
Contents

1	Introduction	1
1.1	Objectives of This Work	4
1.1.1	Summary of Composites Considered	5
2	Classification of Composites	7
2.1	Volume Concentrations	7
2.2	Geometry at Fixed Phase Concentrations	8
2.2.1	Geometrical Classification	9
2.3	Composites with Variable Geometry	10
2.3.1	Geometrical Classification	10
2.3.2	Some Composite Examples	14
3	Preliminaries on Stress/Strain	17
3.1	Stiffness	17
3.1.1	Dilute Suspension	19
3.2	Stress	20
3.3	Composite Stiffness Estimated by SCS	20
4	Composite Stress and Geometry	23
4.1	Volumetric Stress	23
4.1.1	CSA-Composites	23
4.1.2	Any Composite – Geometry Function	24
4.1.3	Geometry Function and Shape Function	25
4.1.4	Shape Functions – A Closer Look	27
4.1.5	Summary	30
4.2	Deviatoric Stress	31
4.2.1	Stress and Geometry	31
4.3	Summary on Stress and Geometry	32
4.3.1	Stress	32
4.3.2	Geo-Function	32

5	Composite Stiffness and Geometry	35
5.1	Bulk Modulus and Shear Modulus	35
5.1.1	Porous Materials and Stiff Pore Systems	35
5.2	Young's Modulus and Poisson's Ratio	36
5.3	Special Composites and Observations	36
5.3.1	CSA-Composites	37
5.3.2	Composites with Special Shear Moduli	37
5.3.3	Paul/Hansen versus Geo-Functions	38
6	Composite Eigenstrain/Stress	39
6.1	Basics	39
6.1.1	Simple Composites	40
6.2	General Geometry	40
6.2.1	Eigenstrain and Eigenstress	40
6.2.2	Pore Pressure in Porous Materials	41
7	Quantification of Geometry	43
7.1	Shape Factors	47
7.1.1	DC-Composites	47
7.1.2	CD-Composites	53
7.1.3	MM-Composites	54
7.2	Shape Functions and Geo-Path	57
7.2.1	Default	57
7.2.2	Alternative I	60
7.2.3	Alternative II	61
7.3	Geo-Paths	62
8	Composite Theory – Elasticity	65
8.1	Illustrative Examples	65
8.1.1	DC-CD Composite	65
8.1.2	Crumbled Foils Composite	67
8.1.3	Particulate (DC-DC) Composite	69
8.2	Other Examples	71
8.2.1	Cracks	71
8.2.2	Special DC-CD Composites	75
8.3	FEM-Analysis versus Theory	78
8.3.1	FEM-Analysis	78
8.3.2	Particulate Composite	80
8.3.3	Defective Particulate Composite	82
8.3.4	Pearls on a String Composite	87
8.3.5	Grid Composite	91
8.3.6	Cracked Material	94
8.3.7	Discussion of FEM-Analysis	95
8.4	Conclusion	98

9	Composite Theory – Conductivity	99
9.1	Theory	99
9.2	Illustrative Examples	100
9.2.1	Porous Materials and Stiff Pore Systems	100
9.2.2	Dilute Porous Materials and Stiff Pore Systems	102
9.2.3	Cracked Materials (Soft and Stiff Cracks)	102
9.2.4	Crumbled Foils Composite	104
9.3	Theory versus Experiments	104
9.3.1	Chloride Diffusion in HCP and HCP with Silica Fume	104
9.3.2	Thermal Conductivity of Plane-Isotropic Fiber Composite	107
9.4	Theory versus SCS-Estimates	109
9.5	Conclusion	109
10	Simplified Composite Theory – Elasticity	113
10.1	Basis of Analysis	115
10.1.1	Geometry	115
10.1.2	Quantification of Composite Geometry	117
10.1.3	Preparation of Composite Analysis	121
10.2	Analysis	122
10.2.1	Bounds and Other Accurate Stiffness Expressions	123
10.2.2	Test of Theory	123
10.3	Illustrative Examples	125
10.3.1	Composites with Spherical Particles (CSA_P)	126
10.3.2	Nearly CSA_P Composites	126
10.3.3	Phase Symmetric Composites	127
10.3.4	Eigenstrain/Stress versus Geometry	132
10.3.5	Porous Materials	132
10.4	Theory and Experiments	137
10.4.1	Some Irregular Geometries	137
10.4.2	Various Porous Materials	140
10.4.3	Sulphur Impregnated Cement/Silicate System	144
10.4.4	Salt Infected Bricks	146
10.4.5	Non-Flexible Particles in Particulate Composite	147
10.4.6	Defective Phase Contact in Concrete	149
10.4.7	Hydrating Cement Paste and Concrete	151
10.5	Conclusion	154
11	Simplified Composite Theory – Conductivity	155
11.1	Illustrative Example	155
11.1.1	On the Accuracy of Simplification	156
11.2	Applications	156
11.2.1	Thermal Conductivity of Fire-Brick	156
11.2.2	Electrical Conductivity of Binary Metallic Mixtures	156

11.2.3 Chloride Diffusion in Cement Paste System	158
11.3 Conclusion	161
12 Diagnostic Aspects of Theory	163
12.1 Stiffness	165
12.1.1 Examination of Stiffness Expressions	165
12.2 Conductivity	171
12.2.1 Examination of SCS-Expressions	171
12.3 Discussion	174
13 Aspects of Materials Design	177
13.1 Geometries versus Properties	177
13.2 Design	178
13.3 Illustrative Examples	178
13.3.1 Stiffness	178
13.3.2 Conductivity	180
13.4 Discussion	182
14 Viscoelasticity	183
14.1 Stress-Strain Relations	184
14.1.1 Analogy Young's Modulus	185
14.1.2 Vibrations	187
14.2 Models of Viscoelastic Materials	189
14.2.1 Simple Models	190
14.2.2 Less Simple Models	190
14.3 Summary, Analysis, and Approximate Analysis	195
14.3.1 Approximate Analysis	196
15 Viscoelastic Composites	199
15.1 Composite Analysis	200
15.1.1 Accurate Analysis	200
15.1.2 Approximate Analysis	200
15.2 Applications	202
15.2.1 Porous Materials and Stiff Pore Systems	203
15.2.2 Particulate Composite	203
15.2.3 Mature Cement Concrete	204
15.2.4 Young Concrete	210
15.2.5 Influence of Geometry on Viscoelastic Composite Behavior	210
15.2.6 Monomer Impregnated HCP and Porous Glass	215
15.2.7 Damping of Wood	218
15.3 Discussion	220
16 Final Remarks	221

A	Elasticity	223
A.1	Isotropy	223
A.1.1	Composite Aspects	223
A.1.2	Stress-Strain	223
A.2	Cubic Elasticity	224
A.2.1	Poly-Cubic Elasticity	225
A.2.2	Composite Aspects	226
B	Dilute Particulate Composites	227
B.1	Cubic Stiffness, Shape Parameters, and Stress	227
B.1.1	Particle Stress	228
B.1.2	Isotropic Stiffness, Shape Coefficients, and Stress	230
B.1.3	Particle Stress	230
C	SCS-Analysis	231
C.1	Stiffness	231
C.1.1	Spherical Particles	232
C.1.2	Various Particle Shapes and Cracks	233
C.1.3	Multi-Shaped Particles	234
C.2	Other Physical Properties	235
C.2.1	Spherical Particles	236
C.2.2	Particles of Various Shapes and Cracks	236
C.2.3	Multi-Shaped Particles	238
D	General Viscoelastic Models	239
E	HCP and Concrete	241
E.1	Volume Models	241
E.2	Porosity of Hardening Cement Paste	242
	Notations	245
	References	249