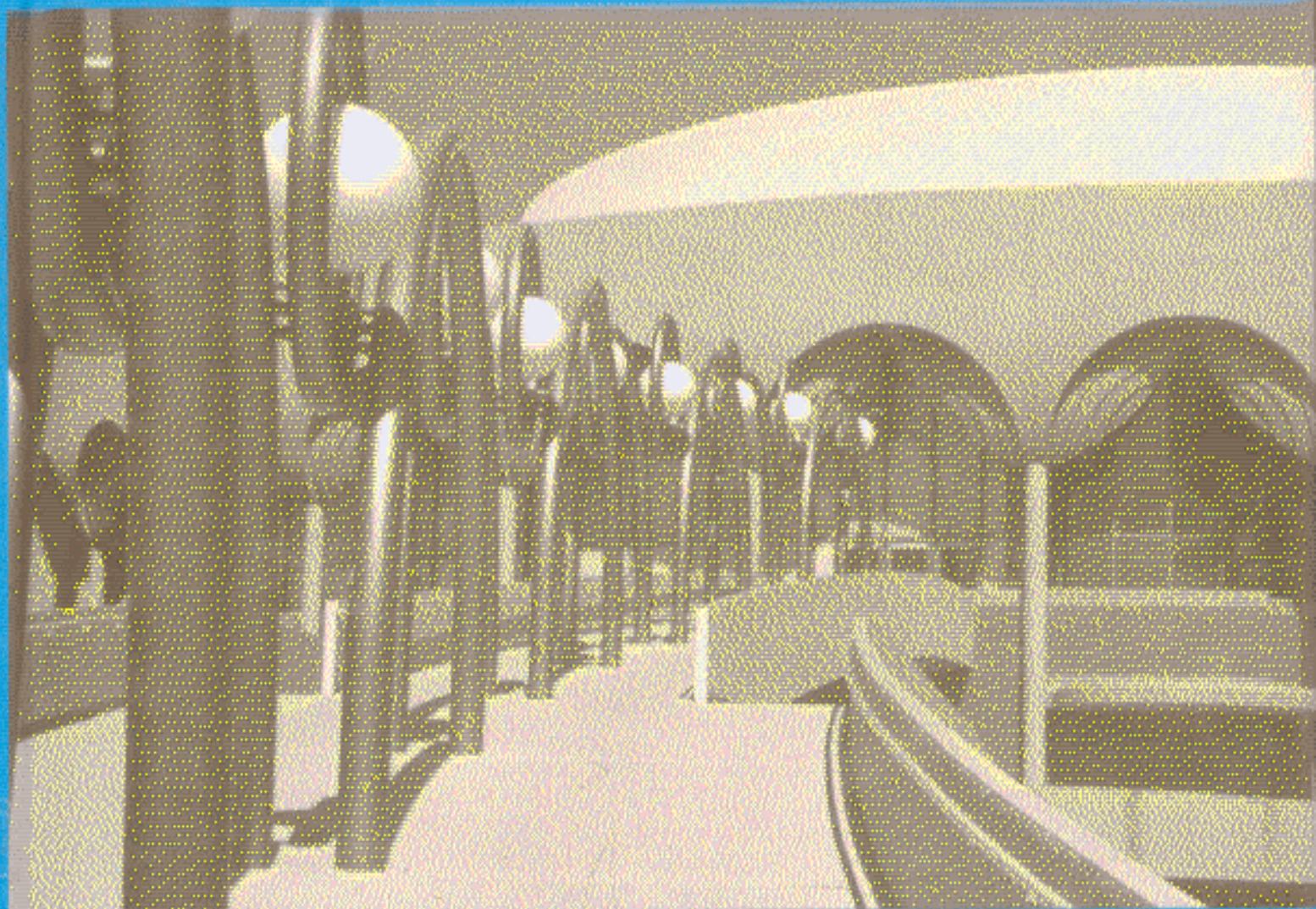


# Introduction to Structural Analysis & Design



S. D. RAJAN

# Contents

---

<b>Chapter 1</b>	<b>Introduction</b>	<b>1</b>
1.1	Structural Engineering	2
1.2	Types of Structural Systems	4
1.3	Structural Analysis	12
1.4	Structural Design	12
1.5	Units and Values	15
1.6	Tips and Aids	16
<b>Chapter 2</b>	<b>Determinate Structural Systems</b>	<b>19</b>
2.1	Components of Structural Systems	20
2.1.1	Structural Members	20
2.1.2	Connections	21
2.1.3	Supports	22
2.2	Free-Body Diagrams	24
2.2.1	Resultant of Distributed Loading	25
2.3	Equilibrium	32
2.4	Determinacy	33
2.5	Simple Determinate Structures	34
2.6	Stability	43
2.7	Planar Truss Analysis	44
2.7.1	Method of Joints	46
2.7.2	General Procedure	46
2.7.3	Method of Sections	56
2.7.4	General Procedure	57
2.7.5	Zero Force Members	62
2.7.6	Unstable Trusses	63
2.8	Planar Frame Analysis	65
2.8.1	Internal Forces	65
2.8.2	Shear Force and Bending Moment Diagrams	70
2.8.3	Shear Force and Bending Moment Diagrams for Beams	73
2.8.4	Shear Force and Bending Moment Diagrams for Frames	86
2.8.5	Unstable Frames	100
<b>Chapter 3</b>	<b>Structural Design Fundamentals</b>	<b>109</b>
3.1	Material Behavior	112
3.1.1	Stress and Strain	112
3.1.2	Material Properties	115
3.1.3	Stress-Strain Relationship	116
3.1.4	Principal Stress and Strain	117
3.2	Stress and Strain Computations	123
3.2.1	Cross-Sectional Properties	123
3.2.2	Axial Force	126

3.2.3	Bending Moment	126
3.2.4	Shear Force	128
3.2.5	Combined Stresses	129
3.3	Theories of Failure	137
3.3.1	Some Causes of Structural Failures	137
3.3.2	Failure Criteria	138
3.4	Commonly Used Structural Materials	142
3.5	Modeling the Structure and the Loads	143
3.6	Design Specifications	150
3.6.1	Design Codes	151
3.6.2	Dead Loads	151
3.6.3	Live Loads	152
3.6.4	Wind Loads	154
3.6.5	Snow and Rain Loads	163
3.6.6	Earthquake Loads	168
3.6.7	Other Design Issues	168
3.7	Simple Design Examples	172
3.7.1	Mathematical Background	172
3.7.2	Design Problems and Issues	173
<b>Chapter 4</b>	<b>Computation of Deflections</b>	<b>191</b>
4.1	Beam Deflection Differential Equation	192
4.2	Moment-Area Method	194
4.3	Conjugate Beam Method	206
4.4	Energy Principles	215
4.5	Principle of Virtual Work	222
4.5.1	Unit Load Method for Beams and Frames	225
4.5.2	Unit Load Method for Trusses	234
<b>Chapter 5</b>	<b>Indeterminate Structural Systems</b>	<b>245</b>
5.1	Force Method	246
5.1.1	Beams	247
5.1.2	Frames	262
5.1.3	Trusses	270
5.1.4	Higher Degrees of Indeterminacy	280
5.2	Slope-Deflection Method	296
5.2.1	Beams	300
5.2.2	Frames without Sidesway	307
5.2.3	Frames with Sidesway	315
<b>Chapter 6</b>	<b>Matrix-Based Numerical Methods of Structural Analysis</b>	<b>335</b>
6.1	Fundamentals of Matrix Algebra	337
6.1.1	Definitions	337
6.1.2	Operations	338
6.2	Direct Stiffness Method	341
6.2.1	Overview	341
6.2.2	Truss Analysis	347
6.2.3	Frame Analysis	362

3.2.3	Bending Moment	126
3.2.4	Shear Force	128
3.2.5	Combined Stresses	129
3.3	Theories of Failure	137
3.3.1	Some Causes of Structural Failures	137
3.3.2	Failure Criteria	138
3.4	Commonly Used Structural Materials	142
3.5	Modeling the Structure and the Loads	143
3.6	Design Specifications	150
3.6.1	Design Codes	151
3.6.2	Dead Loads	151
3.6.3	Live Loads	152
3.6.4	Wind Loads	154
3.6.5	Snow and Rain Loads	163
3.6.6	Earthquake Loads	168
3.6.7	Other Design Issues	168
3.7	Simple Design Examples	172
3.7.1	Mathematical Background	172
3.7.2	Design Problems and Issues	173
<b>Chapter 4</b>	<b>Computation of Deflections</b>	<b>191</b>
4.1	Beam Deflection Differential Equation	192
4.2	Moment-Area Method	194
4.3	Conjugate Beam Method	206
4.4	Energy Principles	215
4.5	Principle of Virtual Work	222
4.5.1	Unit Load Method for Beams and Frames	225
4.5.2	Unit Load Method for Trusses	234
<b>Chapter 5</b>	<b>Indeterminate Structural Systems</b>	<b>245</b>
5.1	Force Method	246
5.1.1	Beams	247
5.1.2	Frames	262
5.1.3	Trusses	270
5.1.4	Higher Degrees of Indeterminacy	280
5.2	Slope-Deflection Method	296
5.2.1	Beams	300
5.2.2	Frames without Sidesway	307
5.2.3	Frames with Sidesway	315
<b>Chapter 6</b>	<b>Matrix-Based Numerical Methods of Structural Analysis</b>	<b>335</b>
6.1	Fundamentals of Matrix Algebra	337
6.1.1	Definitions	337
6.1.2	Operations	338
6.2	Direct Stiffness Method	341
6.2.1	Overview	341
6.2.2	Truss Analysis	347
6.2.3	Frame Analysis	362

<b>6.3</b>	<b>Theorem of Minimum Potential Energy</b>	<b>379</b>
<b>6.4</b>	<b>Finite Element Method</b>	<b>385</b>
6.4.1	Truss Analysis	388
6.4.2	Frame Analysis	393
<b>6.5</b>	<b>Advanced Topics</b>	<b>411</b>
6.5.1	Internal Hinge	411
6.5.2	Skew Supports	419
6.5.3	Support Settlements	421
6.5.4	Typical Connection	424
6.5.5	Thermal Loads	428
<b>Chapter 7</b>	<b>Computer-Based Structural Analysis</b>	<b>437</b>
7.1	Overview	439
7.2	Terminology	440
7.3	Building a Mathematical Model	441
7.4	Steps in Modeling the Structure	444
7.5	Some Basic Checks	470
7.6	More Examples	475
<b>Chapter 8</b>	<b>Optimum Structural Design</b>	<b>495</b>
8.1	Background	497
8.2	Types of Mathematical Programming Problems	501
8.3	Nonlinear Programming (NLP) Problem	503
8.3.1	Kuhn-Tucker Conditions	504
8.3.2	Numerical Solution Techniques	509
8.4	Genetic Algorithm	510
8.4.1	The Basic Algorithm	511
8.4.2	Problem Formulation	516
8.5	Design Examples	516
8.6	Linking Analysis and Design Techniques	527
8.7	Structural Optimization	528
8.7.1	Sizing Optimal Design	529
8.7.2	Shape Optimal Design	531
8.7.3	Topology Optimal Design	532
8.7.4	Combination Optimal Design	534
8.8	Design Examples	538
8.8.1	Broad Classification of Structural Forms	538
8.8.2	Optimal Design Using the GS-USA© Program	542
8.8.3	Case Studies	544
<b>Chapter 9</b>	<b>Design of Steel and Concrete Structures</b>	<b>567</b>
9.1	Introduction to Design of Steel Structures	569
9.1.1	Design of Tension Members	572
9.1.2	Design of Compression Members	576
9.1.3	Column Design	579
9.1.4	Beam Design	584
9.2	Introduction to Design of Concrete Structures	599
9.2.1	Beam Design	603
9.2.2	Column Design	622

<b>Bibliography</b>	<b>641</b>
<b>Answers to Selected Problems</b>	<b>643</b>
<b>Appendix A Material Properties</b>	<b>661</b>
<b>Appendix B Cross-Sectional Properties</b>	<b>663</b>
<b>Appendix C Commonly Used Structural Values</b>	<b>667</b>
<b>Appendix D Catalog of Structural Solutions</b>	<b>671</b>
<b>Appendix E Mathematical Background</b>	<b>675</b>
<b>Index</b>	<b>685</b>