

CONTENTS	i
PREFACE	v
LIST OF SYMBOLS	vii
CHAPTER 1. INTRODUCTION	1
CHAPTER 2. MATERIALS AND MATERIAL PROPERTIES	7
2.1 Face Materials	7
2.2 Estimation of Face Material Properties	9
2.2.1 Rule-of-mixtures	9
2.2.2 "Practical" rule-of-mixtures	10
2.2.3 Conversion weight fraction/volume fraction	11
2.2.4 Thickness prediction	11
2.2.5 Stiffness properties of the lamina	12
2.2.6 Stiffness properties of the laminate	14
2.2.7 Strength of composite laminates	15
2.3 Experimental Determination of Face Material Properties	15
2.4 Core Materials	18
2.4.1 Honeycomb cores	19
2.4.2 Balsa wood	22
2.4.3 Cellular foams	22
2.5 Fatigue Properties of Sandwich Core Materials	25
2.6 Estimations of Core Material Properties	27
2.7 Experimental Determination of Core Material Properties	29
2.8 Adhesives – Description and Properties	31
2.8.1 Requirements on the adhesive	31
2.8.2 Adhesives and their properties	33
2.9 Experimental Determination of the Adhesive Interface Properties	35
CHAPTER 3. FUNDAMENTALS	39
3.1 Flexural Rigidity	39
3.2 Approximations in the Flexural Rigidity	41
3.3 Stresses in the Sandwich Beam	42
3.4 Shear Stresses	42
3.5 Approximation in the Shear Stress	43
3.6 Summary of Approximations	44
3.7 "The Sandwich Effect"	45
3.8 Sandwich with Dissimilar Faces	45
3.9 Equivalent Width	48

CHAPTER 4.	BEAM THEORY	49
4.1	Shear Deformations	50
4.2	Shear Stiffness	51
4.3	Equations in Terms of the Displacement Field	51
4.4	Governing Beam Equations	53
4.5	Equation of Motion	54
4.6	Effect of Thick Faces	57
4.7	Rigid Core	61
4.8	Energy Relations	62
4.9	Examples of Beam Calculations	63
4.9.1	Cantilever beam	63
4.9.2	Shear beam	66
4.9.3	Design example	67
4.9.4	Beam subjected to point load	69
4.9.5	Beam subjected to uniform pressure	74
4.9.6	Beam subjected to hydrostatic pressure	75
4.9.7	Hyperstatic beam example	77
4.9.8	Free vibration of a simply supported sandwich beam	78
4.9.9	Free vibration of a cantilever sandwich beam	80
4.9.10	Free vibration of a clamped sandwich beam	81
4.10	Torsion	81
4.11	Testing of Sandwich Beams	82
4.11.1	The three-point bend (TPB) specimen	82
4.11.2	The four-point bend (FPB) specimen	83
CHAPTER 5	BUCKLING OF SANDWICH BEAMS	87
5.1	Simply Supported Column – Simple Solution	87
5.2	Clamped Column – Rigorous Solution	89
5.3	Buckling of Sandwich Columns with Thick Faces	92
5.4	Buckling Stress Exceeding the Elastic Limit	93
CHAPTER 6	LOCAL BUCKLING OR WRINKLING	95
6.1	Energy Method	96
6.2	Differential Equation Method	99
6.3	Wrinkling under Biaxial Load	100
6.4	Intercellular Buckling	102
6.5	Summary of Buckling Phenomena	104
CHAPTER 7	FAILURE MODES	107
7.1	Formulae for Failure Loads	108
7.2	Failure Mode Maps	112
7.3	Other Design Criteria	114

CHAPTER 8	DESIGN PROCEDURES	115
8.1	Determination of Thicknesses	116
8.2	Single Parameter Optimum	118
8.3	Minimum Weight for Given Stiffness	119
8.4	Minimum Weight for Given Strength	122
CHAPTER 9	SANDWICH PLATES – FUNDAMENTAL EQUATIONS	125
9.1	Governing Equations	126
9.2	Partial Deflections	131
9.3	Equation of Motion	133
9.4	Isotropic Sandwich Plates	135
9.5	Isotropic Sandwich Plate with Thick Faces	136
9.6	Cross-Section Properties	137
9.7	Stresses and Strains	140
9.8	Energy Relations	141
9.9	Boundary Conditions	143
9.10	General Sandwich Theory for Anisotropic Plates	146
CHAPTER 10	SOLUTIONS TO PLATE PROBLEMS	151
10.1	Rotationally-Symmetric Plates	151
10.2	Bending of a Rectangular, Simply Supported, Isotropic Sandwich Plate	155
10.3	Rectangular, Simply Supported, Orthotropic Sandwich Plate	163
10.4	Solution by Energy Method - Ritz's Method	172
10.5	Approximate Solutions for Bending of Orthotropic Sandwich Plates	173
10.6	Buckling of a Simply Supported, Isotropic Sandwich Plate	184
10.7	Buckling of a Simply Supported, Orthotropic Sandwich Plate with Thin Faces	187
10.8	Approximate Buckling Formulae for Orthotropic Sandwich Plates with Various Edge Conditions	190
10.9	Shear Buckling	201
10.10	Combined Buckling and Transverse Load	202
10.11	Free Vibration of a Simply Supported Sandwich Plate	204
10.12	Conclusions	207
CHAPTER 11	SINGLE CURVED SANDWICH SHELLS	209
11.1	Fundamental Equations	209
11.2	Governing Buckling Equation	211
11.3	Buckling of Simply Supported Isotropic Plate Subjected to Uniaxial Load	215
11.4	Buckling due to External Lateral Pressure	219
11.5	Local Buckling of Curved Sandwich Panels	220
11.6	Bending of Single Curved Sandwich Beams - a Practical Approach	220

CHAPTER 12	LOCALISED LOADS - by OLE T. THOMSEN	225
12.1	Elastic Foundation Analogy	226
12.1.1	Classical Winkler foundation model	226
12.1.2	Two-parameter elastic foundation model	231
12.1.3	Specification of boundary conditions	236
12.1.4	Superposition with classical sandwich beam theory	238
12.1.5	Range of applicability – Winkler vs. two-parameter foundation model	240
12.2	Discussion: Application, Results and Parametric Effects	243
12.2.1	Application of method for solving engineering design problems	243
12.2.2	Example	244
12.2.3	Parametric Effects	247
12.3	Concluding Remarks	251
CHAPTER 13	Sandwich and FEM	255
13.1	General Remarks on FEM	255
13.2	Special Considerations for Sandwich Structures	256
13.3	Modelling of for Sandwich Structures	257
13.4	Boundary Conditions	258
13.5	Beam Analysis	260
13.6	Plate Analysis	261
13.7	Shell Analysis	262
13.8	Application Example	262
CHAPTER 14	Joints and Load Introductions	265
14.1	End-closures	266
14.2	Connections	268
14.3	Corners	268
14.4	T-joints	270
14.5	Load Introductions and Fasteners	271
SUBJECT INDEX		275