Contents

| | , | | | | |
|---|---|--------------------------|--|-----|--|
| Prefac | e to the Ninth Edition ix | 4.3 | Principle of Reciprocal Deflections 82 | | |
| Preface to the First Edition xi | | 4.4 | Method of Consistent Deformations | | |
| List of Tables xiii | | | (Strain Compatibility) 82 | | |
| | | 4.5 | Energy Methods 82 | | |
| CHAP | TER 1 | 4.6 | Castigliano's Theorem 83 | | |
| Introduction 1 | | 4.7 | Dimensional Analysis 89 | | |
| | | 4.8 | Remarks on the Use of Formulas 90 | | |
| 1.1 | Terminology 1 | 4.9 | References 92 | | |
| 1.2 | State Properties, Units, and Conversions 1 | CHAF | TED E | | |
| 1.3 | Contents 3 | | PTER 5 | | |
| 1.4 | References 13 | Nume | erical Methods 93 | | |
| CHAP | TER 2 | 5.1 | The Finite Difference Method 93 | | |
| Stress and Strain: Important Relationships 15 | | 5.2 | The Finite Element Method 94 | | |
| Jucaa | | 5.3 | The Boundary Element Method 99 | | |
| 2.1 | Stress 15 | 5.4 | Zeroes of Polynomials 105 | | |
| 2.2 | Strain and the Stress–Strain Relations 19 | 5.5 | Solution of Differential Equations 106 | | |
| 2.3 | Stress Transformations 22 | 5.6 | Numerical Integration 106 | | |
| 2.4 | Strain Transformations 34 | 5.7 | References 107 | | |
| 2.5 | Mohr's Circle 34 | 5.8 | Additional Uncited References for Finite | | |
| 2.6 | Mohr's Circles for 3D Stress Analysis 37 | | Elements 108 | | |
| 2.7 | Tables 40 | 5.9 | Additional Uncited References for Boundary | | |
| 2.8 | References 44 | | Elements 108 | | |
| CHAI | PTER 3 | | | | |
| The Behavior of Bodies under Stress 45 | | CHAI | CHAPTER 6 | | |
| The Benavior of Bodies under Stress 45 | | Experimental Methods 109 | | | |
| 3.1 | Methods of Loading 45 | 6.1 | Measurement Techniques 109 | | |
| 3.2 | Elasticity; Proportionality of Stress and Strain 46 | 6.2 | Electrical Resistance Strain Gages 114 | | |
| 3.3 | Factors Affecting Elastic Properties 47 | 6.3 | Detection of Plastic Yielding 124 | | |
| 3.4 | Load Deformation Relation for a Body 48 | 6.4 | Analogies 124 | | |
| 3.5 | Plasticity 48 | | Wheatstone Bridge 125 | | |
| 3.6 | Creep and Rupture under Long-Time Loading 48 | 6.5 | | | |
| 3.7 | Criteria of Elastic Failure and of Rupture 50 | 6.6 | Nondestructive Testing 126 Tables 129 | | |
| 3.8 | Fatigue 53 | 6.7 | References 135 | | |
| 3.9 | Brittle Fracture 57 | 6.8 | References 155 | | |
| 3.10 | Stress Concentration 58 | CHA | PTER 7 | | |
| 3.11 | Effect of Form and Scale on Strength; Rupture | | | 137 | |
| | Factor 60 | iensi | ion, Compression, Shear, and Combined Stress | 137 | |
| 3.12 | Prestressing 61 | 7.1 | Bar under Axial Tension (or Compression); | | |
| 3.13 | Elastic Stability 62 | | Common Case 137 | | |
| 3.14 | Tables: Mechanical Properties of Materials 65 | 7.2 | Bar under Tension (or Compression); Special | | |
| 3.15 | References 78 | | Cases 139 | | |
| | | 7.3 | Composite Members 141 | | |
| CHAPTER 4 | | 7.4 | Trusses 143 | | |
| Princ | iples and Analytical Methods 81 | 7.5 | Body under Pure Shear Stress 145 | | |
| 4.1 | Equations of Motion and of Equilibrium 81 | 7.6 | Cases of Direct Shear Loading 147 | | |
| 4.2 | Disciple of Companyation 91 | 77 | Combined Stress 147 | | |

Circular-Plate Deflection Due to Shear 392 **CHAPTER 8** 11.3 114 Rimetallic Plates 393 Beams: Flexure of Straight Bars 151 Nonuniform Loading of Circular Plates 397 11.5 Straight Beams (Common Case) Elastically Stressed 151 Circular Plates on Elastic Foundations 397 11.6 Composite Beams and Bimetallic Strips 161 8.2 Circular Plates of Variable Thickness 398 11.7 8.3 Three-Moment Equation 164 11.8 Disk Springs 400 Rigid Frames 165 8.4 Narrow Ring under Distributed Torque about 11.9 Beams on Elastic Foundations 170 Its Axis 401 Deformation Due to the Elasticity of Fixed Supports 174 Bending of Uniform-Thickness Plates with Straight 11.10 Beams under Simultaneous Axial and Transverse 8.7 Boundaries 402 Loading 175 Effect of Large Deflection; Diaphragm 11.11 Beams of Variable Section 179 Stresses 403 Slotted Beams 185 8.9 Plastic Analysis of Plates 407 11.12 Beams of Relatively Great Depth 185 Ultimate Strength 407 Beams of Relatively Great Width 189 8.11 Tables 409 11.14 Beams with Wide Flanges; Shear Lag 192 8.12 11.15 References 458 Beams with Very Thin Webs 193 8.13 Beams Not Loaded in Plane of Symmetry; Flexural **CHAPTER 12** Center 194 Columns and Other Compression Members 463 Straight Uniform Beams (Common Case); Ultimate 12.1 Columns; Common Case 463 Strength 196 12.2 Local Buckling 467 Plastic, or Ultimate Strength, Design 199 8.16 Strength of Latticed Columns 471 12.3 Tables 203 8.17 Eccentric Loading: Initial Curvature 472 12.4 8.18 References 266 Columns under Combined Compression and 12.5 **CHAPTER 9** Bending 474 Curved Beams 269 Thin Plates with Stiffeners 476 Short Prisms under Eccentric Loading 478 12.7 Bending in the Plane of the Curve 269 Table 481 12.8 Deflection of Curved Beams 276 9.2 12.9 References 483 Circular Rings and Arches 284 9.3 Elliptical Rings 293 9.4 **CHAPTER 13** Curved Beams Loaded Normal to Plane of Shells of Revolution; Pressure Vessels; Pipes 485 Curvature 294 Circumstances and General State of Stress 485 Tables 300 9.6 Thin Shells of Revolution under Distributed Loadings 13.2 References 348 9.7 Producing Membrane Stresses Only 485 **CHAPTER 10** Thin Shells of Revolution under Concentrated or Torsion 349 Discontinuous Loadings Producing Bending and Membrane Stresses 488 Straight Bars of Uniform Circular Section under 13.4 Thin Multielement Shells of Revolution 500 Pure Torsion 349 Thin Shells of Revolution under External 13.5 Bars of Noncircular Uniform Section under Pressure 511 Pure Torsion 350 Thick Shells of Revolution 513 13.6 Effect of End Constraint 355 10.3 Pipe on Supports at Intervals 515 13.7 Effect of Longitudinal Stresses 362 Tables 517 13.8 Ultimate Strength of Bars in Torsion 363 References 581 13.9 Torsion of Curved Bars; Helical Springs 363 10.6 10.7 Tables 366 **CHAPTER 14** References 384 10.8 Bodies under Direct Bearing and Shear Stress 585 **CHAPTER 11** Stress Due to Pressure between Elastic Bodies 585 Flat Plates 387 Rivets and Riveted Joints 589 14.2 Miscellaneous Cases 592 Common Case 387 14.3 11.1 Table 595 Bending of Uniform-Thickness Plates with Circular 14.4 Boundaries 388 14.5 References 598

| CHAPTER 15 Elastic Stability 601 | | | | |
|--|---|--|--|--|
| 15.1 15.2 15.3 15.4 15.5 15.6 | General Considerations 601 Buckling of Bars 602 Buckling of Flat and Curved Plates 604 Buckling of Shells 605 Tables 608 References 626 | | | |
| CHAPTER 16 Dynamic and Temperature Stresses 631 | | | | |
| 16.1 | Dynamic Loadings; General Conditions 631 | | | |
| 16.2 | Body in a Known State of Motion 631 | | | |
| 16.3 | Impact and Sudden Loading 639 | | | |
| 16.4 | Impact and Sudden Loading; Approximate | | | |
| 10 | Formulas 640 | | | |
| 16.5 | Remarks on Stress Due to Impact 642 | | | |
| 16.6 | Vibration 643 | | | |
| 16.7 | Temperature Stresses 648 | | | |
| 16.8 | Tables 653 | | | |
| 16.9 | References 669 | | | |
| CHVD. | TER 17 | | | |
| | | | | |
| Stress | Concentration 671 | | | |
| 17.1 | Static Stress and Strain Concentration Factors 671 | | | |
| 17.2 | Stress Concentration Reduction | | | |
| | Methods 676 | | | |
| 17.3 | Tables 679 | | | |
| 17.4 | References 695 | | | |
| CHAPTER 18 | | | | |
| Fatigu | e and Fracture 697 | | | |
| 18.1 | Fatigue in Materials 697 | | | |
| 18.2 | Fatigue Testing 698 | | | |
| 18.3 | Fatigue and Crack Growth 700 | | | |
| 18.4 | Creep 700 | | | |
| 18.5 | Fracture Mechanics 701 | | | |
| 18.6 | The Stress Intensity Factor 703 | | | |
| 18.7 | Fracture Toughness 706 | | | |
| 18.8 | Crack Tip Plasticity 708 | | | |
| 18.9 | The Energy Balance Approach of | | | |
| | Fracture 709 | | | |
| 18.10 | The J Integral 710 | | | |
| 18.11 | Tables 712 | | | |
| 18.12 | References 722 | | | |
| CHAPTER 19 | | | | |
| Stresses in Fasteners, Joints, and Gears 723 | | | | |
| 19.1 | Welding 723 | | | |
| 19.2 | Analysis of Welded Joints 725 | | | |
| 19.3 | Strength of Welded Joints 728 | | | |

| 19.5 | Shearing and Failure Modes in Riveted Joints 733 |
|-------|---|
| 19.6 | Eccentric Loading of Riveted Joints 735 |
| 19.7 | Bolt Strength and Design 738 |
| 19.8 | Gearing and Gear Stress 739 |
| | References 741 |
| 19.9 | References /41 3 |
| CHAPI | |
| Compo | osite Materials 743 |
| 20.1 | Composite Materials Classifications and Components 743 |
| 20.2 | Mechanics of Composite Materials 746 |
| 20.3 | Macromechanics of a Layer (Lamina) 746 |
| 20.4 | Micromechanics of a Layer (Lamina) 749 |
| 20.5 | Failure Criterion for a Layer (Lamina) 752 |
| 20.6 | Macromechanics of a Laminate 756 |
| 20.7 | Classical Lamination Theory 757 |
| 20.8 | Macromechanics of a Laminate: Stress and Strain in |
| | a Laminate 758 |
| 20.9 | Inversion of Stiffness Equation in a Laminate 765 |
| 20.10 | Example of Stresses and Strains in |
| | a Laminate 766 |
| 20.11 | Strength and Failure Analyses of Laminate 769 |
| 20.12 | Composite Sandwich Structures 773 |
| 20.13 | Composite Cellular Structures 775 |
| 20.14 | Tables 777 |
| 20.15 | References 782 |
| | TER 21 Biomechanics 785 |
| | |
| 21.1 | Introduction 785 |
| 21.2 | Biomechanics of Bone 785 Biomechanics of Articular Cartilage 790 |
| 21.3 | Diomeenumes of the second |
| 21.4 | Diomecuanico or remeans |
| 21.5 | Didirection of transcript |
| 21.6 | Biomechanics of Joints 795 Biomechanics of the Knee 795 |
| 21.7 | Didirection of the later |
| 21.8 | Biomechanics of the Hip 797 |
| 21.9 | Biomechanics of the Spine 800 |
| 21.10 | Biomechanics of the Lumbar Spine 802 |
| 21.11 | Biomechanics of the Cervical Spine 806 |
| 21.12 | Biomechanics of the Shoulder 809 |
| 21.13 | Biomechanics of the Elbow 810 |
| 21.14 | |
| 21.15 | * |
| 21.16 | * * |
| 21.17 | |
| 21.18 | |
| 21.19 | |
| 21.20 | |
| 21.21 | |
| 21.22 | Glossary 826 |
| | |

Riveted and Bolted Ioints 733

viii Contents

APPENDIX A

Properties of a Plane Area 827

APPENDIX B

Mathematical Formulas and Matrices 847

APPENDIX C

Glossary 875

Index 885