Fundamentals of Structural Analysis

Fourth Edition

Kenneth M. Leet

Professor Emeritus, Northeastern University

Chia-Ming Uang

Professor, University of California, San Diego

Anne M. Gilbert

Adjunct Assistant Professor, Yale University



TABLE OF CONTENTS

Preface			xv
Chapter 1	Introduction		3
•	1.1	Overview of the Text	3
	1.2	The Design Process: Relationship	
		of Analysis to Design	4
	1.3	Strength and Serviceability	6
	1.4	Historical Development of Structural	
		Systems	7
	1.5	Basic Structural Elements	10
	1.6	Assembling Basic Elements to Form	
		a Stable Structural System	19
	1.7	Analyzing by Computer	21
	1.8	Preparation of Computations	23
	Sumi	mary	24
Chapter 2	Design Loads		27
•	2.1	Building and Design Code	27
	2.2	Loads	28
	2.3	Dead Loads	29
	2.4	Live Loads	36
	2.5	Snow Loads	42
	2.6	Wind Loads	43
	2.7	Earthquake Loads	58
	2.8	Other Loads	62
	2.9	Load Combinations	63
	Summary		64
Chapter 3	Statics of Structures—Reactions		73
•	3.1	Introduction	73
	3.2	Forces	74
	3.3	Supports	81
	3.4	Idealizing Structures	85
	3.5	Free-Body Diagrams	86
	3.6	Equations of Static Equilibrium	88

3.7	Equations of Condition	94
3.8	Influence of Reactions on Stability	
	and Determinacy of Structures	97
3.9	Classifying Structures	105
3.10	Comparison between Determinate	
	and Indeterminate Structures	108
Sumn	nary	111
Trusses		123
4.1	Introduction	123
4.2	Types of Trusses	126
4.3	Analysis of Trusses	127
4.4	Method of Joints	128
4.5	Zero Bars	132
4.6	Method of Sections	134
4.7	Determinacy and Stability	142
4.8	Computer Analysis of Trusses	148
Summary		151
Beams and Frames		167
5.1	Introduction	167
5.2	Scope of Chapter	172
5.3		173
5.4	-	180
5.5	Principle of Superposition	198
5.6		
	of a Beam or Frame	202
5.7	Degree of Indeterminacy	207
Summary		211
Cables		227
6.1	Introduction	227
6.2	Characteristics of Cables	228
6.3	Variation of Cable Force	229
6.4	Analysis of a Cable Supporting	
	Gravity (Vertical) Loads	230
6.5	General Cable Theorem	232
6.6	Establishing the Funicular Shape	
	of an Arch	234
Summary		237
Arches		243
7.1	Introduction	243
7.2	Types of Arches	244
	3.8 3.9 3.10 Summ Trus: 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 Summ Beal 5.1 5.2 5.3 5.4 5.5 5.6 5.7 Summ Cab 6.1 6.2 6.3 6.4 6.5 6.6 Sum Arc 7.1	3.8 Influence of Reactions on Stability and Determinacy of Structures 3.9 Classifying Structures 3.10 Comparison between Determinate and Indeterminate Structures Summary Trusses 4.1 Introduction 4.2 Types of Trusses 4.3 Analysis of Trusses 4.4 Method of Joints 4.5 Zero Bars 4.6 Method of Sections 4.7 Determinacy and Stability 4.8 Computer Analysis of Trusses Summary Beams and Frames 5.1 Introduction 5.2 Scope of Chapter 5.3 Equations for Shear and Moment 5.4 Shear and Moment Curves 5.5 Principle of Superposition 5.6 Sketching the Deflected Shape of a Beam or Frame 5.7 Degree of Indeterminacy Summary Cables 6.1 Introduction 6.2 Characteristics of Cables 6.3 Variation of Cable Force 6.4 Analysis of a Cable Supporting Gravity (Vertical) Loads 6.5 General Cable Theorem 6.6 Establishing the Funicular Shape of an Arch Summary Arches 7.1 Introduction

	7.3 7.4	Three-Hinged Arches Funicular Shape for an Arch That	246	
	Sum	Supports a Uniformly Distributed Load	247 252	
Chapter 8	Live Load Forces: Influence Lines			
•	for Determinate Structures			
	8.1	Introduction	259 259	
	8.2	Influence Lines	259	
	8.3	Construction of an Influence Line		
	8.4	The Müller–Breslau Principle	260	
	8.5	Use of Influence Lines	268	
	8.6	Influence Lines for Girders Supporting	271	
	8.7	Floor Systems Influence Lines for Trusses	274	
	8.8	Live Loads for Highway and	280	
	0.0	Railroad Bridges	20.5	
	8.9	Increase—Decrease Method	285	
	8.10	Absolute Maximum Live Load	288	
	0.20	Moment	202	
	8.11	Maximum Shear	292	
	Sumn		296	
			297	
Chapter 9	Deflections of Beams and Frames		309	
	9.1	Introduction	309	
	9.2	Double Integration Method	310	
	9.3	Moment-Area Method	317	
	9.4	Elastic Load Method	335	
	9.5	Conjugate Beam Method	339	
	9.6	Design Aids for Beams	347	
	Summ	ary	350	
Chapter 10	Work-Energy Methods for			
	Computing Deflections		363	
	10.1	Introduction		
	10.2	Work	363 364	
	10.3	Strain Energy	366	
	10.4	Deflections by the Work-Energy	300	
		Method (Real Work)	369	
	10.5	Virtual Work: Trusses	370	
	10.6	Virtual Work: Beams and	310	
		Frames	387	

	10.7 10.8		399	
	10.0	Displacements	401	
	10.9	Maxwell-Betti Law of Reciprocal		
		Deflections	404	
	Sumn	nary	408	
Chapter 11	Analysis of Indeterminate Structures			
	by the Flexibility Method		421	
	11.1	Introduction	421	
	11.2	Concept of a Redundant	422	
	11.3	Fundamentals of the Flexibility		
		Method	423	
	11.4	Alternative View of the Flexibility		
		Method (Closing a Gap)	426	
	11.5	Analysis Using Internal Releases	436	
	11.6	Support Settlements, Temperature		
		Change, and Fabrication Errors	443	
	11.7	Analysis of Structures with Several		
		Degrees of Indeterminacy	448	
	11.8	Beam on Elastic Supports	455	
	Sumn	nary	458	
Chapter 12	Anal	vois of Indotorminate Pages		
Chapter 12	Analysis of Indeterminate Beams and Frames by the Slope-Deflection			
	Met		467	
	12.1		467	
	12.2		407	
	12.4	Method	468	
	12.3	Derivation of the Slope-Deflection	400	
	12.5	Equation	469	
	12.4	Analysis of Structures by the	409	
	14.7	Slope-Deflection Method	476	
	12.5	Analysis of Structures That Are Free	470	
	12.5	to Sidesway	492	
	12.6	Kinematic Indeterminacy	502	
	Sumn			
	Summ	uu j	503	
Chapter 13	Mon	nent Distribution	513	
	13.1	Introduction	513	
	13.2	Development of the Moment		
		Distribution Method	514	

	13.3	Jacon Distribution	
	13.4	Method with No Joint Translation	519
	15.4	but of Eculis by Montelle	
	12 5	Distribution Co.	520
	13.5	Modification of Member Stiffness	528
	13.6	Analysis of Frames That Are Free to	
	100	Sidesway	543
	13.7	Analysis of an Unbraced Frame for	
	12.0	General Loading	549
	13.8	Analysis of Multistory Frames	554
	13.9	Nonprismatic Members	555
	Sumi	mary	566
Chapter 14	Inde	eterminate Structures:	
	Influ	ence Lines	575
	14.1	Introduction	575
	14.2	Construction of Influence Lines	313
		Using Moment Distribution	576
	14.3	Müller-Breslau Principle	580
	14.4	Qualitative Influence Lines for	300
		Beams	501
	14.5	Live Load Patterns to Maximize Forces	581
		in Multistory Buildings	588
	Sumn		598
		·	296
Chapter 15	App	roximate Analysis of	
		terminate Structures	603
	15.1		603
	15.2	Approximate Analysis of a Continuous	
	150	Beam for Gravity Load	605
	15.3	Approximate Analysis of a Rigid	
	1 ~ 1	Frame for Vertical Load	611
	15.4	Approximate Analysis of a	
	15.5	Continuous Truss	615
	15.5	Estimating Deflections of Trusses	621
	15.6	Trusses with Double Diagonals	623
	15.7	Approximate Analysis of a Multistory	
	160	Rigid Frame for Gravity Load	626
	15.8	Analysis of Unbraced Frames for	
	15.0	Lateral Load	635
	15.9	Portal Method	638
	15.10	Cantilever Method	646
	Summ	ary	651

Chapter 16	Introduction to the General Stiffness Method		
	16.1	Introduction	659 659
	16.2	Comparison between Flexibility and	
		Stiffness Methods	660
	16.3	Analysis of an Indeterminate Structure	
		by the General Stiffness Method	664
	Summ	= -	677
Chapter 17		ix Analysis of Trusses by the	
•	Direc	t Stiffness Method	683
	17.1		683
	17.2	Member and Structure Stiffness	
		Matrices	688
	17.3	Construction of a Member Stiffness	
		Matrix for an Individual Truss Bar	689
	17.4	Assembly of the Structure Stiffness	
		Matrix	690
	17.5	Solution of the Direct Stiffness Method	693
	17.6	Member Stiffness Matrix of an	707
	1/7/7	Inclined Truss Bar	697
	17.7	Coordinate Transformation of a Member	700
	Carana	Stiffness Matrix	709 710
	Sumn	nary	/10
Chapter 18	Matrix Analysis of Beams and Frames by the Direct Stiffness Method		715
	18.1	Introduction	715
	18.2		717
	18.3		
		for a Flexural Member	718
	18.4	The 4×4 Member Stiffness Matrix	
		in Local Coordinates	729
	18.5	The 6 × 6 Member Stiffness Matrix	
		in Local Coordinates	739
	18.6	The 6×6 Member Stiffness Matrix	
		in Global Coordinates	748
	18.7	Assembly of a Structure Stiffness	
		Matrix—Direct Stiffness Method	750
	Sumn	nary	753
Glossary			757
	dd-Num	bered Problems	761
Photo Credits			768
Index			769