanced study.

HARRY PARKER
Philadelphia, Pennsylvania
March, 1938

INTRODUCTION

The principal purpose of this book is to develop the topic of *structural design*. However, to do the necessary work for design, use must be made of various methods of *structural investigation*. The work of investigation consists of the consideration of the tasks required of a structure and the evaluation of the responses of the structure in performing these tasks. Investigation may be performed in various ways, the principal ones being the use of modeling by either mathematics or the construction of physical models. For the designer, a major first step in any investigation is the visualization of the structure and the force actions to which it must respond. In this book, extensive use is made of graphic illustrations in order to encourage the reader in the development of the habit of first clearly *seeing* what is happening, before proceeding with the essentially abstract procedures of mathematical investigation. When working a problem within the book, the reader is encouraged to begin it by drawing an illustration of the problem.

Structural Mechanics

The branch of physics called *mechanics* concerns the actions of forces on physical bodies. Most of engineering design and investigation is based on applications of the science of mechanics. *Statics* is the branch of mechanics that deals with bodies held in a state of unchanging motion by the balanced nature (called *static equilibrium*) of the forces acting on them. *Dynamics* is the branch of mechanics that concerns bodies in motion or in a process of change of shape due to actions of forces. A static condition is essentially unchanging with regard to time; a dynamic condition implies a time-dependent action and response.

When external forces act on a body, two things happen. First, internal forces that resist the actions of the external forces are set up in the body. These internal forces produce *stresses* in the material of the body. Second, the external forces produce *deformations*, or changes in shape, of the body. *Strength of materials*, or *mechanics of materials*, is the study of the properties of material bodies that enable them to resist the actions of external forces, of the stresses within the bodies, and of the deformations of bodies that result from external forces.

Taken together, the topics of applied mechanics and strength of materials are often given the overall designation of *structural mechanics* or *structural analysis*. This is the fundamental basis for structural investigation, which is essentially an analytical process. On the other hand, *design* is a progressive refining process in which a structure is first visualized; then it is investigated for required force responses and its performance is evaluated. Finally—possibly after several cycles of investigation and modification—an acceptable form is derived for the structure.

Units of Measurement

Early editions of this book used U.S. units (feet, inches, pounds, etc.) with equivalent SI (Standard International—aka metric) units in brackets for the basic presentation. In this edition, the basic work is developed with U.S. units only. While the building industry in the United States is now in the slow process of changing to SI units, our decision for the presentation here is a pragmatic one. Most of the references used for this book are still developed primarily in U.S. units and most readers educated in the United States use U.S. units as their first language, even if they now also use SI units.

Table I.1 lists the standard units of measurement in the U.S. system with the abbreviations used in this work and a description of common usage in structural design work. In similar form, Table I.2 gives the corresponding units in the SI system. Conversion factors to be used for shifting from one unit system to the other are given in Table I.3.

TABLE I.1 Units of Measurement: U.S. System

Name of Unit	Abbreviation	Use in Building Design
<i>Length</i>		
Foot	ft	Large dimensions, building plans, beam spans
Inch	in.	Small dimensions, size of member cross sections
<i>Area</i>		
Square feet	ft ²	Large areas
Square inches	in. ²	Small areas, properties of cross sections
<i>Volume</i>		
Cubic yards	yd ³	Large volumes, of soil or concrete (commonly called simply "yards")
Cubic feet	ft ³	Quantities of materials
Cubic inches	in. ³	Small volumes
<i>Force, Mass</i>		
Pound	lb	Specific weight, force, load
Kip	kip, k	1000 pounds
Ton	ton	2000 pounds
Pounds per foot	lb/ft, plf	Linear load (as on a beam)
Kips per foot	kips/ft, klf	Linear load (as on a beam)
Pounds per square foot	lb/ft ² , psf	Distributed load on a surface, pressure
Kips per square foot	k/ft ² , ksf	Distributed load on a surface, pressure
Pounds per cubic foot	lb/ft ³	Relative density, unit weight
<i>Moment</i>		
Foot-pounds	ft-lb	Rotational or bending moment
Inch-pounds	in.-lb	Rotational or bending moment
Kip-feet	kip-ft	Rotational or bending moment
Kip-inches	kip-in.	Rotational or bending moment
<i>Stress</i>		
Pounds per square foot	lb/ft ² , psf	Soil pressure
Pounds per square inch	lb/in. ² , psi	Stresses in structures
Kips per square foot	kips/ft ² , ksf	Soil pressure
Kips per square inch	kips/in. ² , ksi	Stresses in structures
<i>Temperature</i>		
Degree Fahrenheit	°F	Temperature

TABLE I.2 Units of Measurement: SI System

Name of Unit	Abbreviation	Use in Building Design
<i>Length</i>		
Meter	m	Large dimensions, building plans, beam spans
Millimeter	mm	Small dimensions, size of member cross sections
<i>Area</i>		
Square meters	m ²	Large areas
Square millimeters	mm ²	Small areas, properties of member cross sections
<i>Volume</i>		
Cubic meters	m ³	Large volumes
Cubic millimeters	mm ³	Small volumes
<i>Mass</i>		
Kilogram	kg	Mass of material (equivalent to weight in U.S. units)
Kilograms per cubic meter	kg/m ³	Density (unit weight)
<i>Force, Load</i>		
Newton	N	Force or load on structure
Kilonewton	kN	1000 newtons
<i>Stress</i>		
Pascal	Pa	Stress or pressure (1 pascal = 1 N/m ²)
Kilopascal	kPa	1000 pascals
Megapascal	MPa	1,000,000 pascals
Gigapascal	GPa	1,000,000,000 pascals
<i>Temperature</i>		
Degree Celsius	°C	Temperature

Direct use of the conversion factors will produce what is called a *hard conversion* of a reasonably precise form. Even though all of the work done in this book will be in U.S. units, the tables with SI units are given as a handy reference to readers who may be using reference books in SI units or using both systems.

Accuracy of Computations

Structures for buildings are seldom produced with a high degree of dimensional precision. Exact dimensions are difficult to achieve, even for the most diligent of workers and builders. Add this to considerations for the lack of precision in predicting loads for any structure, and the significance of highly precise structural computations

TABLE I.3 Factors for Conversion of Units

To Convert from U.S. Units to SI Units, Multiply by:	U.S. Unit	SI Unit	To Convert from SI Units to U.S. Units, Multiply by:
25.4	in.	mm	0.03937
0.3048	ft	m	3.281
645.2	in. ²	mm ²	1.550×10^{-3}
16.39×10^3	in. ³	mm ³	61.02×10^{-6}
416.2×10^3	in. ⁴	mm ⁴	2.403×10^{-6}
0.09290	ft ²	m ²	10.76
0.02832	ft ³	m ³	35.31
0.4536	lb (mass)	kg	2.205
4.448	lb (force)	N	0.2248
4.448	kip (force)	kN	0.2248
1.356	ft-lb (moment)	N-m	0.7376
1.356	kip-ft (moment)	kN-m	0.7376
16.0185	lb/ft ³ (density)	kg/m ³	0.06243
14.59	lb/ft (load)	N/m	0.06853
14.59	kips/ft (load)	kN/m	0.06853
6.895	psi (stress)	kPa	0.1450
6.895	ksi (stress)	MPa	0.1450
0.04788	psf (load or pressure)	kPa	20.93
47.88	ksf (load or pressure)	kPa	0.02093
$0.566 \times (^\circ\text{F} - 32)$	$^\circ\text{F}$	$^\circ\text{C}$	$(1.8 \times ^\circ\text{C}) + 32$

becomes moot. This is not to be used for an argument to justify sloppy mathematical work, overly sloppy construction, or use of vague theories of investigation of behaviors. Nevertheless, it makes a case for not being highly concerned with any numbers beyond three significant digits.

While most professional design work these days is likely to be done with computer support, most of the work illustrated here is quite simple and was actually performed with a hand calculator (the 8-digit, scientific type is adequate). Rounding off of these computations is done with no apologies.

With the use of the computer, accuracy of computational work is a somewhat different matter. Still, it is the designer (a person) who makes judgments based on the computations and who knows how good the input to the computer was and what the real significance of the degree of accuracy of an answer is.

Symbols

The following shorthand symbols are frequently used.

Symbol	Reading
$>$	is greater than
$<$	is less than
$\geq$	equal to or greater than
$\leq$	equal to or less than
Σ	the sum of
ΔL	change in L

Standard Notation

Notation used in this book complies generally with that used in the building design field. A general attempt has been made to conform to usage in the reference standards commonly used by structural designers. The following list includes all of the notation used in this book that is general and is related to the topic of the book. Specialized notation is used by various groups, especially as related to individual materials: wood, steel, masonry, concrete, and so on. The reader is referred to basic references for notation in special fields. Some of this notation is explained in later parts of this book.

Building codes use special notation that is usually carefully defined by the code, and the reader is referred to the source for interpretation of these definitions. When used in demonstrations of computations, such notation is explained in the text of this book.

A_g = gross area of a section, defined by the outer dimensions

A_n = net area

C = compressive force

E = modulus of elasticity

I = moment of inertia

L = length (usually of a span)

M = bending moment

P = concentrated load

S = elastic section modulus

T = tension force

W = (1) total gravity load; (2) weight, or dead load of an object;
(3) total wind load force; (4) total of a uniformly distributed load or pressure due to gravity

Z = plastic section modulus

A = unit area

E = eccentricity of a nonaxial load, from point of application of the load to the centroid of the section

F = computed stress

H = effective height (usually meaning unbraced height) of a wall or column

L = length, usually of a span

S = spacing, center to center

W = unit of weight or other uniformly distributed load per unit length of member (note: usually $W = wL$ or wl)

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