

Table of Contents

Preface	ix
Chapter 1. Advanced Design at Ultimate Limit State (ULS)	1
1.1. Design at ULS – simplified analysis	1
1.1.1. Simplified rectangular behavior – rectangular cross-section	1
1.1.2. Simplified rectangular behavior – T-cross-section	16
1.1.3. Comparison of design between serviceability limit state and ultimate limit state	22
1.1.4. Biaxial bending of a rectangular cross-section.	28
1.2. ULS – extended analysis	37
1.2.1. Bilinear constitutive law for concrete – rectangular cross-section.	37
1.2.2. Parabola–rectangle constitutive law for concrete – rectangular cross-section.	44
1.2.3. T-cross-section – general resolution for bilinear or parabola–rectangle laws for concrete	53
1.2.4. T-cross-section – general equations for composed bending with normal forces	66
1.3. ULS – interaction diagram	82
1.3.1. Theoretical formulation of the interaction diagram	82
1.3.2. Approximation formulations	94
1.3.3. Graphical results for general cross-sections	98
Chapter 2. Slender Compression Members – Mechanics and Design	103
2.1. Introduction.	103
2.2. Analysis methods	103
2.2.1. General	103
2.2.2. Requirements to second-order analysis	105

2.3. Member and system instability	105
2.3.1. Elastic critical load and effective (buckling) length.	105
2.3.2. System instability principles	110
2.3.3. Concrete column instability – limit load	110
2.4. First- and second-order load effects	112
2.4.1. Global and local second-order effects	112
2.4.2. Single members	113
2.4.3. Frame mechanics – braced and bracing columns	115
2.4.4. Moment equilibrium at joints	119
2.5. Maximum moment formation	120
2.5.1. Maximum first- and second-order moment at the same section.	120
2.5.2. Maximum first- and second-order moment at different sections	124
2.5.3. Curvature-based maximum moment expression	136
2.5.4. Unbraced frame application example	141
2.6. Local and global slenderness limits.	144
2.6.1. Local, lower slenderness limits – general.	144
2.6.2. EC2 – local lower slenderness limits	148
2.6.3. NS-EC2 – Local lower slenderness limits	150
2.6.4. Comparison of the EC2 and NS-EC2 limits	155
2.6.5. Local upper slenderness limit.	156
2.6.6. Global lower slenderness limit	159
2.7. Effect of creep deformations.	163
2.7.1. General	163
2.7.2. Effects on load and deformation capacity.	165
2.7.3. Approximate calculation of creep effects.	169
2.8. Geometric imperfections	176
2.8.1. Imperfection inclination	176
2.8.2. Stiffening structural elements.	176
2.8.3. Stiffened and isolated structural elements	180
2.9. Elastic analysis methods	181
2.9.1. Principles, equilibrium and compatibility.	181
2.9.2. Equilibrium and compatibility at multiple sections	183
2.9.3. Optimization.	185
2.10. Practical linear elastic analysis.	187
2.10.1. Stiffness assumptions.	187
2.10.2. EC2 approach	189
2.10.3. ACI 318 approach.	190
2.11. Simplified analysis and design methods	191
2.11.1. General	191
2.11.2. Simplified second-order analysis	192
2.11.3. Method based on nominal stiffness.	194
2.11.4. Method based on nominal curvature	200

2.12. ULS design	204
2.12.1. Simplified design methods	204
2.12.2. Alternative design methods	205
2.12.3. Design example – framed column	207
Chapter 3. Approximate Analysis Methods	213
3.1. Effective lengths	213
3.1.1. Definition and exact member analysis	213
3.1.2. EC2 effective length of isolated members	218
3.1.3. Alternative effective length expressions	219
3.1.4. Columns with beam restraints	222
3.2. Method of means	227
3.2.1. General	227
3.2.2. Method of means – typical steps	227
3.2.3. Application of the method of means	230
3.3. Global buckling of unbraced or partially braced systems	236
3.3.1. General considerations	236
3.3.2. Flexibility factors	240
3.3.3. System instability and “system” effective lengths	243
3.3.4. Instability of partially braced column – example	248
3.3.5. Instability of partially braced frame – example	251
3.3.6. Sway buckling of unbraced multistory frames	256
3.4. Story sway and moment magnification	262
3.4.1. General	262
3.4.2. Partially braced column – example	264
3.4.3. Partially braced frame – example	266
3.4.4. Sway magnifier prediction of frames with single curvature regions	268
3.4.5. Iterative elastic analysis method	271
3.4.6. Global magnifiers for sway and moments	272
Appendix 1. Cardano’s Method	279
A1.1. Introduction	279
A1.2. Roots of a cubic function – method of resolution	280
A1.2.1. Canonical form	280
A1.2.2. Resolution – one real and two complex roots	281
A1.2.3. Resolution – two real roots	283
A1.2.4. Resolution – three real roots	283
A1.3. Roots of a cubic function – synthesis	285
A1.3.1. Summary of Cardano’s method	285
A1.3.2. Resolution of a cubic equation – example	286
A1.4. Roots of a quartic function – principle of resolution	287

Appendix 2. Steel Reinforcement Table	289
Bibliography	291
Index	305