

Contents

Preface to First Edition	xiii
Preface to Second Edition	xv
Preface to Third Edition	xvii

CHAPTER 1	Introduction	1
1.1	Function of a structure	1
1.2	Loads	2
1.3	Structural systems	2
	Beams	2
	Trusses	3
	Moment frames	3
	Arches	3
	Cables	4
	Shear and core walls	5
	Continuum structures	6
1.4	Support systems	6
1.5	Statically determinate and indeterminate structures	9
1.6	Analysis and design	10
1.7	Structural and load idealization	11
1.8	Structural elements	12
1.9	Materials of construction	13
	Steel	13
	Concrete	14
	Timber	14
	Masonry	15
	Aluminium	15
	Cast iron, wrought iron	16
	Composite materials	16
1.10	The use of computers	16
CHAPTER 2	Principles of Statics	17
2.1	Force	17
	Parallelogram of forces	19
	The resultant of a system of concurrent forces	22
	Equilibrant of a system of concurrent forces	23
	The resultant of a system of non-concurrent forces	24
2.2	Moment of a force	25
	Couples	26
	Equivalent force systems	28

2.3	The resultant of a system of parallel forces	28
2.4	Equilibrium of force systems	30
2.5	Calculation of support reactions	31
	Problems	35
CHAPTER 3	Normal Force, Shear Force, Bending Moment and Torsion	38
3.1	Types of load	38
	Axial load	38
	Shear load	38
	Bending moment	39
	Torsion	39
3.2	Notation and sign convention	41
3.3	Normal force	42
3.4	Shear force and bending moment	47
3.5	Load, shear force and bending moment relationships	61
3.6	Torsion	68
3.7	Principle of superposition	70
	Problems	71
CHAPTER 4	Analysis of Pin-Jointed Trusses	79
4.1	Types of truss	79
4.2	Assumptions in truss analysis	79
4.3	Idealization of a truss	81
4.4	Statical determinacy	82
4.5	Resistance of a truss to shear force and bending moment	86
4.6	Method of joints	88
4.7	Method of sections	91
4.8	Method of tension coefficients	93
4.9	Graphical method of solution	97
4.10	Compound trusses	99
4.11	Space trusses	100
4.12	A computer-based approach	103
	Problems	104
CHAPTER 5	Cables	110
5.1	Lightweight cables carrying concentrated loads	110
5.2	Heavy cables	115
	Governing equation for deflected shape	115
	Cable under its own weight	116
	Cable subjected to a uniform horizontally distributed load	119
	Suspension bridges	123
	Problems	127

CHAPTER 6	Arches	130
6.1	The linear arch	130
6.2	The three-pinned arch	132
	Support reactions — supports on same horizontal level	132
	Support reactions — supports on different levels	135
6.3	A three-pinned parabolic arch carrying a uniform horizontally distributed load	138
6.4	Bending moment diagram for a three-pinned arch	140
	Problems	142
CHAPTER 7	Stress and Strain	146
7.1	Direct stress in tension and compression	146
7.2	Shear stress in shear and torsion	148
7.3	Complementary shear stress	149
7.4	Direct strain	150
7.5	Shear strain	150
7.6	Volumetric strain due to hydrostatic pressure	151
7.7	Stress—strain relationships	152
	Hooke's law and Young's modulus	152
	Shear modulus	152
	Volume or bulk modulus	152
7.8	Poisson effect	154
7.9	Relationships between the elastic constants	156
7.10	Strain energy in simple tension or compression	160
	Deflection of a simple truss	164
	Composite structural members	166
	Thermal effects	168
	Initial stresses and prestressing	172
7.11	Plane stress	175
7.12	Plane strain	179
	Problems	179
CHAPTER 8	Properties of Engineering Materials	184
8.1	Classification of engineering materials	184
	Ductility	184
	Brittleness	184
	Elastic materials	184
	Plasticity	185
	Isotropic materials	185
	Anisotropic materials	185
	Orthotropic materials	185
8.2	Testing of engineering materials	185
	Tensile tests	185
	Compression tests	186

Bending tests	186
Shear tests	188
Hardness tests	188
Impact tests	189
8.3 Stress—strain curves	190
Low carbon steel (mild steel)	190
Aluminium	192
Brittle materials	193
Composites	194
8.4 Strain hardening	195
8.5 Creep and relaxation	195
8.6 Fatigue	195
Crack propagation	200
8.7 Design methods	205
8.8 Material properties	206
Problems	207
CHAPTER 9 Bending of Beams	209
9.1 Symmetrical bending	210
Assumptions	211
Direct stress distribution	211
Elastic section modulus	214
9.2 Combined bending and axial load	220
Core of a rectangular section	223
Core of a circular section	224
9.3 Anticlastic bending	226
9.4 Strain energy in bending	226
9.5 Unsymmetrical bending	227
Assumptions	227
Sign conventions and notation	227
Direct stress distribution	229
Position of the neutral axis	231
9.6 Calculation of section properties	231
Parallel axes theorem	231
Theorem of perpendicular axes	232
Second moments of area of standard sections	232
Product second moment of area	234
Approximations for thin-walled sections	237
Second moments of area of inclined and curved thin-walled sections	239
9.7 Principal axes and principal second moments of area	242
9.8 Effect of shear forces on the theory of bending	244
9.9 Load, shear force and bending moment relationships, general case	245
Problems	245

CHAPTER 10	Shear of Beams	253
10.1	Shear stress distribution in a beam of unsymmetrical section	253
10.2	Shear stress distribution in symmetrical sections	255
10.3	Strain energy due to shear	264
10.4	Shear stress distribution in thin-walled open section beams	265
	Shear centre	268
10.5	Shear stress distribution in thin-walled closed section beams	270
	Shear centre	274
	Problems	279
CHAPTER 11	Torsion of Beams	287
11.1	Torsion of solid and hollow circular section bars	287
	Torsion of a circular section hollow bar	290
	Statically indeterminate circular section bars under torsion	293
11.2	Strain energy due to torsion	296
11.3	Plastic torsion of circular section bars	297
11.4	Torsion of a thin-walled closed section beam	300
11.5	Torsion of solid section beams	303
11.6	Warping of cross sections under torsion	307
	Problems	307
CHAPTER 12	Composite Beams	313
12.1	Steel-reinforced timber beams	313
12.2	Reinforced concrete beams	318
	Elastic theory	318
	Ultimate load theory	325
12.3	Steel and concrete beams	332
	Problems	335
CHAPTER 13	Deflection of Beams	337
13.1	Differential equation of symmetrical bending	337
13.2	Singularity functions	350
13.3	Moment-area method for symmetrical bending	357
13.4	Deflections due to unsymmetrical bending	365
13.5	Deflection due to shear	369
13.6	Statically indeterminate beams	372
	Method of superposition	373
	Built-in or fixed-end beams	375
	Fixed beam with a sinking support	380
	Problems	381
CHAPTER 14	Complex Stress and Strain	389
14.1	Representation of stress at a point	389
14.2	Determination of stresses on inclined planes	390

Biaxial stress system	391
General two-dimensional case	394
14.3 Principal stresses	396
14.4 Mohr's circle of stress	400
14.5 Stress trajectories	403
14.6 Determination of strains on inclined planes	403
14.7 Principal strains	405
14.8 Mohr's circle of strain	407
14.9 Experimental measurement of surface strains and stresses	409
14.10 Theories of elastic failure	415
Ductile materials	416
Brittle materials	424
Problems	426
CHAPTER 15 Virtual Work and Energy Methods	433
15.1 Work	433
15.2 Principle of virtual work	435
Principle of virtual work for a particle	435
Principle of virtual work for a rigid body	436
Virtual work in a deformable body	442
Work done by internal force systems	442
Virtual work due to external force systems	447
Use of virtual force systems	448
Applications of the principle of virtual work	448
15.3 Energy methods	458
Strain energy and complementary energy	458
The principle of the stationary value of the total complementary energy	461
Temperature effects	470
Potential energy	472
The principle of the stationary value of the total potential energy	473
15.4 Reciprocal theorems	476
Theorem of reciprocal displacements	476
Theorem of reciprocal work	480
Problems	481
CHAPTER 16 Analysis of Statically Indeterminate Structures	489
16.1 Flexibility and stiffness methods	489
16.2 Degree of static indeterminacy	491
Rings	491
The entire structure	492
The completely stiff structure	493
Degree of static indeterminacy	494
Trusses	495
16.3 Kinematic indeterminacy	496
16.4 Statically indeterminate beams	499
16.5 Statically indeterminate trusses	506
Self-straining trusses	511

16.6	Braced beams	514
16.7	Portal frames	517
16.8	Two-pinned arches	520
	Secant assumption	523
	Tied arches	526
	Segmental arches	526
16.9	Slope—deflection method	527
16.10	Moment distribution	534
	Principle	534
	Fixed-end moments	535
	Stiffness coefficient	535
	Distribution factor	537
	Stiffness coefficients and carry over factors	537
	Continuous beams	540
16.11	Portal frames	546
	Problems	556

CHAPTER 17 Matrix Methods of Analysis 571

17.1	Axially loaded members	572
17.2	Stiffness matrix for a uniform beam	581
17.3	Finite element method for continuum structures	588
	Stiffness matrix for a beam-element	589
	Stiffness matrix for a triangular finite element	593
	Stiffness matrix for a quadrilateral element	599
	Problems	604

CHAPTER 18 Plastic Analysis of Beams and Frames 611

18.1	Theorems of plastic analysis	611
	The uniqueness theorem	611
	The lower bound, or safe, theorem	611
	The upper bound, or unsafe, theorem	612
18.2	Plastic analysis of beams	612
	Plastic bending of beams having a singly symmetrical cross section	612
	Shape factor	615
	Moment—curvature relationships	618
	Plastic hinges	621
	Plastic analysis of beams	622
	Plastic design of beams	629
	Effect of axial load on plastic moment	629
18.3	Plastic analysis of frames	631
	Problems	639

CHAPTER 19 Yield Line Analysis of Slabs 646

19.1	Yield line theory	646
	Yield lines	646
	Ultimate moment along a yield line	647

Internal virtual work due to an ultimate moment	648
Virtual work due to an applied load	649
19.2 Discussion	658
Problems	658
 CHAPTER 20 Influence Lines	 663
20.1 Influence lines for beams in contact with the load	663
R_A influence line	663
R_B influence line	664
S_K influence line	665
M_K influence line	666
20.2 Mueller-Breslau principle	669
20.3 Systems of travelling loads	672
Concentrated loads	672
Distributed loads	678
Diagram of maximum shear force	681
Reversal of shear force	682
Determination of the point of maximum bending moment in a beam	684
20.4 Influence lines for beams not in contact with the load	687
Maximum values of S_K and M_K	689
20.5 Forces in the members of a truss	689
Counterbracing	693
20.6 Influence lines for continuous beams	694
Problems	699
 CHAPTER 21 Structural Instability	 706
21.1 Euler theory for slender columns	706
Buckling load for a pin-ended column	707
Buckling load for a column with fixed ends	708
Buckling load for a column with one end fixed and one end free	710
Buckling of a column with one end fixed and the other pinned	712
21.2 Limitations of the Euler theory	715
21.3 Failure of columns of any length	716
Rankine theory	716
Initially curved column	718
21.4 Effect of cross section on the buckling of columns	722
21.5 Stability of beams under transverse and axial loads	723
21.6 Energy method for the calculation of buckling loads in columns	
(Rayleigh—Ritz Method)	728
Problems	731
 Appendix A: Table of Section Properties	737
Appendix B: Bending of Beams: Standard Cases	739
Index	741