

# MECHANICS of MATERIALS



**FOURTH EDITION**

**R.C. HIBBELER**

Saranaree University of Technology



31051000607001

# CONTENTS

---

## PREFACE xi

## 1

---

### STRESS 3

- 1.1 Introduction 3
- 1.2 Equilibrium of a Deformable Body 4
- 1.3 Stress 22
- 1.4 Average Normal Stress in an Axially Loaded Bar 24
- 1.5 Average Shear Stress 32
- 1.6 Allowable Stress 48

## 2

---

### STRAIN 67

- 2.1 Deformation 67
- 2.2 Strain 68

## 3

---

### MECHANICAL PROPERTIES OF MATERIALS 83

- 3.1 The Tension and Compression Test 83
- 3.2 The Stress-Strain Diagram 85
- 3.3 Stress-Strain Behavior of Ductile and Brittle Materials 89
- 3.4 Hooke's Law 92
- 3.5 Strain Energy 94
- 3.6 Poisson's Ratio 104
- 3.7 The Shear Stress-Strain Diagram 106
- 3.8 Failure of Materials Due to Creep and Fatigue 109

---

**AXIAL LOAD 117**

- 4.1 Saint-Venant's Principle 117
- 4.2 Elastic Deformation of an Axially Loaded Member 120
- 4.3 Principle of Superposition 133
- 4.4 Statically Indeterminate Axially Loaded Member 134
- 4.5 The Force Method of Analysis for Axially Loaded Members 140
- 4.6 Thermal Stress 148
- 4.7 Stress Concentrations 156
- \*4.8 Inelastic Axial Deformation 162
- \*4.9 Residual Stress 167

---

**TORSION 177**

- 5.1 Torsional Deformation of a Circular Shaft 177
- 5.2 The Torsion Formula 178
- 5.3 Power Transmission 189
- 5.4 Angle of Twist 198
- 5.5 Statically Indeterminate Torque-Loaded Members 213
- \*5.6 Solid Noncircular Shafts 220
- \*5.7 Thin-Walled Tubes Having Closed Cross Sections 223
- 5.8 Stress Concentration 234
- \*5.9 Inelastic Torsion 237
- \*5.10 Residual Stress 244

---

**BENDING 255**

- 6.1 Shear and Moment Diagrams 255
- 6.2 Graphical Method for Constructing Shear and Moment Diagrams 264
- 6.3 Bending Deformation of a Straight Member 282
- 6.4 The Flexure Formula 286
- 6.5 Unsymmetric Bending 304
- \*6.6 Composite Beams 315
- \*6.7 Reinforced Concrete Beams 322
- \*6.8 Curved Beams 324
- 6.9 Stress Concentrations 334
- \*6.10 Inelastic Bending 343
- \*6.11 Residual Stress 352

## TRANSVERSE SHEAR 363

- 7.1 Shear in Straight Members 363
- 7.2 The Shear Formula 365
- 7.3 Shear Stresses in Beams 366
- 7.4 Shear Flow in Built-up Members 382
- 7.5 Shear Flow in Thin-Walled Members 391
- \*7.6 Shear Center 396

## COMBINED LOADINGS 409

- 8.1 Thin-Walled Vessels 409
- 8.2 State of Stress Caused by Combined Loadings 416

## STRESS TRANSFORMATION 439

- 9.1 Plane-Stress Transformation 439
- 9.2 General Equations of Plane-Stress Transformation 444
- 9.3 Principal Stresses and Maximum In-Plane Shear Stress 448
- 9.4 Mohr's Circle—Plane Stress 462
- 9.5 Stress in Shafts Due to Axial Load and Torsion 471
- 9.6 Stress Variations Throughout a Prismatic Beam 472
- 9.7 Absolute Maximum Shear Stress 478

## STRAIN TRANSFORMATION 489

- 10.1 Plane Strain 489
- 10.2 General Equations of Plane-Strain Transformation 491
- \*10.3 Mohr's Circle—Plane Strain 498
- \*10.4 Absolute Maximum Shear Strain 505
- 10.5 Strain Rosettes 508
- 10.6 Material-Property Relationships 512
- \*10.7 Theories of Failure 524

# 11

---

## DESIGN OF BEAMS AND SHAFTS 539

- 11.1 Basis for Beam Design 539
- 11.2 Prismatic Beam Design 541
- \*11.3 Fully Stressed Beams 554
- \*11.4 Shaft Design 558

# 12

---

## DEFLECTIONS OF BEAMS AND SHAFTS 569

- 12.1 The Elastic Curve 569
- 12.2 Slope and Displacement by Integration 573
- \*12.3 Discontinuity Functions 590
- \*12.4 Slope and Displacement by the Moment-Area Method 600
- 12.5 Method of Superposition 614
- 12.6 Statically Indeterminate Beams and Shafts 622
- 12.7 Statically Indeterminate Beams and Shafts—Method of Integration 622
- \*12.8 Statically Indeterminate Beams and Shafts—Moment-Area Method 628
- 12.9 Statically Indeterminate Beams and Shafts—Method of Superposition 634

# 13

---

## BUCKLING OF COLUMNS 649

- 13.1 Critical Load 649
- 13.2 Ideal Column with Pin Supports 652
- 13.3 Columns Having Various Types of Supports 658
- \*13.4 The Secant Formula 669
- \*13.5 Inelastic Buckling 677
- \*13.6 Design of Columns for Concentric Loading 683
- \*13.7 Design of Columns for Eccentric Loading 694

## ENERGY METHODS 705

- 14.1 External Work and Strain Energy 705
- 14.2 Elastic Strain Energy for Various Types of Loading 710
- 14.3 Conservation of Energy 724
- 14.4 Impact Loading 730
- \*14.5 Principle of Virtual Work 740
- \*14.6 Method of Virtual Forces Applied to Trusses 744
- \*14.7 Method of Virtual Forces Applied to Beams 752
- \*14.8 Castigliano's Theorem 762
- \*14.9 Castigliano's Theorem Applied to Trusses 764
- \*14.10 Castigliano's Theorem Applied to Beams 768

## A

---

### GEOMETRIC PROPERTIES OF AN AREA 775

- A.1 Centroid of an Area 775
- A.2 Moment of Inertia for an Area 778
- A.3 Product of Inertia for an Area 782
- A.4 Moments of Inertia for an Area about Inclined Axes 784
- A.5 Mohr's Circle for Moments of Inertia 786

## B

---

### GEOMETRICAL PROPERTIES OF STRUCTURAL SHAPES 792

## C

---

### SLOPES AND DEFLECTIONS OF BEAMS 800

## D

---

### REVIEW FOR THE FUNDAMENTALS OF ENGINEERING EXAM 802

### ANSWERS 822

### INDEX 844