

Contents

Preface

v

PART I. THIN PLATES

1	Introduction	1
1.1	General	1
1.2	History of Plate Theory Development	4
1.3	General Behavior of Plates	7
1.4	Survey of Elasticity Theory	8
	References	14
2	The Fundamentals of the Small-Deflection Plate Bending Theory	17
2.1	Introduction	17
2.2	Strain–Curvature Relations (Kinematic Equations)	17
2.3	Stresses, Stress Resultants, and Stress Couples	20
2.4	<u>The Governing Equation for Deflections of Plates in Cartesian Coordinates</u>	24
2.5	Boundary Conditions	27
2.6	Variational Formulation of Plate Bending Problems	36
	Problems	41
	References	42
3	Rectangular Plates	43
3.1	Introduction	43
3.2	The Elementary Cases of Plate Bending	43
3.3	Navier's Method (Double Series Solution)	47

3.4	Rectangular Plates Subjected to a Concentrated Lateral Force P	54
3.5	Levy's Solution (Single Series Solution)	60
3.6	Continuous Plates	71
3.7	<u>Plates on an Elastic Foundation</u>	76
3.8	Plates with Variable Stiffness	81
3.9	Rectangular Plates Under Combined Lateral and Direct Loads	84
3.10	Bending of Plates with Small Initial Curvature	88
	Problems	90
	References	92
4	Circular Plates	95
4.1	Introduction	95
4.2	Basic Relations in Polar Coordinates	95
4.3	Axisymmetric Bending of Circular Plates	98
4.4	The Use of Superposition for the Axisymmetric Analysis of Circular Plates	109
4.5	Circular Plates on Elastic Foundation	113
4.6	Asymmetric Bending of Circular Plates	116
4.7	Circular Plates Loaded by an Eccentric Lateral Concentrated Force	119
4.8	Circular Plates of Variable Thickness	122
	Problems	128
	References	132
5	Bending of Plates of Various Shapes	133
5.1	Introduction	133
5.2	Elliptical Plates	133
5.3	Sector-Shaped Plates	135
5.4	Triangular Plates	137
5.5	Skew Plates	139
	Problems	140
	References	141
6	Plate Bending by Approximate and Numerical Methods	143
6.1	Introduction	143
6.2	The Finite Difference Method (FDM)	144
6.3	The Boundary Collocation Method (BCM)	152
6.4	The Boundary Element Method (BEM)	156
6.5	The Galerkin Method	166
6.6	The Ritz Method	171
6.7	The Finite Element Method (FEM)	175
	Problems	186
	References	188
7	Advanced Topics	191
7.1	Thermal Stresses in Plates	191
7.2	Orthotropic and Stiffened Plates	197
7.3	The Effect of Transverse Shear Deformation on the Bending of Elastic Plates	207

7.4	Large-Deflection Theory of Thin Plates	215
7.5	Multilayered Plates	231
7.6	Sandwich Plates	233
Problems		237
References		239
<hr/>		
8	Buckling of Plates	241
8.1	Introduction	241
8.2	General Postulations of the Theory of Stability of Plates	241
8.3	The Equilibrium Method	245
8.4	<u>The Energy Method</u>	255
8.5	Buckling Analysis of Orthotropic and Stiffened Plates	259
8.6	Postbuckling Behavior of Plates	265
8.7	Buckling of Sandwich Plates	270
Problems		272
References		273
<hr/>		
9	Vibration of Plates	275
9.1	Introduction	275
9.2	Free Flexural Vibrations of Rectangular Plates	276
9.3	Approximate Methods in Vibration Analysis	278
9.4	Free Flexural Vibrations of Circular Plates	284
9.5	Forced Flexural Vibrations of Plates	286
Problems		288
References		289
<hr/>		
PART II. THIN SHELLS		
10	Introduction to the General Linear Shell Theory	291
10.1	Shells in Engineering Structures	291
10.2	General Definitions and Fundamentals of Shells	293
10.3	Brief Outline of the Linear Shell Theories	294
10.4	Loading-Carrying Mechanism of Shells	299
References		300
<hr/>		
11	Geometry of the Middle Surface	303
11.1	Coordinate System of the Surface	303
11.2	Principal Directions and Lines of Curvature	304
11.3	The First and Second Quadratic Forms of Surfaces	307
11.4	Principal Curvatures	310
11.5	Unit Vectors	311
11.6	Equations of Codazzi and Gauss. Gaussian Curvature.	312
11.7	Classification of Shell Surfaces	313
11.8	Specialization of Shell Geometry	316
Problems		324
References		324

12	The General Linear Theory of Shells	325
12.1	Basic Assumptions	325
12.2	Kinematics of Shells	326
12.3	Statics of Shells	333
12.4	Strain Energy of Shells	340
12.5	Boundary Conditions	341
12.6	Discussion of the Governing Equations of the General Linear Shell Theory	344
12.7	Types of State of Stress for Thin Shells	346
	Problems	347
	References	347
13	The Membrane Theory of Shells	349
13.1	Preliminary Remarks	349
13.2	The Fundamental Equations of the Membrane Theory of Thin Shells	350
13.3	Applicability of the Membrane Theory	351
13.4	The Membrane Theory of Shells of Revolution	352
13.5	Symmetrically Loaded Shells of Revolution	356
13.6	Membrane Analysis of Cylindrical and Conical Shells	361
13.7	The Membrane Theory of Shells of an Arbitrary Shape in Cartesian Coordinates	368
	Problems	371
	References	372
14	Application of the Membrane Theory to the Analysis of Shell Structures	373
14.1	Membrane Analysis of Roof Shell Structures	373
14.2	Membrane Analysis of Liquid Storage Facilities	390
14.3	Axisymmetric Pressure Vessels	402
	Problems	405
	References	409
15	Moment Theory of Circular Cylindrical Shells	411
15.1	Introduction	411
15.2	Circular Cylindrical Shells Under General Loads	412
15.3	Axisymmetrically Loaded Circular Cylindrical Shells	421
15.4	Circular Cylindrical Shell of Variable Thickness Under Axisymmetric Loading	443
	Problems	446
	References	448
16	The Moment Theory of Shells of Revolution	449
16.1	Introduction	449
16.2	Governing Equations	450
16.3	Shells of Revolution Under Axisymmetrical Loads	454
16.4	Approximate Method for Solution of the Governing Equations (16.30)	460

16.5	Axisymmetric Spherical Shells, Analysis of the State of Stress at the Spherical-to-Cylindrical Junction	464
16.6	Axisymmetrically Loaded Conical Shells	475
16.7	Axisymmetric Deformation of Toroidal Shells	478
Problems		479
References		481
17	Approximate Theories of Shell Analysis and Their Applications	483
17.1	Introduction	483
17.2	The Semi-Membrane Theory of Cylindrical Shells	483
17.3	The Donnel–Mushtari–Vlasov Theory of Thin Shells	494
17.4	Theory of Shallow Shells	497
17.5	The Theory of Edge Effect	507
Problems		511
References		514
18	Advanced Topics	515
18.1	Thermal Stresses in Thin Shells	515
18.2	The Geometrically Nonlinear Shell Theory	522
18.3	Orthotropic and Stiffened Shells	531
18.4	Multilayered Shells	538
18.5	Sandwich Shells	541
18.6	The Finite Element Representations of Shells	543
18.7	Approximate and Numerical Methods for Solution of Nonlinear Equations	553
Problems		561
References		562
19	Buckling of Shells	565
19.1	Introduction	565
19.2	Basic Concepts of Thin Shells Stability	565
19.3	Linear Buckling Analysis of Circular Cylindrical Shells	573
19.4	Postbuckling Analysis of Circular Cylindrical Shells	585
19.5	Buckling of Orthotropic and Stiffened Cylindrical Shells	590
19.6	Stability of Cylindrical Sandwich Shells	595
19.7	Stability of Shallow Shells Under External Normal Pressure	597
19.8	Buckling of Conical Shells	599
19.9	Buckling of Spherical Shells	600
19.10	Design Stability Analysis	602
Problems		606
References		607
20	Vibrations of Shells	609
20.1	Introduction	609
20.2	Free Vibrations of Cylindrical Shells	610
20.3	Free Vibrations of Conical Shells	618
20.4	Free Vibrations of Shallow Shells	619
20.5	Free Vibrations of Stiffened Shells	622

20.6	Forced Vibrations of Shells	624
Problems		627
References		627
Appendix A. Some Reference Data		629
A.1	Typical Properties of Selected Engineering Materials at Room Temperatures (U.S. Customary Units)	630
A.2	Typical Properties of Selected Engineering Materials at Room Temperatures (International System (SI) Units)	631
A.3	Units and Conversion Factors	632
A.4	Some Useful Data	632
A.5	Typical Values of Allowable Loads	632
A.6	Failure Criteria	632
Appendix B. Fourier Series Expansion		635
B.1	Dirichlet's Conditions	635
B.2	The Series Sum	635
B.3	Coefficients of the Fourier Series	636
B.4	Modification of Relations for the Coefficients of Fourier's Series	636
B.5	The Order of the Fourier Series Coefficients	637
B.6	Double Fourier Series	639
B.7	Sharpening of Convergence of the Fourier Series	640
References		640
Appendix C. Verification of Relations of the Theory of Surfaces		641
C.1	Geometry of Space Curves	641
C.2	Geometry of a Surface	643
C.3	Derivatives of Unit Coordinate Vectors	645
C.4	Verification of Codazzi and Gauss Equations	649
Appendix D. Derivation of the Strain–Displacement Relations		651
D.1	Variation of the Displacements Across the Shell Thickness	651
D.2	Strain Components of the Shell	653
Appendix E. Verification of Equilibrium Equations		655
Index		659