

Contents

Preface	V
1. Introduction	1
1.0 Fundamental concepts	1
1.1 Membrane shells, bent shells	2
1.2 Basic geometric concepts	5
1.3 Basic static concepts	11
1.4 Basic formulas	20
2. Shells of revolution	22
2.0 On shells of revolution in general	22
2.1 Equilibrium equations	25
2.2 Shells of revolution subjected to axisymmetric loads	29
2.3 Spherical shell subjected to axisymmetric loads	33
2.4 Ellipsoid shell of revolution subjected to axisymmetric loads	36
2.5 Cycloid shell of revolution subjected to axisymmetric loads	41
2.6 Anticatenoid shell of revolution subjected to axisymmetric loads ...	44
2.7 Paraboloid shell of revolution subjected to axisymmetric loads	49
2.8 Conical shell of revolution subjected to axisymmetric loads	53
2.9 Hyperboloid shell of revolution subjected to axisymmetric loads ...	56
2.10. Hyperboloid shell of revolution of constant strength subjected to its own weight	60
2.11. Graphical method of analysis for shells of revolution subjected to axisymmetric loads	63
2.12. Design rules	65
2.13. Shells of revolution subjected to antisymmetric loads	70
2.14. Spherical shell subjected to antisymmetric loads	75
2.15. Paraboloid shell of revolution subjected to antisymmetric loads	81
2.16. Conical shell subjected to antisymmetric loads	88
2.17. Cylindrical shell subjected to antisymmetric loads	94
2.18. Shells of revolution subjected to periodic loads	97
2.19. Spherical shell subjected to periodic loads	100
2.20. Conical shell subjected to periodic loads	106
2.21. Cylindrical shell subjected to periodic loads	108
2.22. Shell of revolution supported by columns	110
2.23. Hyperboloid shell of revolution subjected to wind load	113

3.	Cylindrical shells	127
3.0.	On cylindrical shells in general	127
3.1.	Equilibrium equations of cylindrical shells	130
3.2.	Different types of barrel vaults	132
3.3.	Barrel vaults with a circular profile	137
3.4.	Barrel vaults with an elliptic profile	139
3.5.	Barrel vaults with a cycloidal profile	141
3.6.	Barrel vaults with a catenoidal profile	144
3.7.	Barrel vaults with a parabolic profile	147
3.8.	Barrel vaults with Wiedemann profile	149
3.9.	Barrel vaults with a funicular profile	151
3.10.	Design rules	153
4.	Shells of arbitrary shape	158
4.0.	On shells of arbitrary shape in general	158
4.1.	Fundamentals	158
4.2.	Equilibrium equations in rectangular and in oblique co-ordinates ..	162
4.3.	Equilibrium equations in cylindrical polar co-ordinates	165
4.4.	Differential equation of the stress function in rectangular and in oblique co-ordinates	169
4.5.	Differential equation of the stress function in cylindrical polar co- ordinates	171
4.6.	Geometrical interpretation of the stress function	173
4.7.	Physical interpretation of the stress function	174
4.8.	Various kinds of shell problems	178
4.9.	On the boundary conditions of the stress function in general	181
4.10.	Free edge	183
4.11.	Edge supported by a plane edge girder	186
4.12.	Edge supported by a vertical wall	189
4.13.	Edge supported by a rigid structure	193
4.14.	Support conditions of the corners	193
4.15.	State of stress of the corners	196
4.16.	State of stress of special points	200
4.17.	State of stress of affine shells	204
4.18.	Design rules	210
5.	Triangular shells	214
5.0.	On triangular shells in general	214
5.1.	Paraboloid shell of revolution over an equilateral triangular ground plan, subjected to a uniformly distributed load	215
5.2.	Paraboloid shell of revolution over an equilateral triangular ground plan, subjected to an axisymmetrically distributed load	225
5.3.	Paraboloid shell of revolution over an equilateral triangular ground plan, subjected to a load uniformly distributed over the middle surface	233

5.4.	Paraboloid shell of revolution over a right-angled isosceles triangular ground plan, subjected to a uniformly distributed load	240
5.5.	Paraboloid shell of revolution over an isosceles triangular ground plan, subjected to a vertical load distributed according to a polynomial . .	253
5.6.	Paraboloid shell of revolution over an isosceles triangular ground plan, subjected to an arbitrarily distributed vertical load	270
5.7.	Paraboloid shell of revolution over a triangular ground plan, subjected to a distributed edge load	282
5.8.	Shells of special shape over an equilateral triangular ground plan . .	287
5.9.	Paraboloid shell of revolution over an arc-triangular ground plan . .	293
6.	Rectangular shells	301
6.0.	On rectangular shells in general	301
6.1.	Elliptic paraboloid shell over a rectangular ground plan. Solution by a double Fourier series	302
6.2.	Elliptic paraboloid shell over a rectangular ground plan. Solution by a simple Fourier series	305
6.3.	Elliptic paraboloid shell over a rectangular ground plan. Solution with the aid of tables	310
6.4.	Elliptic paraboloid shell over a rectangular ground plan. Singularity at the corners	343
6.5.	Elliptic paraboloid shell over a rectangular ground plan. Solution by the finite difference method	346
6.6.	Paraboloid shell of revolution over a square ground plan. Approximate solution by collocation	354
6.7.	Pseudoparaboloid shell over a rectangular ground plan	361
6.8.	Pseudoparaboloid shell over a square ground plan	373
6.9.	Horseshoe shell over a rectangular ground plan	381
6.10.	Sickle shell over a rectangular ground plan	389
6.11.	Spherical shell over a square ground plan	399
6.12.	Barrel vaults. Treatment in a rectangular co-ordinate system	407
7.	Diagonal shells	413
7.0.	On diagonal shells in general	413
7.1.	Doubly symmetric diagonal shell	414
7.2.	Quadruply symmetric diagonal shell	423
8.	Conoidal shells	430
8.0.	On conoidal shells in general	430
8.1.	Lying conoidal shell with a parabolic directing curve	432
8.2.	Standing conoidal shell with a parabolic directing curve	442
8.3.	Helicoidal shell	455

9.	Hyperbolic paraboloid shells	458
9.0.	On hyperbolic paraboloid shells in general	458
9.1.	Rectangular twisted shells	459
9.2.	Skew quadrangular twisted shells	468
9.3.	Twisted quadrangular shells with an inclined axis	469
9.4.	Composite twisted shells	475
9.5.	Saddle shells	484
10.	Sectorial shells	494
10.0	On sectorial shells in general	494
10.1.	Sectorial shell with plane vertical edges	496
10.2.	Sectorial shell with cylindrical sectors	502
10.3.	Sectorial shell with doubly-curved sectors and overhanging edges ..	510
10.4.	Sectorial shell with sectors formed according to a translational surface and with overhanging edges	519
10.5.	Sectorial shell with conical sectors	529
10.6.	Sectorial shell with free edges and unbent dividing ribs	532
10.7.	Sectorial shell without ties, having unbent edge girders and dividing ribs	535
11.	Polygonal shells	543
11.0.	On polygonal shells in general	543
11.1.	Determination of the stress function of polygonal shells by finite difference equations	545
11.2.	Computation of the specific internal forces by extrapolation	553
11.3.	Checking the method of extrapolation	557
11.4.	Stress function values of polygonal shells with various numbers of sides	563
11.5.	Polygonal shells with a circular skylight opening	570
12.	Point-supported shells	584
12.0.	On point-supported shells in general	584
12.1.	Point-supported shell over an arbitrary polygonal ground plan	585
12.2.	Point-supported shell over an equilateral triangular ground plan ...	597
12.3.	Point-supported shell over a square ground plan	608
12.4.	Point-supported shell over a regular polygonal ground plan	617
13.	Star shells	625
13.0.	On star shells in general	625
13.1.	Star shell subjected to a load uniformly distributed in ground plan .	625
13.2.	Star shell subjected to axisymmetrically distributed loads	641

14. Shells over an elliptic ground plan	653
14.0. On shells over an elliptic ground plan in general	653
14.1. Elliptic paraboloid shells over an elliptic ground plan	653
14.2. Hyperbolic paraboloid shell over an elliptic ground plan	658
14.3. Cylindrical shell over an elliptic ground plan	661
15. Shell apses	663
15.0. On shell apses in general	663
15.1. Shell apse over a circular segment-shaped ground plan	664
15.2. Shell apse over an elliptic segment-shaped ground plan	673
15.3. Shell apse over a parabolic segment-shaped ground plan	675
15.4. Shell apse over a hyperbolic segment-shaped ground plan	677
15.5. Shell apse over a triangular ground plan	679
15.6. Shell apse formed by a quarter sphere	682
16. Bending theory	688
16.0. On bending theories in general	688
16.1. Specific internal forces of shallow shells	688
16.2. Equilibrium equations of shallow shells	690
16.3. Compatibility equation of shallow shells	693
16.4. Deformation function of shallow shells	694
16.5. Displacement functions of shallow shells	696
16.6. Edge moments of shallow shells	697
16.7. Criticism of the shell theory	701
Literature	703
Subject index	719