620.112 BOR 3d ed.

CONTENTS

1/THEORIES OF STRESS AND STRAIN 1

1-1/Definition of Stress at a Point 6

1-2/Stress Notation 8

1-3/Symmetry of the Stress Array and Stress on an Arbitrarily Oriented Plane 11

1-4/Transformation of Stress. Principal Stresses. Other Properties 15

1-5/Differential Equations of Motion of a Deformable Body 33

1-6/Deformation of a Deformable Body 38

1-7/Strain Theory. Principal Strains 40

1-8/Strain of a Volume Element 48

1-9/Small-Displacement Theory 50

2/STRESS-STRAIN-TEMPERATURE RELATIONS 61

2-1/Elastic and Nonelastic Response of a Solid 62

2-2/First Law of Thermodynamics, Internal-Energy Density, Complementary Internal-Energy Density 66

2-3/Hooke's Law. Anisotropic Elasticity 73

2-4/Hooke's Law. Isotropic Elasticity 74

2-5/Equations of Thermoelasticity for Isotropic Materials 81

2-6/Initiation of Yield. Yield Criteria 82

3/FAILURE CRITERIA 101

3-1/Modes of Failure 103

1/FAILURE BY ELASTIC DEFLECTION 105

2/FAILURE BY EXTENSIVE YIELDING 106

3/FAILURE BY FRACTURE 109

3-2 / Failure Criteria. Excessive Deflections 110
3-3 / Failure Criteria. Yield Initiation. Extensive Yield 113
3-4 / Failure Criteria. Fracture 132
3-5 / Progressive Fracture (High Cycle Fatigue for Number of Cycles $N > 10^6$) 144

4/APPLICATION OF ENERGY METHODS: ELASTIC DEFLECTIONS AND STATICALLY INDETERMINATE MEMBERS AND STRUCTURES 155

4-1 / Principle of Stationary Potential Energy 156
4-2 / Castigliano's Theorem on Deflections 163
4-3 / Castigliano's Theorem on Deflections for Linear Load-Deflection Relations 168
4-4 / Deflections of Statically Determinate Structures 175
4-5 / Statically Indeterminate Structures 190

5/TORSION 209

5-1 / Torsion of a Cylindrical Bar of Circular Cross Section 210
5-2 / Śaint-Venant's Semi-Inverse Method 214
5-3 / Linear Elastic Solution 221
5-4 / The Prandtl Elastic-Membrane (Soap-Film) Analogy 226
5-5 / Narrow Rectangular Cross Section 230
5-6 / Hollow Thin-Wall Torsion Members. Multiply Connected Cross Section 233
5-7 / Thin-Wall Torsion Members with Restrained Ends 242
5-8 / Fully-Plastic Torsion 252

6/UNSYMMETRICAL BENDING OF STRAIGHT BEAMS 259

6-1 / Definition of Shear Center in Bending. Symmetrical and Unsymmetrical Bending 259
6-2 / Bending Stresses in Beams Subjected to Unsymmetrical Bending 267
6-3 / Deflections of Straight Beams Subjected to Unsymmetrical Bending 281

6-4 / Change in Direction of Neutral Axis and Increase in Stress and Deflection in Rolled Sections Due to a Very Small Inclination of Plane of Loads to a Principal Plane 286

6-5 / Fully Plastic Load for Unsymmetrical Bending 288

7 / SHEAR CENTER FOR THIN-WALL BEAM CROSS SECTIONS 293

7-1 / Approximations Employed for Shear in Thin-Wall Beam Cross Sections 293

7-2 / Shear Flow in Thin-Wall Beam Cross Sections 296

7-3 / Shear Center for a Channel Section 299

7-4 / Shear Center of Composite Beams Formed From Stringers and Thin Webs 308

7-5 / Shear Center of Box Beams 315

7-6 / Straight Shafts Subjected to Combined Loads 321

8 / CURVED BEAMS 327

8-1 / Introduction 327

8-2 / Circumferential Stress in a Curved Beam 328

8-3 / Radial Stresses in Curved Beams 341

8-4 / Correction of Circumferential Stresses in Curved Beams Having I, T, or Similar Cross Sections 345

8-5 / Deflections of Curved Beams 354

8-6 / Statically Indeterminate Curved Beams. Closed Ring Subjected to a Concentrated Load 360

8-7 / Fully Plastic Loads for Curved Beams 363

9 / BEAMS ON ELASTIC FOUNDATIONS 369

9-1 / General Theory 370

9-2 / Infinite Beam Subjected to Concentrated Load: Boundary Conditions 372

9-3 / Infinite Beam Subjected to a Distributed Load Segment 386

9 4 / Semi-Infinite Beam Subjected to Loads at Its End 391

9-5 / Semi-Infinite Beam with Concentrated Load Near Its End 392
9-6 / Short Beams 394
9-7 / Thin-Wall Circular Cylinders 396

10 / FLAT PLATES 405

A / BASIC EQUATIONS AND SIMPLE SOLUTIONS 405
10-1 / Introduction 405
10-2 / Stress Resultants in a Flat Plate 407
10-3 / Kinematics: Strain-Displacement Relations for Plates 411
10-4 / Equilibrium Equations for Small-Displacement Theory of Flat Plates 416
10-5 / Stress-Strain-Temperature Relations for Isotropic Elastic Plates 419
10-6 / Strain Energy of a Plate 424
10-7 / Boundary Conditions for Plates 425
10-8 / Solution of Plate Problems 429
10-9 / Failure Loads for Circular and Rectangular Plates 435

B / SUMMARY OF CERTAIN PLATE SOLUTIONS **441**
10-10 / Small Elastic Deflections of Circular Plates. Theory and Experiment 441
10-11 / Large Elastic Deflections of Circular Plates. Clamped Edge 447
10-12 / Large Elastic Deflections of Circular Plates. Simply Supported Edge 453
10-13 / Small Elastic Deflections of Rectangular Plates. Uniform Load 455
10-14 / Stress in Rectangular Plate Supported on Two Opposite Edges by Beams 462

11 / THE THICK-WALL CYLINDER 471

11-1 / Basic Relations 471
11-2 / Stress Components for a Cylinder with Closed Ends 475
11-3 / Stress Components and Radial Displacement for Constant Temperature 479
11-4 / Criteria of Failure 483

11-5/Fully Plastic Pressure. Autofrettage 492
11-6/Cylinder Solution for Temperature Change Only 498

12/STRESS CONCENTRATIONS. BASIC CONCEPTS 503

12-1/Nature of Stress. A Concentration Problem Stress Concentration Factor 506
12-2/Stress Concentration Factors. Theory of Elasticity 511
12-3/Stress Concentration Factors. Experimental Techniques 522
12-4/Stress Gradiants Due to Concentrated Load 530
12-5/The Stationary Crack 532
12-6/Crack Propagation. Stress Intensity Factor 537

13/EFFECTIVE STRESS CONCENTRATION FACTORS. APPLICATIONS 549

13-1/Stress Concentration Factors—Combined Loads 549
13-2/Effective Stress Concentration Factors 559
13-3/Effective Stress Concentration Factors. Repeated Loads 567
13-4/Effective Stress Concentration Factors. Other Influences 569
13-5/Effective Stress Concentration Factors. Inelastic Strains 575

14/CONTACT STRESSES 581

14-1/Introduction 581
14-2/The Problem of Determining Contact Stresses 582
14-3/Assumptions on Which a Solution for Contact Stresses is Based 585
14-4/Notation and Meaning of Terms 591
14-5/Expressions for Principal Stresses 592
14-6/Method of Computing Contact Stresses 594
14-7/Deflection of Bodies in Point Contact 604
14-8/Stress for Two Bodies in Contact over Narrow Rectangular Area (Line Contact). Loads Normal to Contact Area 613
14-9/Stress for Two Bodies in Line Contact. Loads Normal and Tangent to Contact Area 616

15 / STRUCTURAL INSTABILITY. BUCKLING 629

A / COLUMNS 629

15-1 / Elastic Buckling of Ideal Slender Column 630

15-2 / Imperfect Slender Column 636

15-3 / Inelastic Buckling 638

15-4 / Two Formulas for Inelastic Buckling of an Ideal Column 639

15-5 / Tangent-Modulus Formula for an Inelastic Buckling Load. Load at which Inelastic Bending of Ideal Column Begins 641

15-6 / Double-Modulus Formula 645

15-7 / Comparison of the Two Formulas for the Inelastic Buckling Load 649

B / CYLINDRICAL TUBES, RINGS, AND FLAT PLATES 653

15-8 / The Problem Defined 653

15-9 / Critical Load for Elastic Buckling of Rings The Slender Thin-Wall Circular Tube. 655

15-10 / Empirical Formulas 662

15-11 / Effect of End Restraints on Elastic Buckling of Tube 662

15-12 / Inelastic Buckling of Tube 666

15-13 / Post-Buckling Strength of Flat Plates 668

APPENDIX / SECOND MOMENT (MOMENT OF INERTIA) OF A PLANE AREA 675

A-1 / Moments of Inertia of a Plane Area 675

A-2 / Parallel Axis Theorem 676

A-3 / Transformation Equations for Moments and Products of Inertia 680

INDEX 685