

- Preface p. xiii
- Notation p. xvii
- 1. Why ductility control? p. 1
 - 1.1. Nature of the problem p. 1
 - 1.1.1. Main purpose of seismic design p. 1
 - 1.1.2. Main lessons after the last strong earthquakes p. 4
 - 1.2. Evolution process of ductility concepts p. 7
 - 1.2.1. Early development p. 7
 - 1.2.2. Modern design concepts p. 9
 - 1.2.3. Response control concept p. 10
 - 1.3. Leading role of ductility in structural design p. 15
 - 1.3.1. Ductility definition p. 15
 - 1.3.2. Ductility for plastic design p. 17
 - 1.3.3. Ductility for earthquake design p. 19
 - 1.4. Progress in design methodology p. 20
 - 1.4.1. International activity p. 20
 - 1.4.2. Progress in conceptions p. 22
 - 1.4.3. Progress in design p. 24
 - 1.4.4. Progress in construction p. 27
 - 1.5. Progress in codification p. 28
 - 1.5.1. The long way from theory to practice p. 28
 - 1.5.2. Required steps in code elaboration p. 30
 - 1.6. Challenge in design methodologies p. 31
 - 1.6.1. After the last severe earthquakes p. 31
 - 1.6.2. Challenge in concept p. 32
 - 1.6.3. Challenge in design p. 33
 - 1.6.4. Challenge in construction p. 35
 - 1.7. Conclusions p. 36
 - 1.8. References p. 36
- 2. Learning from earthquakes: seismic decade 1985-1995 p. 41
 - 2.1. Damage of steel structure during the recent earthquakes p. 41
 - 2.2. Michoacan earthquake p. 42
 - 2.2.1. Earthquake characteristics p. 42
 - 2.2.2. General information about damage of steel structures p. 45
 - 2.2.3. Pino Suarez building p. 47
 - 2.3. Northridge earthquake p. 51
 - 2.3.1. General description of Californian earthquakes p. 51
 - 2.3.2. Loma Prieta earthquake p. 55
 - 2.3.3. Northridge earthquake characteristics p. 60
 - 2.3.4. Damage of buildings p. 64
 - 2.3.5. Moment connection fracture p. 69
 - 2.4. Kobe earthquake p. 73
 - 2.4.1. Earthquake characteristics p. 73

- 2.4.2. Damage of steel structures p. 79
- 2.4.3. Behaviour of connections p. 81
- 2.4.4. Ashiyahama apartment buildings p. 86
- 2.5. Conclusions p. 91
- 2.6. References p. 92
- 3. Basic design philosophy p. 104
- 3.1. Performance based seismic design p. 104
- 3.1.1. Multi-level seismic design criteria p. 104
- 3.1.2. Performance levels p. 105
- 3.1.3. Economic evaluation of performance levels p. 106
- 3.1.4. Multi-level design approaches p. 107
- 3.1.5. Coherent strategy for seismic design p. 112
- 3.1.6. Definition of earthquake design levels p. 114
- 3.2. Site ground motions p. 119
- 3.2.1. Earthquake parameters p. 119
- 3.2.2. Source characteristics p. 120
- 3.2.3. Propagation path effects p. 126
- 3.2.4. Site soil effects p. 133
- 3.2.5. Building effects p. 137
- 3.2.6. Assessing near-field earthquakes p. 139
- 3.3. Ground motions modelling p. 140
- 3.3.1. Basic representations p. 140
- 3.3.2. Recorded time-history representation p. 140
- 3.3.3. Artificially generated time-history representation p. 142
- 3.3.4. Response spectra for SDOF p. 150
- 3.3.5. Response spectra for MDOF p. 158
- 3.3.6. Power spectral density function p. 159
- 3.4. Conceptual design p. 160
- 3.4.1. Seismo-resistant architecture p. 160
- 3.4.2. Structural configuration p. 165
- 3.5. Structural analysis methods p. 168
- 3.5.1. Structure modelling p. 168
- 3.5.2. Methods of analysis p. 171
- 3.6. Design methods p. 178
- 3.6.1. Conceptual methodology for design p. 178
- 3.6.2. Preliminary design p. 178
- 3.6.3. Final design p. 179
- 3.7. Design criteria for three performance levels p. 181
- 3.7.1. Rigidity, strength and ductility triade p. 181
- 3.7.2. Rigidity design criterion p. 182
- 3.7.3. Strength design criterion p. 188
- 3.7.4. Ductility design criterion p. 192
- 3.8. Design criteria for two performance levels p. 200
- 3.8.1. Structural demands for two levels p. 200

- 3.8.2. Structure design p. 201
- 3.8.3. Correlation among design criteria p. 202
- 3.9. Conclusions p. 207
- 3.10. References p. 208
- 4. Material and element ductilities p. 222
- 4.1. Erosion of native properties p. 222
- 4.2. Material ductility p. 222
- 4.2.1. Selecting material promising good ductility p. 222
- 4.2.2. Main factors influencing the steel properties p. 223
- 4.2.3. Native steel performances p. 226
- 4.2.4. Idealisation of stress--strain curve p. 232
- 4.2.5. Influence of high-velocity loading p. 235
- 4.2.6. Influence of cyclic loading p. 243
- 4.2.7. Ductile, brittle and fatigue fractures p. 250
- 4.3. Element ductility p. 255
- 4.3.1. Main factors influencing the element ductility p. 255
- 4.3.2. Through-thickness properties of structural steels p. 255
- 4.3.3. Random variability of plate mechanical properties p. 257
- 4.3.4. Plastic buckling of plates p. 262
- 4.3.5. Behaviour of plates under cyclic loading p. 267
- 4.4. Plastic collapse mechanisms p. 271
- 4.4.1. Plate behaviour at collapse p. 271
- 4.4.2. Plastic collapse mechanism types p. 272
- 4.4.3. Rigid-plastic analysis p. 274
- 4.4.4. Plastic moment capacity of yield lines p. 276
- 4.5. Fracture collapse mechanisms p. 279
- 4.5.1. Ultimate moment capacity p. 280
- 4.5.2. Rotation of fracture lines p. 281
- 4.5.3. Rigid fracture analysis p. 282
- 4.6. Plastic and fracture mechanisms of plates p. 284
- 4.6.1. Plastic mechanisms for compression plates p. 284
- 4.6.2. Plastic mechanisms for bended plates p. 296
- 4.7. Ductility classes for elements p. 302
- 4.7.1. Behaviour classes p. 302
- 4.7.2. Width-to-thickness ratio p. 303
- 4.8. Conclusions p. 305
- 4.9. References p. 307
- 5. Section and stub ductilities p. 314
- 5.1. Ductility erosion due to section behaviour p. 314
- 5.2. Section ductility p. 315
- 5.2.1. Main factors influencing the section ductility p. 315
- 5.2.2. Plastic behaviour of sections p. 316
- 5.2.3. Moment-curvature relationship p. 325
- 5.2.4. Ductility classes of sections p. 331

- 5.3. Stub ductility p. 335
- 5.3.1. Determination of section ductility using the stub behaviour p. 335
- 5.3.2. Local plastic mechanism problems p. 336
- 5.4. Ductility of I-section stubs p. 337
- 5.4.1. Main factors influencing stub ductility p. 337
- 5.4.2. Experimental results p. 338
- 5.4.3. Numerical tests p. 341
- 5.4.4. Comparison of theoretical and experimental results p. 346
- 5.4.5. Influence of stub parameters p. 347
- 5.4.6. Influence of steel quality p. 353
- 5.4.7. Influence of loading type p. 355
- 5.4.8. Ductility classes for I-section stubs p. 363
- 5.5. Ductility of box-section stubs p. 366
- 5.5.1. Main factors influencing the stub ductility p. 366
- 5.5.2. Theoretical and experimental results p. 367
- 5.5.3. Rigid-plastic analysis p. 371
- 5.5.4. Pulsatory axial loading p. 376
- 5.5.5. Ductility classes for box-section stubs p. 377
- 5.5.6. Ductility of concrete-filled box-sections p. 378
- 5.6. Conclusions p. 381
- 5.7. References p. 383
- 6. Member ductility evaluation p. 389
- 6.1. Ductility erosion due to member behaviour p. 389
- 6.2. Main factors influencing the member ductility p. 390
- 6.3. Assessment of the member ductility in a structure p. 395
- 6.3.1. Modelling the member behaviour p. 395
- 6.3.2. Simplified method using the standard beam approach p. 399
- 6.3.3. Plastic behaviour of standard beams p. 408
- 6.3.4. Actual moment-rotation curve p. 415
- 6.3.5. Definition of ultimate rotation capacity for monotonic statically loads p. 418
- 6.4. Effects of joints on the member ductility p. 420
- 6.4.1. Representation of joints in the structure analysis p. 420
- 6.4.2. Behaviour of joints p. 421
- 6.4.3. New joint design philosophy p. 426
- 6.4.4. Generalized standard beam p. 433
- 6.4.5. Improved standard beam p. 435
- 6.5. Effects of seismic loading on the member ductility p. 439
- 6.5.1. Influence of seismic loading type p. 439
- 6.5.2. Dynamic behaviour of standard beam p. 439
- 6.5.3. Behaviour of standard beam under pulse loading p. 442
- 6.5.4. Behaviour of standard beam under cyclic loading p. 446
- 6.6. Member behavioural classes p. 448
- 6.7. Conclusions p. 450
- 6.8. References p. 450

- 7. Advances in member ductility p. 461
- 7.1. Recent development p. 461
- 7.2. Ductility of I-section members p. 462
 - 7.2.1. Monotonic experimental tests p. 462
 - 7.2.2. Analytical approaches p. 470
 - 7.2.3. FEM numerical tests p. 479
 - 7.2.4. Plastic collapse mechanism method p. 486
 - 7.2.5. Empirical methods p. 491
 - 7.2.6. Influence of yield ratio p. 499
 - 7.2.7. Influence of strain-rate p. 501
 - 7.2.8. Cyclic loading p. 503
- 7.3. Ductility of box- and hollow- section members p. 515
 - 7.3.1. Design aspects p. 515
 - 7.3.2. Experimental tests p. 516
 - 7.3.3. Theoretical results p. 521
- 7.4. Ductility of composite I-section beams p. 526
 - 7.4.1. Design aspects p. 526
 - 7.4.2. Effective width p. 527
 - 7.4.3. Ductility of beam under positive (sagging) moments p. 530
 - 7.4.4. Ductility of beam under negative (hogging) moments p. 534
- 7.5. Ductility of open-web members (trusses) p. 536
 - 7.5.1. Design aspects p. 536
 - 7.5.2. Ductility of conventional systems p. 537
 - 7.5.3. Ductility of special systems p. 538
- 7.6. Conclusions p. 540
- 7.7. References p. 541
- 8. Comprehensive methodology for ductility design p. 554
 - 8.1. Basis of a comprehensive methodology p. 554
 - 8.1.1. Limits of the current seismic design practice p. 554
 - 8.1.2. Design methodology based on multi-level criteria p. 555
 - 8.2. Required ductility p. 572
 - 8.2.1. Reasons for a simplified method p. 572
 - 8.2.2. Simplified push-over method p. 573
 - 8.2.3. Required plastic rotation capacity: kinematic ductility p. 574
 - 8.2.4. Influence of seismic actions: hysteretic ductility p. 578
 - 8.3. Available ductility under static and monotonic actions p. 584
 - 8.3.1. Member plastic rotation capacity p. 584
 - 8.3.2. I-section members p. 588
 - 8.3.3. X-section beam-columns p. 622
 - 8.3.4. Box-section members p. 624
 - 8.3.5. Hollow-section members p. 627
 - 8.3.6. Composite-section beams p. 632
 - 8.4. Influence of seismic actions p. 639
 - 8.4.1. Main factors p. 639

- 8.4.2. Influence of strain-rate p. 640
- 8.4.3. Influence of repeated cyclic actions p. 646
- 8.5. Structural damage p. 652
 - 8.5.1. Damage index p. 652
 - 8.5.2. Damage levels p. 653
- 8.6. Worked examples p. 655
 - 8.6.1. Main characteristics of structure p. 655
 - 8.6.2. Structure subjected to far-field interplate earthquake p. 656
 - 8.6.3. Structure subjected to near-field intraplate earthquake p. 662
- 8.7. Conclusions p. 665
- 8.8. References p. 666
- Appendix Ductrot M computer program Dana Petcu and Victor Gioncu p. 671
- A.1 General description p. 671
- A.2 User guide p. 672
- A.3 Acknowledgement p. 680
- Index p. 683