building structures

second edition

from concepts to design

malcolm millais

Contents

Preface to the Second Edition *viii*

INTRODUCTION **1**

0.1 Pre-historic design 1
0.2 Traditional design 2
0.3 The effect of civilisation 4
0.4 The search for structural understanding 6
0.5 The modern approach to structural design 9
0.6 The conceptual understanding of structural behaviour 10
References – Introduction 12

CHAPTER 1 *Loads and load paths* **13**

1.1 Natural loads 13
1.2 Useful loads 19
1.3 Accidental loads 21
1.4 Loading summary 21
1.5 Reaction loads 24
1.6 Load paths 30

CHAPTER 2 *Internal forces* **37**

2.1 Axial forces 37
2.2 Bending moments and shear forces 39
2.3 A simple plane frame 43
2.4 Slabs 49
2.5 The structural action of load paths 50
2.6 Twisting forces 54
2.7 Summary 55

CHAPTER 3 *Structural element behaviour* **57**

3.1 Structural elements 57
3.2 Concepts of stress and stress distribution 60
3.3 Axial stresses 65
3.4 Bending stresses 68
3.5 Shear stresses 76
3.6 Torsional stresses 77
3.7 Curved elements 80
3.8 Combined stresses 81

CHAPTER 4 *Advanced concepts of stress* **86**

4.1 Principal stresses in one-dimensional elements 86
4.2 Principal stresses in two-dimensional elements 92
4.3 The role of shear stresses in beams 95
4.4 Effect of beam cross-section 99
4.5 *Biaxial bending* 103
4.6 Torsion and warping of open sections 106
4.7 Composite elements and pre-stressing 107
4.8 Summary 116
References – Chapter 4 116

CHAPTER 5 *Structural materials* **117**

5.1 Types of material behaviour 117
5.2 Actual structural materials 120
5.3 *Soil as a structural material* 122
5.4 Non-structural effects 130

CHAPTER 6 *Safe structures and failure* **134**

6.1 Basic concepts of safety 134
6.2 Types of structural collapse 145
6.3 Plastic behaviour 148
6.4 Axial instability 154
6.5 Relationship of structural theories 163
References – Chapter 6 167

CHAPTER 7 *Geometry and structural behaviour* **168**

7.1 Geometry of structures 168
7.2 The behaviour of structural systems 170
7.3 Trusses and frames 178
7.4 *Cables and arches* 186
7.5 Three-dimensional structures 188
7.6 Prevention of axial instability 190

CHAPTER 8 *Behaviour of a simple building* **193**

8.1 *Basic structure and loading* 193
8.2 The roof and walls 201
8.3 The portal frames 205
8.4 The wind bracing system 207
8.5 The floor structure 209
8.6 The foundations 209
8.7 Summary 211

CHAPTER 9 *Real structures* **212**

9.1 Durham Cathedral 213
9.2 The Palm House 220
9.3 Zarzuela Hippodrome 229
9.4 CNIT Exposition Palace 235
9.5 Federal Reserve Bank 242
9.6 Bank of China 248
References – Chapter 9 256

CHAPTER 10 *Structural conception* **257**

10.1 Structures in buildings 257
10.2 Conceptual load paths 259
10.3 Load path geometry 262

10.4 Overall structural behaviour 264
10.5 Choice of materials and elements 268
10.6 Element connection 273
10.7 Structures and building construction 279

CHAPTER 11 *Structures and built form* **284**

11.1 The masonry dome and Christopher Wren 285
11.2 The arrival of the skeletal structure 293
11.3 Engineers, architects, decoration and theory 297
11.4 Architects embrace engineering 300
11.5 Engineering as fantasy 304
11.6 Engineered curved structures 308
11.7 Engineering fantasy becomes reality 314
11.8 Guggenheim, computers and beyond 323
References – Chapter 11 327

CHAPTER 12 *A simple approach to calculations* **330**

12.1 The basic questions 331
12.2 Units 331
12.3 Real loads 332
12.4 The beam and the cantilever 335
12.5 More complex beams 341
12.6 Simple frames 346
12.7 Calculation of stresses in beams and columns 349
12.8 Triangulated structures 353
12.9 Deflection and stiffness 356
12.10 Slenderness and axial stability 361
12.11 Four examples of simple calculations 363
12.12 Summary 371
References – Chapter 12 372

CHAPTER 13 *The mathematical basis* **373**

13.1 Functions and differentiation 373
13.2 Integration 379
13.3 The axially loaded element 381
13.4 The laterally loaded beam 386
13.5 The general beam element 396
13.6 Joint stiffness 403
13.7 The stiffness method 407
13.8 Summary 414
References – Chapter 13 415

Further Reading 416
Index 418