

# Contents

|  |     |
|--|-----|
| <i>Introduction to the sixth edition</i> | xi  |
| <i>Contributors</i>                      | xv  |
| <i>Notation</i>                          | xxv |

## SECTION 1: DESIGN SYNTHESIS

|   |     |
|---|-----|
| <b>1 Single-storey buildings</b>  | 1   |
| Range of building types; Anatomy of structure; Loading; Design of common structural forms   |     |
| <b>2 Multi-storey buildings</b>   | 42  |
| Introduction; Factors influencing choice of form; Anatomy of structure; Worked example  |     |
| <b>3 Industrial steelwork</b>   | 94  |
| Range of structures and scale of construction; Anatomy of structure; Loading; Structure in its wider context  |     |
| <b>4 Bridges</b>  | 124 |
| Introduction; Selection of span; Selection of type; Codes of practice; Traffic loading; Other actions; Steel grades; Overall stability and articulation; Initial design; Worked example |     |
| <b>5 Other structural applications of steel</b>   | 169 |
| Towers and masts; Space frames; Cable structures; Steel in residential construction; Atria  |     |

## SECTION 2: STEEL TECHNOLOGY

|   |     |
|---|-----|
| <b>6 Applied metallurgy of steel</b>  | 222 |
| Introduction; Chemical composition; Heat treatment; Manufacture and effect on properties; Engineering properties and mechanical tests; Fabrication effects and service performance; Summary |     |
| <b>7 Fracture and fatigue</b>   | 248 |
| Fracture; Linear elastic fracture mechanics; Elastic-plastic fracture mechanics; Materials testing for fracture properties; Fracture-safe design; Fatigue                                   |     |
| <b>8 Sustainability and steel construction</b>  | 275 |
| Introduction; Economic impacts; Social impacts; Environmental impacts; Embodied energy; Operational energy; Summary   |     |

### SECTION 3: DESIGN THEORY

|    |   |     |
|----|---|-----|
| 9  | <b>Introduction to manual and computer analysis</b>   | 286 |
|    | Introduction; Element analysis; Line elements; Plates; Analysis of skeletal structures; Finite element method   |     |
| 10 | <b>Beam analysis</b>  | 325 |
|    | Simply-supported beams; Propped cantilevers; Fixed, built-in or encastré beams; Continuous beams; Plastic failure of single members; Plastic failure of propped cantilevers |     |
| 11 | <b>Plane frame analysis</b>   | 342 |
|    | Formulae for rigid frames; Portal frame analysis  |     |
| 12 | <b>Applicable dynamics</b>  | 354 |
|    | Introduction; Fundamentals of dynamic behaviour; Distributed parameter systems; Damping; Finite element analysis; Dynamic testing   |     |

### SECTION 4: ELEMENT DESIGN

|    |  |     |
|----|--|-----|
| 13 | <b>Local buckling and cross-section classification</b>   | 373 |
|    | Introduction; Cross-sectional dimensions and moment–rotation behaviour; Effect of moment–rotation behaviour on approach to design and analysis; Classification table; Economic factors   |     |
| 14 | <b>Tension members</b>   | 383 |
|    | Introduction; Types of tension member; Design for axial tension; Combined bending and tension; Eccentricity of end connections; Other considerations; Cables; Worked examples  |     |
| 15 | <b>Columns and struts</b>  | 402 |
|    | Introduction; Common types of member; Design considerations; Cross-sectional considerations; Compressive resistance; Torsional and flexural-torsional buckling; Effective lengths; Special types of strut; Economic points; Worked examples  |     |
| 16 | <b>Beams</b>   | 431 |
|    | Common types of beam; Cross-section classification and moment capacity, $M_c$ ; Basic design; Lateral bracing; Bracing action in bridges – U-frame design; Design for restricted depth; Cold-formed sections as beams; Beams with web openings; Worked examples  |     |
| 17 | <b>Plate girders</b>   | 470 |
|    | Introduction; Advantages and disadvantages; Initial choice of cross-section for plate girders in buildings; Design of plate girders used in buildings to BS 5950: Part 1: 2000; Initial choice of cross-section for plate girders used in bridges; Design of steel bridges to BS 5400: Part 3; Worked examples |     |

|                                     |   |     |
|-------------------------------------|---|-----|
| 18                                  | <b>Members with compression and moments</b>   | 511 |
|                                     | Occurrence of combined loading; Types of response – interaction; Effect of moment gradient loading; Selection of type of cross-section; Basic design procedure; Cross-section classification under compression and bending; Special design methods for members in portal frames; Worked examples                                |     |
| 19                                  | <b>Trusses</b>  | 541 |
|                                     | Common types of trusses; Guidance on overall concept; Effects of load reversal; Selection of elements and connections; Guidance on methods of analysis; Detailed design considerations for elements; Factors dictating the economy of trusses; Other applications of trusses; Rigid-jointed Vierendeel girders; Worked examples |     |
| 20                                  | <b>Composite deck slabs</b>   | 577 |
|                                     | Introduction; Deck types; Normal and lightweight concretes; Selection of floor system; Basic design; Fire resistance; Diaphragm action; Other constructional features; Worked example   |     |
| 21                                  | <b>Composite beams</b>  | 601 |
|                                     | Application of composite beams; Economy; Guidance on span-to-depth ratios; Types of shear connection; Span conditions; Analysis of composite section; Basic design; Worked examples   |     |
| 22                                  | <b>Composite columns</b>  | 651 |
|                                     | Introduction; Design of encased composite columns; Design of concrete-filled tubes; Worked example  |     |
| <b>SECTION 5: CONNECTION DESIGN</b> |   |     |
| 23                                  | <b>Bolts</b>  | 671 |
|                                     | Types of bolt; Methods of tightening and their application; Geometric considerations; Methods of analysis of bolt groups; Design strengths; Tables of strengths   |     |
| 24                                  | <b>Welds and design for welding</b>   | 685 |
|                                     | Advantages of welding; Ensuring weld quality and properties by the use of standards; Recommendations for cost reduction; Welding processes; Geometric considerations; Methods of analysis of weld groups; Design strengths  |     |
| 25                                  | <b>Plate and stiffener elements in connections</b>  | 711 |
|                                     | Dispersion of load through plates and flanges; Stiffeners; Prying forces; Plates loaded in-plane  |     |
| 26                                  | <b>Design of connections</b>  | 721 |
|                                     | Introduction; Simple connections; Moment connections; Summary; Worked examples  |     |

|                           |  |      |
|---------------------------|--|------|
| 27                        | <b>Foundations and holding-down systems</b>  | 816  |
|                           | Foundations; Connection of the steelwork; Analysis; Holding-down systems; Worked examples  |      |
| SECTION 6: OTHER ELEMENTS |  |      |
| 28                        | <b>Bearings and joints</b>   | 842  |
|                           | Introduction; Bearings; Joints; Bearings and joints – other considerations   |      |
| 29                        | <b>Steel piles</b>   | 867  |
|                           | Bearing piles; Sheet piles; Pile driving and installation; Durability  |      |
| 30                        | <b>Floors and orthotropic decks</b>  | 906  |
|                           | Steel plate floors; Open-grid flooring; Orthotropic decks  |      |
| SECTION 7: CONSTRUCTION   |  |      |
| 31                        | <b>Tolerances</b>  | 917  |
|                           | Introduction; Standards; Implications of tolerances; Fabrication tolerances; Erection tolerances   |      |
| 32                        | <b>Fabrication</b>   | 948  |
|                           | Introduction; Economy of fabrication; Welding; Bolting; Cutting; Handling and routeing of steel; Quality management  |      |
| 33                        | <b>Erection</b>  | 971  |
|                           | Introduction; The method statement; Planning; Site practices; Site fabrication and modifications; Steel decking and shear connectors; Quality control; Cranes and craneage; Safety; Special structures   |      |
| 34                        | <b>Fire protection and fire engineering</b>  | 1013 |
|                           | Introduction; Standards and building regulations; Structural performance in fire; Developments in fire-safe design; Methods of protection; Fire testing; Fire engineering  |      |
| 35                        | <b>Corrosion and corrosion prevention</b>  | 1030 |
|                           | The corrosion process; Effect of the environment; Design and corrosion; Surface preparation; Metallic coatings; Paint coatings; Application of paints; Weather-resistant steels; The protective treatment specification                        |      |
| 36                        | <b>The Eurocodes</b>   | 1053 |
|                           | The Eurocodes – background and timescales; Conformity with EN 1990 – basis of design; EC3 Design of steel structures; EC4 Design of composite steel and concrete structures; Implications of the Eurocodes for practice in the UK; Conclusions |      |

## **Appendix**

### **Steel technology**

|  |      |
|--|------|
| Elastic properties of steel              | 1071 |
| European standards for structural steels | 1072 |

### **Design theory**

|   |      |
|---|------|
| Bending moment, shear and deflection tables for         |      |
| cantilevers   | 1077 |
| simply-supported beams                                  | 1079 |
| built-in beams  | 1087 |
| propped cantilevers                                     | 1094 |
| Bending moment and reaction tables for continuous beams | 1102 |
| Influence lines for continuous beams                    | 1105 |
| Second moments of area of                               |      |
| two flanges   | 1116 |
| rectangular plates                                      | 1118 |
| a pair of unit areas                                    | 1122 |
| Geometrical properties of plane sections                | 1124 |
| Plastic modulus of                                      |      |
| two flanges   | 1127 |
| rectangles  | 1128 |
| Formulae for rigid frames                               | 1130 |

### **Element design**

|   |      |
|---|------|
| Explanatory notes on section dimensions and properties, bolts and welds |      |
| 1 General   | 1148 |
| 2 Dimensions of sections  | 1149 |
| 3 Section properties  | 1151 |
| 4 Bolts and welds   | 1160 |
| Tables of dimensions and gross section properties                       |      |
| Universal beams   | 1166 |
| Universal columns   | 1172 |
| Joists  | 1175 |
| Universal bearing piles   | 1178 |
| Hot-finished:   |      |
| circular hollow sections  | 1181 |
| square hollow sections  | 1183 |
| rectangular hollow sections   | 1185 |
| Cold-formed:  |      |
| circular hollow sections  | 1187 |
| square hollow sections  | 1190 |
| rectangular hollow sections   | 1192 |
| Asymmetric beams  | 1195 |
| Parallel flange channels  | 1197 |

|   |      |
|---|------|
| Two parallel flange channels:   |      |
| laced   | 1201 |
| back to back  | 1202 |
| Equal angles  | 1203 |
| Unequal angles  | 1204 |
| Equal angles: back to back  | 1206 |
| Unequal angles: long legs back to back  | 1207 |
| Castellated universal beams   | 1208 |
| Structural tees cut from universal beams  | 1214 |
| Structural tees cut from universal columns  | 1218 |
| Extracts from BS 5950: Part 1: 2000   |      |
| Deflection limits (Section two: Table 8)  | 1220 |
| Design strengths for steel (Section three: Table 9)   | 1221 |
| Limiting width-to-thickness ratios for sections other than CHS and<br>RHS (Section three: Table 11) | 1222 |
| Limiting width-to-thickness ratios for CHS and RHS (Section three:<br>Table 12)                     | 1223 |
| Bending strengths (Section four: Tables 16 and 17)  | 1224 |
| Strut table selection (Section four: Table 23)  | 1227 |
| Compressive strength (Section four: Table 24)   | 1228 |
| <b>Connection design</b>  |      |
| Bolt data   |      |
| Hole sizes  | 1236 |
| Bolt strengths  | 1236 |
| Spacing, end and edge distances   | 1237 |
| Maximum centres of fasteners  | 1237 |
| Maximum edge distances  | 1238 |
| Back marks in channel flanges   | 1240 |
| Back marks in angles  | 1240 |
| Cross centres through flanges   | 1241 |
| Bolt capacities   |      |
| Non-preloaded ordinary bolts in S275  | 1242 |
| Non-preloaded countersunk bolts in S275   | 1244 |
| Non-preloaded HSFG bolts in S275  | 1246 |
| Preloaded HSFG bolts in S275: non-slip in service   | 1247 |
| Preloaded HSFG bolts in S275: non-slip under factored loads   | 1248 |
| Preloaded countersunk HSFG bolts in S275: non-slip in service                                       | 1249 |
| Preloaded countersunk HSFG bolts in S275: non-slip under<br>factored loads                          | 1250 |
| Non-preloaded ordinary bolts in S355  | 1251 |
| Non-preloaded countersunk bolts in S355   | 1253 |
| Non-preloaded HSFG bolts in S355  | 1255 |
| Preloaded HSFG bolts in S355: non-slip in service   | 1256 |
| Preloaded HSFG bolts in S355: non-slip under factored loads   | 1257 |

|  |      |
|--|------|
| Preloaded countersunk HSFG bolts in S355: non-slip in service                    | 1258 |
| Preloaded countersunk HSFG bolts in S355: non-slip under factored loads          | 1259 |
| <b>Bolt and weld groups</b>  |      |
| Bolt group moduli – fasteners in the plane of the force                          | 1260 |
| Bolt group moduli – fasteners not in the plane of the force                      | 1264 |
| Weld group moduli – welds in the plane of the force                              | 1266 |
| Capacities of fillet welds   | 1270 |
| Weld group moduli – welds not in the plane of the force                          | 1271 |
| <b>Other elements</b>  |      |
| <b>Sheet pile sections</b>   |      |
| Larssen sections   | 1274 |
| Frodingham sections  | 1275 |
| Box sheet piles  | 1276 |
| High modulus piles   | 1277 |
| H-piles  | 1279 |
| Floor plate design tables  | 1280 |
| <b>Construction</b>  |      |
| Fire information sheets  | 1282 |
| Section factors for  |      |
| universal beams  | 1302 |
| universal columns  | 1303 |
| circular hollow sections   | 1304 |
| rectangular hollow sections  | 1305 |
| rectangular hollow sections (square)   | 1306 |
| Minimum thickness of spray protection  | 1307 |
| Basic data on corrosion  | 1308 |
| <b>Codes and standards</b>   |      |
| British and European standards covering the design and construction of steelwork | 1311 |
| Index  | 1323 |