

Contents

Preface to the second edition	xi
Preface to the first edition	xiii
1. Structural systems	1
Introduction	1
Simply suspended cable structures	2
Pretensioned cable beam structures	4
Pretensioned cable net structures	7
Pretensioned cable grid structures	8
General structural characteristics	11
Bibliography	13
2. The nature and statistical properties of wind	14
Introduction	14
The nature of wind	15
Mean wind speed and variation of mean velocity with height	17
Statistical properties of the fluctuating velocity component of wind	19
<i>Variance and standard deviation</i>	20
<i>Auto-correlation and auto-covariance functions</i>	21
<i>Spectral density functions of longitudinal velocity fluctuations</i>	21
<i>Cross-correlation and cross-covariance functions</i>	24
<i>Cross-spectral density and coherence functions for longitudinal velocity fluctuations</i>	25
The probability density function and peak factor for the fluctuating component of wind	26
The cumulative distribution function	28
Pressure, drag and lift forces	28
References	32
3. The nature and statistical properties of earthquakes	33
Introduction	33
Types and propagation of seismic waves	33
Recording of earthquakes	35
Magnitude and intensity of earthquakes	35
Influence of magnitude and surface geology on the characteristics of earthquakes	35
Representation of ground motion	37

Construction and representation of response spectra	39
Power spectral density functions for earthquakes	42
Soil-structure interaction	43
References	44
4. Generation of wind and earthquake histories	45
Introduction	45
Generation of single wind histories by a Fourier series	45
Generation of wind histories by the autoregressive method	46
Generation of spatially correlated wind histories	50
Numerical illustration	52
Generation of earthquake histories	52
Cross-correlation of earthquake histories	58
Design earthquakes	59
References	61
5. Freely hanging cables	63
Introduction	63
The governing equation for freely hanging cables	63
Cables with assumed distributed load w_x along the span	65
<i>Uniformly distributed load</i>	65
<i>Uniformly tapering distributed load</i>	68
<i>Two symmetrically placed triangularly distributed loads</i>	70
References	71
6. Static analysis of cable structures	72
Introduction	72
Structures subjected to point loads only	75
<i>The total potential energy at \mathbf{x} in displacement space</i>	75
<i>The gradient vector of the total potential energy at \mathbf{x} in displacement space</i>	78
<i>The method of steepest descent</i>	79
<i>The method of conjugate gradients</i>	80
<i>The Newton-Raphson method</i>	80
<i>The total potential energy at \mathbf{x}_{k+1} in displacement space</i>	82
<i>Determination of S from the steplength polynomial</i>	83
<i>Member forces and displacements at \mathbf{x}_{k+1} in displacement space</i>	84
Laterally loaded cable elements	84
Slackening cable elements	85
Cable rupture	85
Cable elements with nonlinear stress-strain relationships	85
Buckling of strut elements	87
Change of temperature	87
Numerical ill-conditioning and scaling	87
Convergency criteria	88
Summary of the iterative procedures	88

Numerical example	89
<i>First iteration</i>	91
<i>Second iteration</i>	94
References	97

7. Dynamic analysis of weakly nonlinear cable roof structures: frequency domain analysis	99
The importance and extent of dynamic analysis	99
Aeroelasticity and dynamic response	99
Dynamic response analysis of aeroelastically stable cable roofs	100
Dynamic response of one-DOF systems to turbulent wind	101
Relationships of response, drag force and wind velocity spectra for one-DOF systems	102
Dynamic response of multi-DOF structures to turbulent wind	106
Summary of expressions used in the frequency domain method for multi-DOF systems	109
Modal force spectra for wind for three-DOF systems	109
Aerodynamic damping of multi-DOF systems	110
Dynamic wind response analysis of weakly damped structures	112
Dynamic response of cable structures to earthquakes studied using frequency domain analysis	113
Dynamic response of one-DOF systems to earthquakes studied using power spectra	113
Influence of the dominant frequency of the ground on the magnitude of structural response	114
Dynamic response of multi-DOF structures to earthquakes studied using power spectra	115
Conclusion	116
References	117
8. Dynamic analysis of nonlinear cable structures: time domain analysis	118
Basic concepts	118
The force components of dynamic time-dependent loads	119
<i>Force components due to wind</i>	119
<i>Force components due to support movements such as those caused by earthquakes and explosions</i>	120
<i>Force components due to other forms of dynamic loading</i>	120
Dynamic analysis in the time domain	120
<i>Assumptions</i>	121
<i>Total potential work at time $(\tau + \Delta\tau)$</i>	122
<i>Total potential energy</i>	124
<i>Total potential structural energy dissipation</i>	125
<i>Total potential work of inertia forces</i>	126

<i>Total potential work of wind</i>	127
<i>Total potential work of inertia forces due to support movements</i>	128
<i>Total potential work of independent dynamic forces</i>	129
<i>Convergency and scaling</i>	129
Stability and accuracy	130
Numerical illustration	130
References	136
9. Damping ratios and damping matrices	138
Introduction	138
Measurement and evaluation of damping and damping ratios	138
The influence of air at resonance	139
Damping matrices	142
Modelling of structural damping by orthogonal damping matrices	142
<i>First method</i>	142
<i>Second method</i>	143
References	145
10. Cables and terminals	146
Wire strand rope	146
Steel	148
Manufacture of cables	148
Environmental factors affecting steel cables	150
<i>Moisture</i>	151
<i>Water in mass (sea, river, lake or pond water)</i>	151
<i>Water as discrete droplets (rain or driven spray)</i>	151
<i>Water vapour</i>	151
<i>Heat and cold</i>	152
<i>Solar radiation</i>	152
Solid particles	152
Protective coatings	153
Cable properties	153
Cable terminations	154
Linearization of cables—prestressing	157
Creep	160
Fatigue	161
Flexibility of cables	162
References	163
11. Tension anchors	164
Introduction	164
Types and suitability of tension anchors	165
Gravity anchors	167
Plate, mushroom and other anchors	167
<i>Theory</i>	167
<i>Strip anchors</i>	168
<i>Circular anchors</i>	169

<i>Rectangular anchors</i>	170
<i>Group action</i>	170
<i>Pull-out tests in sand</i>	171
<i>Pull-out tests in clay</i>	171
<i>Long-term uplift capacity</i>	171
<i>Factor of safety</i>	172
Tension piles	172
<i>Tension piles in granular material</i>	172
<i>Tension piles in clay</i>	173
<i>Factor of safety</i>	174
Ground anchors	175
<i>Sand and gravel</i>	175
<i>Medium-to-fine sand ($k < 10^3$ m/s)</i>	176
<i>Clay</i>	177
<i>Soft rock</i>	177
<i>Other points</i>	178
<i>Caution</i>	178
Rock anchors	178
<i>Mechanical anchors</i>	178
<i>Bonded anchors</i>	178
<i>Rock sockets</i>	180
<i>Design considerations</i>	180
Concluding remarks	180
References	181

12. Cable beams and cable grids	182
Introduction	182
Structural characteristics	182
Preliminary design analysis of cable beams and grids	188
Design and construction	195
Cladding and cladding materials	214
Erection of cable beams	221
Influence of boundary geometry on the forces at the boundary	221
Preliminary design—example	224
References	230
13. Cable net roofs	231
Introduction	231
Shape finding	231
Static and dynamic characteristics	239
Loading	261
Preliminary design analysis	261
Static and dynamic modelling of cable net structures	261
Design details	268
Methods of erection	272
Cladding and cladding materials	273
References	274

14. Design considerations	276
Introduction	276
Architectural requirements	276
Site location and geological information	277
Shape finding	277
Roof cladding and cladding materials	278
Wind and snow loading	278
Computer analysis and the use of models	279
Corrosion protection	280
Fire rating	280
Choice of contractor	281
Design and construction costs	281
Conclusion	282
15. Index	283