DIN EN 1994-1-1:2010-12 (E)

Eurocode 4: Design of composite steel and concrete structures - Part 1-1: Gen eral rules and rules for buildings (includes Corrigendum AC:2009)

Contents

Page

Foreword 8

Section 1 General 12

1.1 Scope 12
1.1.1 Scope of Eurocode 4 12
1.1.2 Scope of Part 1.1 of Eurocode 4 12
1.2 Normative references 13
1.2.1 General reference standards 13
1.2.2 Other reference standards 13
1.3 Assumptions 14
1.4 Distinction between principles and application rules 14
1.5 Definitions 14
1.5.1 General 14
1.5.2 Additional terms and definitions used in this Standard 14
1.6 Symbols 15

Section 2 Basis of design 22

2.1 Requirements 22
2.2 Principles of limit state design 23
2.3 Basic variables 23
2.3.1 Actions and environmental influences 23
2.3.2 Material and product properties 23
2.3.3 Classification of actions 23
2.4 Verification by the partial factor method 23
2.4.1 Design values 23
2.4.1.1 Design values of actions 23
2.4.1.2 Design values of material or product properties 23
2.4.1.3 Design values of geometrical data 24
2.4.1.4 Design resistances 24
2.4.2 Combination of actions 24
2.4.3 Verification of static equilibrium (EQU) 24

Section 3 Materials 24

3.1 Concrete 24
3.2 Reinforcing steel 25
3.3 Structural steel 25
3.4 Connecting devices 25
3.4.1 General 25
3.4.2 Headed stud shear connectors 25
3.5 Profiled steel sheeting for composite slabs in buildings 25

Section 4 Durability 25

4.1 General 25
4.2 Profiled steel sheeting for composite slabs in buildings 26

Section 5 Structural analysis 26

5.1 Structural modelling for analysis ... 26
5.1.1 Structural modelling and basic assumptions ... 26
5.1.2 Joint modelling ... 26
5.1.3 Ground-structure interaction ... 26
5.2 Structural stability ... 27
5.2.1 Effects of deformed geometry of the structure ... 27
5.2.2 Methods of analysis for buildings ... 27
5.3 Imperfections ... 28
5.3.1 Basis ... 28
5.3.2 Imperfections in buildings ... 28
5.3.2.1 General ... 28
5.3.2.2 Global imperfections ... 29
5.3.2.3 Member imperfections ... 29
5.4 Calculation of action effects ... 29
5.4.1 Methods of global analysis ... 29
5.4.1.1 General ... 29
5.4.1.2 Effective width of flanges for shear lag ... 29
5.4.2 Linear elastic analysis ... 30
5.4.2.1 General ... 30
5.4.2.2 Creep and shrinkage ... 31
5.4.2.3 Effects of cracking of concrete ... 32
5.4.2.4 Stages and sequence of construction ... 33
5.4.2.5 Temperature effects ... 33
5.4.2.6 Pre-stressing by controlled imposed deformations ... 33
5.4.3 Non-linear global analysis ... 33
5.4.4 Linear elastic analysis with limited redistribution for buildings ... 34
5.4.5 Rigid plastic global analysis for buildings ... 35
5.5 Classification of cross-sections ... 36
5.5.1 General ... 36
5.5.2 Classification of composite sections without concrete encasement ... 37
5.5.3 Classification of composite sections for buildings with concrete encasement ... 37

Section 6 Ultimate limit states ... 38

6.1 Beams ... 38
6.1.1 Beams for buildings ... 38
6.1.2 Effective width for verification of cross-sections ... 40
6.2 Resistances of cross-sections of beams ... 40
6.2.1 Bending resistance ... 40
6.2.1.1 General ... 40
6.2.1.2 Plastic resistance moment Mpl,Rd of a composite cross-section ... 40
6.2.1.3 Plastic resistance moment of sections with partial shear connection in buildings ... 42
6.2.1.4 Non-linear resistance to bending ... 43
6.2.1.5 Elastic resistance to bending ... 44
6.2.2 Resistance to vertical shear ... 45
6.2.2.1 Scope ... 45
6.2.2.2 Plastic resistance to vertical shear ... 45
6.2.2.3 Shear buckling resistance ... 45
6.2.2.4 Bending and vertical shear ... 45
6.3 Resistance of cross-sections of beams for buildings with partial encasement ... 46
6.3.1 Scope ... 46
6.3.2 Bending resistance ... 46
6.3.3 Resistance to vertical shear ... 47
6.3.4 Bending and vertical shear ... 48
6.4 Lateral-torsional buckling of composite beams ... 48
6.4.1 General ... 48
6.4.2 Verification of lateral-torsional buckling of continuous composite beams with cross-sections in Class 1, 2 and 3 for buildings ... 49
6.4.3 Simplified verification for buildings without direct calculation ... 51
6.5 Transverse forces on webs ... 52
6.5.1 General ... 52
6.5.2 Flange-induced buckling of webs ... 52

6.6 Shear connection 52
6.6.1 General 52
6.6.1.1 Basis of design 52
6.6.1.2 Limitation on the use of partial shear connection in beams for buildings 53
6.6.1.3 Spacing of shear connectors in beams for buildings 54
6.6.2 Longitudinal shear force in beams for buildings 55
6.6.2.1 Beams in which non-linear or elastic theory is used for resistances of one or more cross-sections 55
6.6.2.2 Beams in which plastic theory is used for resistance of cross-sections 55
6.6.3 Headed stud connectors in solid slabs and concrete encasement 55
6.6.3.1 Design resistance 55
6.6.3.2 Influence of tension on shear resistance 56
6.6.4 Design resistance of headed studs used with profiled steel sheeting in buildings 56
6.6.4.1 Sheeting with ribs parallel to the supporting beams 56
6.6.4.2 Sheeting with ribs transverse to the supporting beams 57
6.6.4.3 Biaxial loading of shear connectors 58
6.6.5 Detailing of the shear connection and influence of execution 58
6.6.5.1 Resistance to separation 58
6.6.5.2 Cover and concreting for buildings 58
6.6.5.3 Local reinforcement in the slab 59
6.6.5.4 Haunches other than formed by profiled steel sheeting 59
6.6.5.5 Spacing of connectors 60
6.6.5.6 Dimensions of the steel flange 60
6.6.5.7 Headed stud connectors 60
6.6.5.8 Headed studs used with profiled steel sheeting in buildings 61
6.6.6 Longitudinal shear in concrete slabs 61
6.6.6.1 General 61
6.6.6.2 Design resistance to longitudinal shear 61
6.6.6.3 Minimum transverse reinforcement 62
6.6.6.4 Longitudinal shear and transverse reinforcement in beams for buildings 62
6.7 Composite columns and composite compression members 63
6.7.1 General 63
6.7.2 General method of design 65
6.7.3 Simplified method of design 66
6.7.3.1 General and scope 66
6.7.3.2 Resistance of cross-sections 67
6.7.3.3 Effective flexural stiffness, steel contribution ratio and relative slenderness 69
6.7.3.4 Methods of analysis and member imperfections 70
6.7.3.5 Resistance of members in axial compression 70
6.7.3.6 Resistance of members in combined compression and uniaxial bending 71
6.7.3.7 Combined compression and biaxial bending 73
6.7.4 Shear connection and load introduction 74
6.7.4.1 General 74
6.7.4.2 Load introduction 74
6.7.4.3 Longitudinal shear outside the areas of load introduction 77
6.7.5 Detailing Provisions 78
6.7.5.1 Concrete cover of steel profiles and reinforcement 78
6.7.5.2 Longitudinal and transverse reinforcement 78
6.8 Fatigue 78
6.8.1 General 78
6.8.2 Partial factors for fatigue assessment for buildings 79
6.8.3 Fatigue strength 79
6.8.4 Internal forces and fatigue loadings 80
6.8.5 Stresses 80
6.8.5.1 General 80
6.8.5.2 Concrete 80
6.8.5.3 Structural steel 80
6.8.5.4 Reinforcement 81
6.8.5.5 Shear connection 81
6.8.6 Stress ranges 82
6.8.6.1 Structural steel and reinforcement 82
6.8.6.2 Shear connection 82

6.8.7 Fatigue assessment based on nominal stress ranges 83
6.8.7.1 Structural steel, ~reinforcement and concreteTM 83
6.8.7.2 Shear connection 83

Section 7 Serviceability limit states 84

7.1 General 84
7.2 Stresses 84
7.2.1 General 84
7.2.2 Stress limitation for buildings 85
7.3 Deformations in buildings 85
7.3.1 Deflections 85
7.3.2 Vibration 86
7.4 Cracking of concrete 86
7.4.1 General 86
7.4.2 Minimum reinforcement 87
7.4.3 Control of cracking due to direct loading 88

Section 8 Composite joints in frames for buildings 89

8.1 Scope 89
8.2 Analysis, modelling and classification 90
8.2.1 General 90
8.2.2 Elastic global analysis 90
8.2.3 Classification of joints 90
8.3 Design methods 91
8.3.1 Basis and scope 91
8.3.2 Resistance 91
8.3.3 Rotational stiffness 91
8.3.4 Rotation capacity 91
8.4 Resistance of components 92
8.4.1 Scope 92
8.4.2 Basic joint components 92
8.4.2.1 Longitudinal steel reinforcement in tension 92
8.4.2.2 Steel contact plate in compression 92
8.4.3 Column web in transverse compression 93
8.4.4 Reinforced components 93
8.4.4.1 Column web panel in shear 93
8.4.4.2 Column web in transverse compression 93

Section 9 Composite slabs with profiled steel sheeting for buildings 94

9.1 General 94
9.1.1 Scope 94
9.1.2 Definitions 95
9.1.2.1 Types of shear connection 95
9.1.2.2 Full shear connection and partial shear connection 95
9.2 Detailing provisions 96
9.2.1 Slab thickness and reinforcement 96
9.2.2 Aggregate 97
9.2.3 Bearing requirements 97
9.3 Actions and action effects 97
9.3.1 Design situations 97
9.3.2 Actions for profiled steel sheeting as shuttering 98
9.3.3 Actions for composite slab 98
9.4 Analysis for internal forces and moments 98
9.4.1 Profiled steel sheeting as shuttering 98
9.4.2 Analysis of composite slab 98
9.4.3 Effective width of composite slab for concentrated point and line loads 99
9.5 Verification of profiled steel sheeting as shuttering for ultimate limit states 100
9.6 Verification of profiled steel sheeting as shuttering for serviceability limit states 100
9.7 Verification of composite slabs for ultimate limit states 100

9.7.1 Design criterion 100
9.7.2 Flexure 101
9.7.3 Longitudinal shear for slabs without end anchorage 102
9.7.4 Longitudinal shear for slabs with end anchorage 104
9.7.5 Vertical shear 104
9.7.6 Punching shear 104
9.8 Verification of composite slabs for serviceability limit states 104
9.8.1 Control of cracking of concrete 104
9.8.2 Deflection 105

Annex A (informative) Stiffness of joint components in buildings 106

A.1 Scope 106
A.2 Stiffness coefficients 106
A.2.1 Basic joint components 106
A.2.1.1 Longitudinal steel reinforcement in tension 106
A.2.1.2 Steel contact plate in compression 106
A.2.2 Other components in composite joints 108
A.2.2.1 Column web panel in shear 108
A.2.2.2 Column web in transverse compression 108
A.2.3.1 Column web panel in shear 108
A.2.3.2 Column web in transverse compression 108
A.3 Deformation of the shear connection 109

Annex B (informative) Standard tests 110

B.1 General 110
B.2 Tests on shear connectors 110
B.2.1 General 110
B.2.2 Testing arrangements 110
B.2.3 Preparation of specimens 111
B.2.4 Testing procedure 112
B.2.5 Test evaluation 112
B.3 Testing of composite floor slabs 113
B.3.1 General 113
B.3.2 Testing arrangement 114
B.3.3 Preparation of specimens 115
B.3.4 Test loading procedure 115
B.3.5 Determination of design values for m and k 116
B.3.6 Determination of the design values for u,Rd 117

Annex C (informative) Shrinkage of concrete for composite structures for buildings 118

Bibliography 118

A.2.3 Reinforced components 108