



BSI Standards Publication

Eurocode 2 — Design of concrete structures

Part 1-1: General rules and rules for buildings,
bridges and civil engineering structures

National foreword

This British Standard is the UK implementation of EN 1992-1-1:2023. It supersedes BS EN 1992-1-1:2004+A1:2014, BS EN 1992-2:2005 and BS EN 1992-3:2006, which will be withdrawn on 30 March 2028.

The UK participation in its preparation was entrusted to Technical Committee B/525/2, Structural use of concrete.

A list of organizations represented on this committee can be obtained on request to its committee manager.

National choice is allowed in this standard where explicitly stated within notes. The National Annex to this standard contains the national choices to be used for buildings and civil engineering works constructed in the UK.

The first generation of EN Eurocodes was published between 2002 and 2007, with conflicting British Standards withdrawn in 2010. This document forms part of the second generation of EN Eurocodes.

The second generation of EN Eurocodes is expected to be published between 2023 and 2026. These documents are being published as soon as they are available. This is being done to enable users to prepare for the transition from the first generation to second generation of EN Eurocodes.

UK adoptions of the first generation of EN Eurocodes will be withdrawn by BSI on 30 March 2028. Until that date, the first generation documents should be considered as the applicable standards for buildings and civil engineering works constructed in the UK unless otherwise specified by the relevant authority or in the specification for a particular project.

This standard is intended to be used with its National Annex and other referenced documents, including other second generation Eurocodes, as an interdependent suite of documents.

While the use of provisions in this standard in conjunction with first generation Eurocodes is not precluded, it should be undertaken with care and should only be done when users are satisfied that it will not result in a lower level of reliability than the minimum level set in the first generation Eurocodes and associated UK National Annexes.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2023
Published by BSI Standards Limited 2023

ISBN 978 0 539 16233 2

ICS 91.010.30; 91.080.40

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2023.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English Version

**Eurocode 2 - Design of concrete structures - Part 1-1:
General rules and rules for buildings, bridges and civil
engineering structures**

Eurocode 2 : Calcul des structures en béton - Partie 1-1
: Règles générales - Règles pour les bâtiments, les ponts
et les ouvrages de génie civil

Eurocode 2 - Bemessung und Konstruktion von
Stahlbeton- und Spannbetontragwerken - Teil 1-1:
Allgemeine Regeln und Regeln für Hochbauten,
Brücken und Ingenieurbauwerke

This European Standard was approved by CEN on 23 July 2023.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Contents

Page

European foreword	12
0 Introduction	14
1 Scope	17
1.1 Scope of EN 1992-1-1	17
1.2 Assumptions	17
2 Normative references	17
3 Terms, definitions and symbols	19
3.1 Terms and definitions	19
3.2 Symbols and abbreviations	31
3.2.1 Latin upper case letters	31
3.2.2 Latin lower case letters	36
3.2.3 Greek letters	45
3.3 Symbols in Annex A	53
3.3.1 Latin upper case letters	53
3.3.2 Latin lower case letters	54
3.3.3 Greek lower case letters	54
3.4 Symbols in Annex I	54
3.4.1 Latin upper case letters	54
3.4.2 Latin lower case letters	54
3.4.3 Greek lower case letters	55
3.5 Symbols in Annex J	55
3.5.1 Latin upper case letters	55
3.5.2 Latin lower-case letters	56
3.5.3 Greek lower-case letters	57
3.6 Symbols in Annex L	58
3.6.1 Latin upper case letters	58
3.6.2 Latin lower case letters	58
3.6.3 Greek letters	59
3.7 Symbols in Annex R	59
3.7.1 Latin upper case letters	59
3.7.2 Latin lower case letters	60
3.7.3 Greek letters	60
3.8 Abbreviations	60
3.9 Units	61
3.10 Sign conventions	61
4 Basis of design	61
4.1 General rules	61
4.1.1 Basic requirements	61
4.1.2 Structural reliability and quality management	62
4.1.3 Design service life	62
4.2 Basic variables	62
4.2.1 Actions and time-dependent effects	62
4.2.2 Geometric data	64
4.3 Verification by the partial factor method	64
4.3.1 Partial factor for shrinkage action	64
4.3.2 Partial factors for prestress action	64
4.3.3 Partial factors for materials	65
4.4 Requirements for connection of elements to concrete members	65

5	Materials.....	66
5.1	Concrete.....	66
5.1.1	General.....	66
5.1.2	Properties and related conditions.....	66
5.1.3	Strength.....	67
5.1.4	Elastic deformation.....	68
5.1.5	Creep and shrinkage.....	68
5.1.6	Design assumptions.....	70
5.2	Reinforcing steel.....	72
5.2.1	General.....	72
5.2.2	Properties.....	72
5.2.3	Welding of reinforcing bars.....	73
5.2.4	Design assumptions.....	73
5.2.5	Reinforcement bar couplers.....	74
5.2.6	Headed bars for reinforcement.....	74
5.3	Prestressing steel.....	74
5.3.1	General.....	74
5.3.2	Properties.....	75
5.3.3	Design assumptions.....	76
5.4	Prestressing systems.....	77
5.4.1	General.....	77
5.4.2	Anchorage zones.....	78
6	Durability and concrete cover.....	78
6.1	General.....	78
6.2	Requirements for durability.....	78
6.3	Environmental exposure conditions.....	79
6.4	Exposure resistance classes.....	83
6.5	Concrete cover.....	84
6.5.1	Nominal cover.....	84
6.5.2	Minimum cover.....	84
6.5.3	Allowance in design for deviation in cover.....	88
7	Structural analysis.....	89
7.1	General.....	89
7.2	Structural modelling for analysis.....	89
7.2.1	Geometric imperfections.....	89
7.2.2	Idealisation of the structure.....	93
7.2.3	Geometric data.....	93
7.3	Methods of analysis.....	95
7.3.1	Linear elastic analysis.....	95
7.3.2	Linear elastic analysis with redistribution.....	96
7.3.3	Plastic analysis.....	98
7.3.4	Non-linear analysis.....	98
7.4	Second order structural analysis of members and systems with axial force.....	99
7.4.1	General.....	99
7.4.2	Creep.....	100
7.4.3	Methods of analysis.....	100
7.4.4	Compression member with biaxial bending.....	102
7.5	Lateral instability of slender beams.....	103
7.6	Prestressed members and structures.....	103
7.6.1	General.....	103
7.6.2	Prestressing force.....	104
7.6.3	Immediate losses of prestress.....	104

7.6.4	Time dependent losses of prestress	106
7.6.5	Effects of prestressing at ultimate limit state	107
8	Ultimate Limit States (ULS)	108
8.1	Bending with or without axial force	108
8.1.1	General	108
8.1.2	Stress distribution in the compression zones	110
8.1.3	Bending in slabs	110
8.1.4	Confined concrete	111
8.2	Shear	113
8.2.1	General verification procedure	113
8.2.2	Detailed verification for members without shear reinforcement	117
8.2.3	Members with shear reinforcement	121
8.2.4	In-plane shear and transverse bending	126
8.2.5	Shear between web and flanges	127
8.2.6	Shear at interfaces	129
8.3	Torsion and combined actions	134
8.3.1	General considerations for torsion	134
8.3.2	Internal forces due to torsion in compact or closed sections	134
8.3.3	Internal forces due to torsion in open sections	135
8.3.4	Torsional resistance of compact or closed sections	135
8.3.5	Design procedure for combination of actions	136
8.3.6	Interaction formula	137
8.4	Punching	137
8.4.1	General	137
8.4.2	Shear-resisting effective depth, control perimeter and shear stress	138
8.4.3	Punching shear resistance of slabs without shear reinforcement	142
8.4.4	Punching shear resistance of slabs with shear reinforcement	145
8.5	Design with strut-and-tie models and stress fields	148
8.5.1	General	148
8.5.2	Struts and compression fields	150
8.5.3	Ties	152
8.5.4	Nodes	152
8.5.5	Transfer of concentrated forces into a member	155
8.6	Partially loaded areas	157
9	Serviceability Limit States (SLS)	160
9.1	General	160
9.2	Stress limitations and crack control	161
9.2.1	General considerations	161
9.2.2	Minimum reinforcement areas to avoid yielding	163
9.2.3	Refined control of cracking	165
9.3	Deflection control	171
9.3.1	General consideration	171
9.3.2	Simplified deflection control by span/depth-ratio for buildings	171
9.3.3	Simplified calculation of deflections for reinforced concrete building structures	173
9.3.4	General method for deflection calculations	174
9.4	Vibrations	175
10	Fatigue	176
10.1	General	176
10.2	Combination of actions	176
10.3	Internal forces and stresses for fatigue verification	176
10.4	Simplified verification of reinforcing or prestressing steel	178

10.5	Simplified verification of concrete under compression.....	178
10.6	Simplified verification of concrete under shear	179
10.7	Simplified verification of shear at interfaces.....	179
11	Detailing of reinforcement and post-tensioning tendons	180
11.1	General.....	180
11.2	Spacing of bars	180
11.3	Permissible mandrel diameters for bent bars	181
11.4	Anchorage of reinforcing steel in tension and compression.....	182
11.4.1	General.....	182
11.4.2	Anchorage of straight bars.....	183
11.4.3	Anchorage of bundles	186
11.4.4	Anchorage of bars with bends and hooks.....	187
11.4.5	Anchorage of bars with welded transverse reinforcement	187
11.4.6	Anchorage of U-bar loops	188
11.4.7	Anchorage of headed bars in tension.....	188
11.4.8	Anchorage of bonded post-installed reinforcing steel	190
11.5	Laps of reinforcing steel in tension and compression and mechanical couplers ...	191
11.5.1	General.....	191
11.5.2	All types of laps	191
11.5.3	Laps of bundles	195
11.5.4	Laps using U-bar loops	196
11.5.5	Laps using headed bars.....	198
11.5.6	Mechanical couplers	200
11.5.7	Full penetration butt weld and fillet weld splices.....	200
11.6	Post-tensioning tendons.....	201
11.6.1	General.....	201
11.6.2	Minimum spacing of ducts	201
11.6.3	Minimum radius of curvature and straight length of tendons adjacent to anchorages	202
11.6.4	Anchorage, couplers and deviators of post-tensioning tendons.....	203
11.7	Deviation forces due to curved tensile and compressive chords	203
12	Detailing of members and particular rules	204
12.1	General.....	204
12.2	Minimum reinforcement rules.....	204
12.3	Beams	206
12.3.1	General.....	206
12.3.2	Longitudinal reinforcement.....	208
12.3.3	Shear and torsion reinforcement.....	209
12.3.4	Suspension reinforcement for indirect support.....	211
12.4	Slabs	211
12.4.1	General.....	211
12.4.2	Shear reinforcement	213
12.5	Slab-column connections and column bases.....	213
12.5.1	Punching shear reinforcement.....	213
12.5.2	Integrity reinforcement against progressive collapse of flat slabs.....	216
12.6	Columns	217
12.7	Walls and deep beams.....	218
12.8	Foundations	219
12.9	Tying systems for robustness of buildings	221
12.9.1	General.....	221
12.9.2	Dimensioning of ties	222
12.9.3	Required resistances for ties	222

12.10	Supports, bearings and expansion joints.....	223
13	Additional rules for precast concrete elements and structures.....	226
13.1	General.....	226
13.2	Specific requirements.....	226
13.3	Concrete.....	226
13.3.1	Strength for heat curing.....	226
13.3.2	Creep and shrinkage.....	226
13.4	Structural analysis.....	227
13.4.1	General.....	227
13.4.2	Losses of prestress during heat curing.....	227
13.5	Design and detailing of pre-tensioning tendons.....	228
13.5.1	Arrangement of tendons.....	228
13.5.2	Anchorage zones.....	229
13.5.3	Transfer of prestress.....	229
13.5.4	Anchorage of tensile force at ULS.....	230
13.5.5	Shear resistance of precast members without shear reinforcement.....	231
13.6	Floor systems for buildings.....	232
13.6.1	Distribution of loads.....	232
13.6.2	Diaphragm action.....	233
13.6.3	Tying systems for buildings.....	233
13.7	Connections and supports.....	234
13.7.1	Connections.....	234
13.7.2	Supports.....	236
13.8	Pocket foundations for buildings.....	236
13.8.1	General.....	236
13.8.2	Pocket foundations with keyed surface.....	236
13.8.3	Pocket foundations with smooth or rough surfaces.....	237
14	Plain and lightly reinforced concrete structures.....	238
14.1	General.....	238
14.2	Concrete.....	238
14.3	Structural analysis.....	238
14.4	Ultimate limit states.....	239
14.4.1	General.....	239
14.4.2	Design resistance to bending with axial force.....	239
14.4.3	Shear.....	239
14.4.4	Torsion.....	240
14.4.5	Ultimate limit states induced by structural deformation (buckling).....	240
14.5	Serviceability limit states.....	242
14.6	Detailing of members and particular rules.....	243
14.6.1	Structural members.....	243
14.6.2	Construction joints.....	243
14.6.3	Strip and pad footings.....	243
Annex A (informative)	Adjustment of partial factors for materials.....	244
A.1	Use of this annex.....	244
A.2	Scope and fields of application.....	244
A.3	General.....	244
Annex B (normative)	Time dependent behaviour of materials: strength, creep, shrinkage and elastic strain of concrete and relaxation of prestressing steel.....	251
B.1	Use of this annex.....	251

B.2	Scope and field of application.....	251
B.3	General.....	251
B.4	Development of concrete strength and stiffness with time	252
B.5	Basic formulae for determining the creep coefficient.....	253
B.6	Basic formulae for determining the shrinkage strain	256
B.7	Tests on elastic deformations, creep and shrinkage.....	258
B.8	Detailed analysis for creep at variable loading.....	259
B.9	Relaxation of prestressing steel.....	260
Annex C (normative) Requirements for materials		262
C.1	Use of this annex.....	262
C.2	Scope and field of application.....	262
C.3	Concrete.....	262
C.4	Reinforcing steel.....	262
C.5	Prestressing steel.....	265
C.6	Couplers.....	268
C.7	Headed bars	269
C.8	Post-installed reinforcing steel systems.....	269
Annex D (informative) Evaluation of early-age and long-term cracking due to restraint .		271
D.1	Use of this annex.....	271
D.2	Scope and field of application.....	271
D.3	General.....	271
D.4	Assessment of temperature history	272
D.5	Stress calculations	274
D.6	Crack width calculations	275
Annex E (normative) Additional rules for fatigue verification		276
E.1	Use of this annex.....	276
E.2	Scope and field of application.....	276
E.3	General.....	276
E.4	Verification using damage equivalent stress range.....	276
E.5	Explicit verifications using <i>Palmgren-Miner</i> Rule.....	278
Annex F (informative) Safety formats for non-linear analysis.....		281
F.1	Use of this annex.....	281
F.2	Scope and field of application.....	281
F.3	General.....	281
F.4	Partial factor method (PFM)	282
F.5	Global factor method (GFM).....	283

F.6	Full probabilistic method	284
F.7	Model uncertainty	284
	Annex G (normative) Design of membrane-, shell- and slab elements.....	286
G.1	Use of this annex	286
G.2	Scope and field of application	286
G.3	Design of membrane elements in ULS	286
G.4	Design of shell- and slab elements in ULS.....	288
G.5	Refined control of cracking in membrane elements in SLS	291
	Annex H (informative) Guidance on design of concrete structures for water-tightness	293
H.1	Use of this annex	293
H.2	Scope and field of application	293
H.3	General	293
H.4	Tightness classes	293
	Annex I (informative) Assessment of Existing Structures.....	296
I.1	Use of this annex	296
I.2	Scope and field of application	296
I.3	General	296
I.4	Basis of assessment	297
I.5	Materials	299
I.6	Durability - Minimum cover for bond	301
I.7	Structural analysis	302
I.8	Ultimate Limit States (ULS).....	303
I.9	Serviceability Limit States (SLS)	310
I.10	Fatigue	310
I.11	Detailing of reinforcement and post-tensioning tendons	311
I.12	Detailing of members and particular rules - Minimum reinforcement rules.....	314
	Annex J (informative) Strengthening of Existing Concrete Structures with CFRP.....	315
J.1	Use of this annex	315
J.2	Scope and field of application	315
J.3	General	315
J.4	Basis of design	315
J.5	Materials	316
J.6	Durability	318
J.7	Structural analysis	318
J.8	Ultimate Limit States (ULS).....	319
J.9	Serviceability Limit States (SLS)	324

J.10	Fatigue.....	325
J.11	Bond and anchorage of CFRP systems	326
J.12	Detailing of members and particular rules	332
J.13	Additional rules for precast concrete elements and structures	333
J.14	Lightly reinforced concrete structures	333
J.15	Material requirements for ABR strengthening systems	333
Annex K (normative) Bridges.....		334
K.1	Use of this annex.....	334
K.2	Scope and field of application.....	334
K.3	Terms, definitions and symbols.....	334
K.4	Basis of design	334
K.5	Materials.....	334
K.6	Durability and concrete cover	334
K.7	Structural analysis.....	336
K.8	Ultimate limit states (ULS).....	336
K.9	Serviceability limit states (SLS)	336
K.10	Fatigue verification	337
K.11	Detailing of reinforcement and post-tensioning tendons	346
K.12	Detailing of members and particular rules	346
K.13	Additional rules for precast concrete elements and structures	348
K.14	Plain and lightly reinforced concrete structures.....	349
K.15	Amendments to Annex G	349
Annex L (informative) Steel Fibre Reinforced Concrete Structures.....		350
L.1	Use of this annex.....	350
L.2	Scope and field of application.....	350
L.3	General.....	350
L.4	Basis of design - Partial factors for materials	350
L.5	Materials.....	351
L.6	Durability - Minimum cover	354
L.7	Structural analysis - Plastic analysis.....	354
L.8	Ultimate Limit States (ULS)	355
L.9	Serviceability Limit States (SLS) - Crack control.....	358
L.10	Fatigue.....	359
L.11	Detailing of reinforcement and post-tensioning tendons	359
L.12	Detailing of members and particular rules	359
L.13	Additional rules for precast concrete elements and structures	361

L.14	Lightly reinforced SFRC structures	361
L.15	Requirements for Materials: SFRC	362
	Annex M (normative) Lightweight aggregate concrete structures	364
M.1	Use of this annex	364
M.2	Scope and field of application	364
M.3	General	364
	Annex N (informative) Recycled aggregates concrete structures	367
N.1	Use of this annex	367
N.2	Scope and field of application	367
N.3	General	367
	Annex O (informative) Simplified approaches for second order effects	370
O.1	Use of this Annex	370
O.2	Scope and field of application	370
O.3	Critical load of building structures	370
O.4	Critical load of isolated members	371
O.5	Slenderness ratio and effective length of isolated members	372
O.6	Slenderness criteria for isolated members	373
O.7	Simplified analysis of isolated members based on nominal curvature	373
O.8	Second order elastic method	376
	Annex P (informative) Alternative cover approach for durability	378
P.1	Use of this Annex	378
P.2	Scope and field of application	378
P.3	Minimum cover	378
P.4	Indicative strength classes for durability	380
	Annex Q (normative) Stainless reinforcing steel	381
Q.1	Use of this annex	381
Q.2	Scope and field of application	381
Q.3	General	381
Q.4	Minimum cover for durability	382
Q.5	Fatigue verification	383
	Annex R (informative) Embedded FRP reinforcement	384
R.1	Use of this annex	384
R.2	Scope and field of application	384
R.3	General	384
R.4	Verification- Partial factors for FRP reinforcement	384
R.5	Materials	385

R.6	Durability - Concrete cover.....	387
R.7	Structural analysis.....	387
R.8	Ultimate Limit States (ULS)	387
R.9	Serviceability Limit States (SLS) - Special rules for FRP reinforcement	389
R.10	Fatigue.....	390
R.11	Detailing of FRP reinforcement	390
R.12	Detailing of members and particular rules	392
R.13	Additional rules for precast concrete elements and structures	394
R.14	Lightly reinforced concrete structures	394
R.15	Material requirements for FRP reinforcement	395
R.16	Surface reinforcement for large diameter bars	395
Annex S (informative)	Minimum reinforcement for crack control and simplified control of cracking	396
S.1	Use of this annex.....	396
S.2	Scope and field of application.....	396
S.3	Minimum reinforcement areas for crack width control	396
Bibliography		400

European foreword

This document (EN 1992-1-1:2023) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2027 and conflicting national standards shall be withdrawn at the latest by March 2028.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1992-1-1:2004, EN 1992-2:2005 and EN 1992-3:2006 and their amendments and corrigenda.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

The main changes compared to the previous edition are listed below:

- the scope of EN 1992-1-1 was extended to higher material strengths - for concrete up to class C100, for reinforcing steel to B700, for prestressing steel strand to Y2060 – and covering stainless steel;
- a new performance-based method for durability design of concrete structures was introduced;
- ULS design models were updated for confined concrete, shear and punching shear without and with shear reinforcement, strut-and-tie modelling, and size effect considered where relevant;
- provisions for anchorage and laps of reinforcing steel were updated to consider non-linear bond characteristics and size effect, and new anchorage methods for U-bar loops, headed bars and post-installed bars were integrated;
- an informative annex provides statistical data of material and dimensional properties as basis for the partial factors;
- creep and shrinkage models were updated and unified for normal strength and high strength — concretes;
- assumed material characteristics not directly used in design are listed in Annex C as basis for specifications and interface to product standards;
- a new informative annex gives provisions for early-age thermo-mechanical design;
- a new informative annex gives requirements for use of non-linear finite element methods;

- informative annexes provide guidance for the assessment of existing structures, for strengthening with FRP materials, for steel fibre reinforced concrete structures, for recycled aggregates concrete structures, for embedded FRP reinforcement, and for minimum reinforcement for crack control and simplified control of cracking.

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990, Eurocode: Basis of structural and geotechnical design
- EN 1991, Eurocode 1: Actions on structures
- EN 1992, Eurocode 2: Design of concrete structures
- EN 1993, Eurocode 3: Design of steel structures
- EN 1994, Eurocode 4: Design of composite steel and concrete structures
- EN 1995, Eurocode 5: Design of timber structures
- EN 1996, Eurocode 6: Design of masonry structures
- EN 1997, Eurocode 7: Geotechnical design
- EN 1998, Eurocode 8: Design of structures for earthquake resistance
- EN 1999, Eurocode 9: Design of aluminium structures
- New parts are under development, e.g. Eurocode for design of structural glass.

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 1992 (all parts)

(1) EN 1992 applies to the design of buildings, bridges and civil engineering structures in plain, reinforced and prestressed concrete. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990, *Basis of structural and geotechnical design*.

(2) EN 1992 is only concerned with the requirements for resistance, serviceability, durability and fire resistance of concrete structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

(3) EN 1992 is subdivided into various parts:

- EN 1992-1-1, Design of concrete structures — Part 1-1: General rules and rules for buildings, bridges and civil engineering structures,
- EN 1992-1-2, Design of concrete structures — Part 1-2: Structural fire design,
- EN 1992-4, Design of concrete structures — Part 4: Design of fastenings for use in concrete.

0.3 Introduction to EN 1992-1-1

- (1) EN 1992-1-1 describes the principles and requirements for safety, serviceability and durability of concrete structures. It is based on the limit state concept used in conjunction with a partial factor method.
- (2) EN 1992-1-1 also serves as a reference document for other CEN TCs concerning structural matters.
- (3) Numerical values for partial factors and other reliability parameters are recommended as basic values that provide an acceptable level of reliability. They have been selected assuming that an appropriate level of workmanship and of quality management applies. When EN 1992-1-1 is used as a base document by other CEN/TCs the same values need to be taken.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for EN 1992-1-1

National choice is allowed in this document where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1992-1-1 can have a National Annex containing all national choices to be used for the design of buildings, bridges and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this document is to be used.

When no national choice is made and no default is given in this document, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1992-1-1 through notes to the following:

4.2.1.5(3)	4.3.1(1)	4.3.2(1)	4.3.2(2)
4.3.3(1)	4.3.3(4)	5.1.3(3)	5.1.4(2)
5.1.5(4)	5.1.6(1)	5.1.6(2)	5.2.1(5)
5.2.2(1)	5.3.1(3)	5.3.2(1)	5.4.1(1)
6.3(3)	6.3(5)	6.4(1)	6.5.2.1(2)
6.5.2.2(1)	6.5.2.2(2)	6.5.2.2(3)	6.5.2.2(4)
6.5.2.2(5)	6.5.2.2(6)	6.5.2.2(9)	6.5.3(1)
7.3.2(5)	8.2.1(3)	8.2.2(5)	8.4.2(1)
8.4.4(4)	8.4.4(5)	8.4.4(6)	9.2.1(6)

9.2.3(2)	11.4.2(2)	11.4.2(3)	11.5.2(2)
11.6.3(2)	12.3.1(1)	12.4.1(1)	12.6(1)
12.7(2)	12.9.3(1)	14.2(1)	14.4.5.2(1)
A.3(1)	A.3(3)	A.3(6)	B.3(1)
B.6(1)	C.6(1)	C.7(1)	C.8(2)
E.4.2(1)	F.5.2(1)	F.7(2)	F.7(8)
H.4.2(4)	I.4.2.1(2)	I.5.2.1(3)	I.5.2.2(1)
I.8.3.1(1)	I.9.1(2)	J.4(1)	J.5.1(2)
K.5(2)	K.6(2)	K.6(3)	K.6(4)
K.7(2)	K.7(3)	K.8(2)	K.8(3)
K.8(4)	K.8(5)	K.8(6)	K.9(2)
K.9(3)	K.10.1(2)	K.11(2)	K.11(3)
K.11(4)	K.11(5)	K.12.2(1)	K.13(2)
K.13(4)	K.15(1)	L.4(1)	L.5.1(1)
L.5.5.2(1)	L.6(4)	L.7(1)	L.11.2(1)
L.12.3.1(2)	Q.3(1)	Q.4(2)	R.4(1)
R.5.1(2)			

National choice is allowed in FprEN 1992-1-1 on the application of the following informative annexes:

Annex A	Annex D	Annex F	Annex H
Annex I	Annex J	Annex L	Annex N
Annex O	Annex P	Annex R	Annex S

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1992-1-1

(1) This document gives the general basis for the design of structures in plain, reinforced and prestressed concrete made with normal weight, lightweight and heavyweight aggregates. It gives specific rules for buildings, bridges and civil engineering structures, including temporary structures; additional requirements specific to bridges are given in Annex K. The rules are valid under temperature conditions between -40 °C and $+100\text{ °C}$ generally. This document complies with the principles and requirements for the safety, serviceability, durability and robustness of structures, the basis of their design and verification that are given in EN 1990.

(2) This document is only concerned with the requirements for resistance, serviceability, durability, robustness and fire resistance of concrete structures. Other requirements, e.g. concerning thermal or sound insulation, are not considered.

(3) This document does not cover:

- resistance to fire (see EN 1992-1-2);
- fastenings in concrete (see EN 1992-4);
- seismic design (see EN 1998 (all parts));
- particular aspects of special types of civil engineering works (such as dams, pressure vessels);
- structures made with no-fines concrete, aerated or cellular concrete, lightweight aggregate concrete with open structure components;
- structures containing steel sections considered in design (see EN 1994 (all parts)) for composite steel and concrete structures;
- structural parts made of concrete with a smallest value of the upper sieve aggregate size $D_{\text{lower}} < 8\text{ mm}$ (or if known $D_{\text{max}} < 8\text{ mm}$) unless otherwise stated in this Eurocode.

1.2 Assumptions

(1) The assumptions of EN 1990 apply to EN 1992-1-1.

(2) It is assumed that the requirements for execution and workmanship given in EN 13670 are complied with.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions ('may' clauses), possibilities ('can' clauses), and in notes.

EN 197-1, *Cement — Part 1: Composition, specifications and conformity criteria for common cements*

EN 206, *Concrete — Specification, performance, production and conformity*

EN 1992-1-1:2023 (E)

EN 1504-4, *Products and systems for the protection and repair of concrete structures — Definitions, requirements, quality control and evaluation of conformity — Part 4: Structural bonding*

EN 1542, *Products and systems for the protection and repair of concrete structures — Test methods — Measurement of bond strength by pull-off*

EN 1990:2023, *Eurocode — Basis of structural and geotechnical design*

EN 1991 (all parts), *Eurocode 1 — Actions on structures*

EN 1992-1-2:2023, *Eurocode 2 — Design of concrete structures — Part 1-2: General rules — Structural fire design*

EN 1992-4, *Eurocode 2 — Design of concrete structures — Part 4: Design of fastenings for use in concrete*

EN 1993 -1-9, *Eurocode 3 — Design of steel structures — Part 1-9: Fatigue*

EN 1997 (all parts), *Eurocode 7 — Geotechnical design*

EN 13670, *Execution of concrete structures*

EN 13791:2019, *Assessment of in-situ compressive strength in structures and pre-cast concrete components*

EN 14651, *Test method for metallic fibre concrete — Measuring the flexural tensile strength (limit or proportionality (LOP), residual)*

EN ISO 14130, *Fibre reinforced plastic composites — Determination of apparent interlaminar shear strength by short beam-method (ISO 14130)*

EN ISO 17660, *Welding — Welding of reinforcing steel*

ISO 10406 (all parts), *Fibre-reinforced polymer (FRP) reinforcement of concrete — Test methods*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990 and the following apply.

3.1.1

anchoring mortar

mortar based on organic or inorganic binder, or a mixture of these, installed at a fluid or paste consistency with the aim to anchor reinforcing steel bars in a drilled hole in concrete structures and to transfer the axial forces in the reinforcing steel bar to the concrete structure

3.1.2

beam

linear member subject primarily to flexure and shear with cross-section width not exceeding 4 times its cross-section depth (otherwise it should be considered as a slab) and an effective span of not less than 3 times the cross-section depth

3.1.3

biaxial bending

simultaneous bending about two principal axes

3.1.4

braced members or systems

structural members or subsystems, which in analysis and design are assumed to be stabilised by bracing members and hence, not contributing to the overall horizontal stability of a structure

Note 1 to entry: Unbraced members are not stabilized by bracing members.

3.1.5

bracing members or systems

structural members or subsystems, which in analysis and design are assumed to contribute to the overall horizontal stability of a structure

3.1.6

buckling

failure due to instability of a member or structure under compression buckling or flexural buckling

3.1.7

buckling load

load at which buckling occurs; for isolated elastic members, it is synonymous with the Euler load

3.1.8

carbon steel

weldable non-alloy reinforcing steel

3.1.9

chord

compression or tension part of a member idealised as having a narrow width and which interacts with adjacent membrane elements through longitudinal shear

3.1.10

column

linear member subjected primarily to axial compression forces, with cross-section width not exceeding 4 times its cross-section depth (otherwise it should be considered as a wall) and the length is at least 3 times the cross-section depth

3.1.11

compression field

region of a stress field where concrete is subjected to uniaxial compressive stresses

3.1.12

confinement reinforcement

reinforcement which can increase the uniaxial concrete compressive strength and the deformation capacity through the favourable effect of transverse compressive stresses or can reduce the required anchorage length by preventing cover spalling

Note 1 to entry: It can consist of stirrups, links, U-bars, headed bars or hoops placed perpendicular or at an angle to the axis of the member.

Note 2 to entry: Confinement reinforcement can reduce the design anchorage length if it is anchored into the body of the section.

3.1.13

couplers

steel reinforcement products used for the mechanical splicing of steel reinforcing bars

3.1.14

cover, concrete

distance between the surface of a reinforcement bar or tendon (including links and stirrups and surface reinforcement where relevant) and the nearest concrete surface

3.1.15

cover, minimum

minimum value of the concrete cover provided in order to ensure (i) safe transmission of bond forces, (ii) protection of the steel against corrosion (durability)

3.1.16

cover, nominal

specified value of the concrete cover defined as a minimum cover plus an allowance in design for deviation

3.1.17**crack formation phase**

phase of the cracking process which occurs when stresses exceed the cracking resistance and in which the full crack pattern is not yet developed, typically it is the type of cracking due to imposed deformations with large crack spacings, and for which an increase in the imposed strain will not increase crack width but instead it will form new cracks

3.1.18**crack width, calculated**

calculated crack width at surface of member

3.1.19**creep, basic**

creep occurring in concrete when there is no moisture transfer with the surrounding environment

3.1.20**creep, drying**

creep, additional to basic creep, occurring in concrete when there is moisture transfer with the surrounding environment, the total creep is the sum of basic and drying creep

3.1.21**deep beam**

beam for which the effective span l_{eff} is less than 3 times the overall cross-section depth h

3.1.22**deformation capacity**

ability of a member or part of it or a structure to deform while maintaining its resistance

3.1.23**damp patch**

area which, when touched, might leave a light film of moisture on the hand but no droplets of water (i.e. beading)

3.1.24**diaphragm**

planar member able to resist in-plane forces

3.1.25**effective tension area**

concrete area in tension around reinforcement within which the crack opening is effectively controlled by the reinforcement (area of concrete that needs to be subject to tension up to the tensile resistance of concrete to produce a new crack)

3.1.26**effective depth**

in a cross-section, distance from the extreme compression fibre to the centroid of the resultant force of the longitudinal tension reinforcement

3.1.27

effective length

length used to account for the shape of the deflection curve; it can also be defined as buckling length, i.e. the length of a pin-ended column with constant axial force, having the same cross-section and buckling load as the actual member

3.1.28

European Technical Product Specification

- European Product Standard (EN), or
- European Technical Assessment (ETA) based on a European Assessment Document (EAD), or
- product documentation based on a transparent and reproducible assessment that complies with all requirements of the relevant EAD

3.1.29

execution specification

document covering all drawings, technical data and requirements necessary for the execution of a particular project

3.1.30

exposure resistance classes

classes for defining the resistance of concrete against corrosion induced by carbonation (XRC) or by chlorides (XRDS) and damage caused by freeze/thaw attack (XRF)

3.1.31

external tendon

tendon external to the concrete, either within the depth of the cross-section or on the surface of the cross-section

3.1.32

first order effects

action effects calculated without consideration of the effect of structural deformations, but including geometric imperfections

3.1.33

flat slab

slab supported directly by columns, can be solid, ribbed or waffle

3.1.34

general anchorage zone

zone in which the tendon force is dispersed over the member cross-section until a linear stress distribution may be assumed

3.1.35

headed bar

reinforcing bar with head attached at one or both ends

3.1.36**hook**

end part of a reinforcement, bent at not less than 135°

3.1.37**hoop**

closed reinforcement or spiral reinforcement enclosing longitudinal reinforcement in compression members

3.1.38**indented reinforcement**

reinforcing steel with at least two rows of indentations, which are uniformly distributed over the entire length

3.1.39**internal force**

resultant of stresses in cross-section of a member (axial force, shear force, bending moment, torsion)

3.1.40**internal tendon**

tendon which is placed inside the concrete either with bond or without bond to the concrete

3.1.41**isolated member**

member for which no load redistribution to adjacent members is possible

3.1.42**isolated precast element**

precast element for which no load redistribution to adjacent members is possible

3.1.43**lattice girder**

two dimensional or three dimensional metallic structure comprising an upper chord, one or more lower chords and continuous or discontinuous diagonals which are welded or mechanically connected to the chords

3.1.44**lightweight aggregate concrete**

concrete having a closed structure and an oven-dry density of not less than 800 kg/m³ and not more than 2 000 kg/m³, consisting of or containing a proportion of artificial or natural lightweight aggregates having a particle dry density of less than 2 000 kg/m³

3.1.45**linear member**

structural element, straight or curved, with one dimension significantly larger than the others (such as beams and columns)

3.1.46

link

reinforcement bent to form single or multiple legs that surrounds longitudinal reinforcement, if provided in the form of links these can be closed or open with sufficient anchorage at their ends

Note 1 to entry: See also “Stirrup” which has a similar definition as “Link”, but does not include single leg Z- or C-shaped reinforcement.

3.1.47

local anchorage zone

zone in the immediate vicinity of the tendon anchorage or coupling device in which the tendon force is transmitted from the anchorage or coupling device to the concrete

3.1.48

loop

U-shaped reinforcement where both legs transmit their forces to other reinforcement or to concrete through bond

3.1.49

main reinforcement

in one-way slabs, the bending reinforcement placed in the direction perpendicular to the supports, in other members the longitudinal reinforcement with the largest overall capacity

3.1.50

membrane

planar member subjected primarily to in plane forces

3.1.51

nodal region

region of a stress field where the force is transferred amongst concurrent compression fields and/or ties

3.1.52

node

point of intersection of struts and/or ties transferring forces amongst them

3.1.53

nonlinear analysis

analysis method using models that account for mechanical and geometrical non-linear behaviour

3.1.54

ordinary reinforcement

reinforcement which is not prestressed, where not specified otherwise, it is made of reinforcing steel

3.1.55

plain reinforcement

reinforcement with a smooth surface

3.1.56**plain or lightly reinforced concrete members**

structural concrete members having no reinforcement (plain concrete) or less reinforcement than the minimum amounts as defined in Clause 12

3.1.57**planar member**

structural member with a dimension in one direction (depth) significantly smaller than those in the other directions (width) with width / depth > 4 (such as slabs, walls and shells)

3.1.58**pocket (or socket) foundation**

member (precast, cast-insitu or partly precast) forming a tight pit for embedding the bottom of a precast column, fixed with infilled cast-insitu concrete

3.1.59**post-installed reinforcing steel system**

deformed straight reinforcing steel bar and anchoring mortar installed using tools for drilling and preparing the hole (e.g. roughening and cleaning) as well as for injection of the mortar (e.g. dispenser, nozzles, piston plug, if applicable)

3.1.60**post-tensioning**

prestress technique which consists in applying the prestress to tendons positioned in a hardened concrete member within a complete assembly of anchorages, sheathing with coating (for unbonded applications) or ducts to be grouted (for bonded applications)

3.1.61**precast concrete element**

factory produced or site manufactured element cast and cured in a place other than its final location in the structure

3.1.62**precast concrete product**

concrete element manufactured in accordance with a product standard by an industrial process under a factory production control system and protected from weather conditions during production

3.1.63**precast structure**

structure assembled from precast concrete elements, connected to ensure the required structural integrity

3.1.64**prestress**

effect of prestressing process, namely, internal forces in the sections and the deformations of the structure

3.1.65

prestressing process

process of prestressing consists in applying forces to the concrete structure and the tendons

3.1.66

prestressed reinforcement

reinforcement made of strands, wires or bars subjected to a prestressing process, where not specified otherwise, it is made of prestressing steel

3.1.67

pre-tensioning

process by which tendons are stressed before and remain stressed during their embedment in cast concrete

3.1.68

pre-tensioning tendon

tendon in which the prestressed reinforcement is embedded in and bonded directly to concrete

3.1.69

reinforcement

assembly of bars and/or tendons, prestressed (prestressed reinforcement) or not (ordinary reinforcement), embedded in or connected to concrete members, which, where not specified otherwise, is made of steel and is bonded to the concrete

3.1.70

ribbed reinforcement

reinforcing bars with at least two rows of ribs uniformly distributed over the entire length

3.1.71

ribbed slab

slab with narrow ribs spanning in one direction

3.1.72

second order effects

additional action effects caused by structural deformations

3.1.73

secondary reinforcement

in one-way slabs, the bending reinforcement placed in the direction parallel to the supports

3.1.74

shear reinforcement, shear assemblies

stirrups, links, headed bars or bent-up bars specifically placed to resist action effects caused by shear and torsion

3.1.75

shell

planar member, either plane or curved, that carries both in-plane and out of plane forces

Note 1 to entry: Cylindrical shells are simply curved, spherical shells are double curved.

3.1.76**shrinkage, basic**

shrinkage occurring in concrete when there is no humidity transfer with the surrounding environment

Note 1 to entry: Basic shrinkage is also known as autogenous shrinkage.

3.1.77**shrinkage, drying**

shrinkage, additional to basic shrinkage, occurring in concrete when there is humidity transfer with the surrounding environment

Note 1 to entry: The total shrinkage is the sum of basic and drying shrinkage.

3.1.78**slab**

planar member loaded primarily perpendicularly to its plane for which the minimum panel dimension is not less than 4 times the overall thickness, possibly acting also as diaphragm

3.1.79**slab, solid**

slab without voids or ribs

3.1.80**spiral reinforcement**

continuously wound reinforcement in form of a helix, cylindrical or prismatic

3.1.81**stabilized cracking**

phase of the cracking process in which the crack pattern is fully developed and an increase in the actions will normally result in an increase in the crack opening

Note 1 to entry: This type of cracking is typically associated with applied external loads, when such loads are sensibly above the cracking loads.

3.1.82**stainless steel**

stainless reinforcing steel in accordance with EN 10370

3.1.83**stirrup**

reinforcement bent to form double or multiple legs that surrounds longitudinal reinforcement

Note 1 to entry: Stirrups can be closed or open with sufficient anchorage at their ends.

3.1.84**stress field**

stress state in a structure equilibrating the external actions

3.1.85

strut

resultant of a compression field, part of a strut-and-tie model

3.1.86

strut-and-tie model

model composed of the resultant forces of a stress field with struts for the compression fields and ties for the tension reinforcement

3.1.87

support, direct

bearing by contact forces pushing against the member

3.1.88

support, indirect

support with local tensile stresses in the supporting member caused by applied loads

3.1.89

technical documentation of post-tensioning system

documentation containing all information relevant for design and construction of post-tensioned structures in accordance with this Eurocode

3.1.90

tendon

in post-tensioned applications, the tendon is a complete assembly consisting of anchorages, prestressing steel (strand, wire, bar), and sheathing with coating for unbonded applications or ducts with grout for bonded applications; in pre-tensioned applications, the tendon is an individual element of prestressed reinforcement

3.1.91

tendon protection level

designation of a class or level of corrosion protection provided to tendons

3.1.92

tie

tension member as part of a strut-and-tie model representing concentrated or distributed reinforcements

3.1.93

transverse reinforcement

reinforcement arranged perpendicular to the bar considered

Note 1 to entry: In linear members it can consist of stirrups, links or hoops enclosing the longitudinal reinforcement considered; in planar member it consists of straight reinforcement parallel to the free surface.

3.1.94**unbonded tendon**

tendon for post-tensioned members where bond of the prestressed reinforcement to the member is permanently prevented by encasing it in sheathing with soft filler or by placing the tendon outside the concrete section (see external tendon)

3.1.95**waffle slabs**

slab with narrow ribs spanning in both directions

3.1.96**wall**

planar member subjected primarily to in plane forces, with cross-section width exceeding 4 times its thickness (otherwise it should be considered as a column) and the height is at least 3 times the section thickness

Terms and definitions in Annex I**3.1.97****corrosion penetration depth**

loss in cross-sectional radius of a bar due to homogeneous corrosion (not pitting corrosion or localized zones)

3.1.98**pitting corrosion**

form of localised corrosion that leads to the creation of cavities or holes in the metal

Terms and definitions in Annex J**3.1.99****adhesive**

material that possesses enough adhesive strength to join CFRP reinforcement to a concrete surface

3.1.100**adhesively bonded CFRP reinforcement**

externally or Near Surface Mounted CFRP reinforcement bonded to concrete using adhesive to provide a longitudinal shear connection

3.1.101**CFRP bar**

thermally hardened, unidirectional CFRP reinforcement industrially manufactured in various shapes used as NSM reinforcement

3.1.102**Carbon Fibre Reinforced Polymer****CFRP**

fibre-polymer composite material comprising industrially manufactured carbon fibres embedded in a polymer matrix

3.1.103

Carbon Fibre Reinforced Polymer (CFRP) system

composite comprising carbon fibres with an accompanying adhesive material that is bonded to an adequately prepared concrete strata for the purpose of strengthening a structural concrete component

3.1.104

concrete cover separation

failure mode occurring at the end of adhesively bonded reinforcement, where a shift in tensile force may detach the concrete cover and the entire adhesively bonded reinforcement

3.1.105

externally bonded reinforcement

EBR

adhesively bonded CFRP reinforcement installed externally to a concrete surface

3.1.106

externally bonded stirrups

externally bonded CFRP system, embracing the member in closed or U-shaped form

3.1.107

Near Surface Mounted (NSM) reinforcement

adhesively bonded CFRP bar installed in slots cut into the existing concrete cover zone

3.1.108

sheets

textile surface structure comprising dry parallel fibre bundles arranged in one or more directions

3.1.109

slot

small recess cut into the concrete cover zone with predetermined dimensions along the member filled with adhesive in which adhesively bonded CFRP strips or bars (NSM) are embedded

3.1.110

strip

thermally hardened, unidirectional CFRP reinforcement industrially prefabricated in various rectangular flat shapes used as NSM or EBR reinforcement

Terms and definitions in Annex L

3.1.111

Steel Fibre Reinforced Concrete

SFRC

concrete to which steel fibres are included into the concrete matrix to achieve post cracking residual strength

3.1.112**residual flexural strength**

stress at the outer most tension layer of a SFRC cross-section in bending corresponding to a certain crack width determined using linear elastic material behaviour and the assumption that plane sections remain plane during bending

3.1.113**residual tensile strength**

uniaxial tensile stress corresponding to a certain crack opening derived from the residual flexural strength using design rules provided in Annex L

3.1.114**residual strength class**

classification that defines the response of a SFRC beyond the cracking strain of concrete. This class defines the strength of the SFRC concrete without additional reinforcing bars or prestressing

3.1.115**ductility class**

classification that is defined by the ratio between the residual flexural strengths at $CMOD_1$ and $CMOD_3$

Terms and definitions in Annex R**3.1.116****Fibre Reinforced Polymer****FRP**

fibre-polymer composite material comprising industrially manufactured fibres embedded in a polymer matrix

3.1.117**fibre reinforced polymer (FRP) reinforcement**

assembly of profiled or roughened fibre reinforced polymer reinforcement bars, embedded in or connected to concrete members

3.2 Symbols and abbreviations

For the purposes of this document, the following symbols apply.

3.2.1 Latin upper case letters

A	Correction factor
A_c	Cross-sectional area of concrete
A_{cc}	Compressive area
$A_{c,eff}$	Effective concrete area
A_{cc}	Area of confinement core of partially loaded area
A_{c0}	Loaded area in partially loaded area
A_{c1}	Contributing area in partially loaded area
A_e	Equivalent area of reinforcement

A_{gt}	Elongation at maximum force
A_k	Area enclosed by centrelines of connecting walls of cross section
A_p	Cross-sectional area of prestressed reinforcement
$A_{p,red}$	Reduced cross-sectional area of prestressing steel
A_s	Cross-sectional area of ordinary reinforcement
A_{sc}	Cross-sectional area of longitudinal reinforcement in the compression chord; confinement reinforcement
$A_{s,conf}$	Cross-sectional area of one leg of confinement reinforcement
$A_{s,confx}, A_{s,confy}$	Value of $A_{s,conf}$ in the x and y -directions, respectively
A_{sf}	Cross-sectional area of the transverse reinforcement in a flange
A_{si}	Cross-sectional area of bonded reinforcement across interface
A_{sint}	Robustness reinforcement in flat slabs
A_{sl}	Effective area of tensile reinforcement
$A_{s,min}$	Minimum cross-sectional area of reinforcement
$A_{s,min,h}$	Minimum amount of horizontal reinforcement
$A_{s,min,v}$	Minimum amount of vertical reinforcement
$A_{s,min,w1}$	Area of minimum reinforcement to be placed at the most tensioned face of the section part under consideration to control cracking
$A_{s,min,w2}$	Area of minimum reinforcement to be placed at the least tensioned face of the section part under consideration to control cracking
$A_{s,web}$	Reinforcement area to be provided in the web over a height limited by the neutral axis and the centroid of reinforcement with a spacing not exceeding 300 mm, to control cracking
A_{st}	Cross-sectional area of longitudinal reinforcement in the tension chord; transverse reinforcement
A_{std}	Tie down reinforcement in laps of headed bars
$A_{st,min}$	Minimum transverse reinforcement
$A_{s,v}$	Amount of vertical reinforcement
A_{sw}	Cross-sectional area of shear reinforcement
$A_{sw,min}$	Minimum cross-sectional area of shear reinforcement
$A_{s,req,span}$	Amount of required flexural non-prestressed reinforcement
C	Coefficient for fatigue strength of concrete under compression
C_m	Coefficient used to obtain an equivalent constant moment to calculate second order effects in elements with differing end moments
D_h	Diameter of a circular hoop or spiral reinforcement (defined by the bar's axis)
D_{lower}	Smallest value of the upper sieve size D in an aggregate for the coarsest fraction of aggregates in the concrete permitted by the specification of concrete [EN 206]
D_{max}	Declared value of the upper sieve size D of the coarsest fraction of aggregates actually used in the concrete [EN 206]

D_{upper}	Largest value of the upper sieve size D in an aggregate for the coarsest fraction of aggregates in the concrete permitted by the specification of concrete [EN 206]
E	Effect of actions
E_{cd}	Design value of modulus of elasticity of concrete
$E_{c,eff}$	Effective modulus of elasticity of concrete accounting for creep deformations
E_{cm}	Secant modulus of elasticity of concrete
$E_{c,28}$	Secant modulus of elasticity of concrete at age of 28 days
E_p	Design value of modulus of elasticity of prestressing steel
E_s	Design value of modulus of elasticity of ordinary reinforcing steel
EI	Bending stiffness
EI_{eff}	Effective bending stiffness
E_t	Action effect (force or stress) at time t
$E_{t=0}$	Internal force or stress at time $t=0$
E_{wc}	Force or stress assuming the structure was built without changes in the support conditions
F	Action
F_{cd}	Design value of the compression force in a compression chord or in a strut (compression positive)
F_d	Design value of an action
ΔF_d	Design value of the change of the axial force in the flange over the length Δx
F_{Ed}	Design value of actions
$F_{Ed,2}$	Fictitious magnified horizontal force to account for global second order effects
$F_{Ed,sup}$	Design support reaction due to the loads applied on the beam or the slab
F_{fat}	Relevant fatigue action (e.g. traffic load or other cyclic load)
$F_{H,0Ed}$	First order horizontal force due to wind, imperfections etc.
$F_{H,1Ed}$	Fictitious horizontal force
$F_{H,i}$	Transverse force representing a geometrical imperfection
F_{td}	Design value of the tension force in a tension chord or tie or in the transverse reinforcement
F_{Vi}	Vertical load to calculate $F_{H,i}$
F_{VB}	Buckling load of the bracing structure
F_{VBB}	Flexural buckling load of a cantilever, restricted by the floors, with base rotation
F_{VBS}	Buckling load due to localised lateral storey deformations
F_{VEd}	Total design vertical load on the bracing structure and the members braced by it
F_{Rd}	Design value of the resistance of a tie or of a tension chord
G_{cd}	Design value of the elastic shear modulus
G_k	Characteristic value of a permanent action

H	Distance between the points of application of two aligned forces
I	Second moment of area of concrete section
I_{cr}	Second moment of area of cracked concrete section
I_g	Second moment of area of the gross concrete cross-section
$J(t, t_0)$	Creep function or creep compliance, representing the total stress-dependent strain per unit stress
L	Total height of the building above the base
L_x, L_y	Spans of slab in x- and y-directions
M	Bending moment in linear members
M_{01}, M_{02}	First order end moments, including effect of imperfections such that $ M_{02} \geq M_{01} $
M_{0Ed}	Maximum first order moment due to the fundamental load combination, including the effect of imperfections
M_{0Eqp}	Maximum first order moment due to the quasi-permanent load combination
M_2	Nominal 2 nd order moment
M_{cr}	Cracking moment of the section in presence of the simultaneous axial force N_{Ed} , which may be calculated on the basis of the concrete tensile strength f_{ctm} assuming linear stress distribution and neglecting any contribution from reinforcement
M_{Ed}	Design value of the applied internal bending moment
M_{Edy}	Design moment about y-axis, including second order moment, where relevant
M_{Edz}	Design moment about z-axis, including second order moment, where relevant
M_{Rd}	Moment capacity
$M_{Rdy,N}$	Moment resistance about y-axis for the given axial force
$M_{Rdz,N}$	Moment resistance about z-axis for the given axial force
M_{rep}	Cracking moment with extreme fibre tension reaching the relevant tensile strength for sections without prestressing
$M_{R,min}$	Bending strength of the section with $A_{s,min}$ in presence of the simultaneous axial force N_{Ed}
M_y	Moment when strain in tension reinforcement equals ε_{yd}
ΔM_{Ed}	Reduction in the design support moment for a beam or slab continuous over a support that can be considered to provide no restraint to rotation; additional moment to calculate chord forces
N	Axial force in linear members ; number of load cycles
N^*	Number of load cycles corresponding to $\Delta\sigma_{Rsk}$
N_a	Axial force in column above floor or diaphragm
N_B	Elastic buckling load (<i>Euler</i>)
N_b	Axial force in column below floor or diaphragm
N_{Ed}	Design value of the applied axial force
N_{Edw}	Design value of the axial force in the web
N_{obs}	Number of lorries per year

N_{Rd}	Design value of axial resistance
$N_{Rd,0}$	Design value of axial resistance without accompanying moments
N_{Vd}	Design value of the sum of the additional axial forces in the tension and in the compression chords due to shear in a cross-section
N_{years}	Design service life of bridge
P	Prestressing force
P_d	Design value of the prestressing force
P_k	Characteristic value of the prestressing force
$\bar{Q}$	Factor for traffic type
$Q_{k,i}$	Characteristic variable action
$Q(t)$	Total amount of hydration heat
R	Resistance
R_{ax}	Restraint factor
$R_{ax,1}$	Restraint factor corresponding to the boundary conditions present after concreting
$R_{ax,2}$	Restraint factor corresponding to the boundary conditions present when the maximum temperature drop is expected to occur
$R_{ax,3}$	Restraint factor corresponding to the boundary conditions prevalent during the development of drying shrinkage
R_{cr}	Cracking risk
R_d	Design value of the resistance
$R_e, R_{p0,2}$	Tensile yield strength of reinforcing steel
$R_{ea,cr}$	Project parameter related to the admissible risk of cracking
RH	Relative humidity of the ambient environment in %
RH_{eq}	Internal relative humidity of concrete at equilibrium, accounting for self-desiccation in high performance concrete
R_m	Structural resistance based on a non-linear verification performed using the mean values of the material properties and the nominal geometrical dimensions; tensile strength of reinforcing or prestressing steel
R_{min}	Minimum radius of curvature of tendons
$R_{p0,1}$	Tensile yield strength of prestressing steel
S	First moment of area above and about the centroidal axis
S_{Ed}	Individual design actions for interaction formula
S_{Rd}	Individual design resistances for interaction formula
S_s	First order moment of area of the required tension and compression reinforcements with respect to the centroid of the gross cross-section
T	Torsional moment; tension force in lapped headed bars
T_0	Temperature of the restraining structure
T_1, T_2	Tension forces in legs of U-bar loops

T_{ci}	Temperature of fresh concrete
$T_{c,max}$	Maximum temperature in concrete due to hydration heat
T_{Ed}	Design value of the applied torsional moment
T_{col}, T_i, T_p, T_v	Tensile force in horizontal ties to columns, internal, peripheral and vertical ties
T_{max}	Maximum temperature during heat treatment
ΔT_{min}	Long term maximum temperature drop
$T_{Rd,c}$	Design value of axial resistance related to concrete failure in laps using U-bar loops
TS_{Mu}	Tension stiffening effect at ultimate limit state
TS_{My}	Tension stiffening effect at yield
V	Shear force in linear members
V_{bcd}	Design shear force carried by the bottom chord
V_{Ed}	Design shear force in the section considered
V_{Edi}	Shear force acting parallel to the interface
Vol	Volume of traffic (tonnes/year/track)
ΔV_{Ed}	Portion of shear force which may be subtracted from V_{Ed} due to favorable circumstances
V^*_R	Coefficient of variation of structural resistance
$V_{Rd,hog}$	Resistance provided by hogging reinforcement in flat slabs
$V_{Rd,int}$	Resistance of flat slabs without shear reinforcement for robustness
$V_{Rd,w,int}$	Resistance of flat slabs with shear reinforcement for robustness
V_{tcd}	Design shear force carried by the top chord

3.2.2 Latin lower case letters

a	Distance; geometrical data; distance from concrete surface to the centre of the outside layer of reinforcement (Figure 9.3)
a_{cs}	Effective shear span with respect to the control section
$a_{cs,0}$	a_{cs} without considering effect of prestressing or external load
a_F	Projection of a foundation from the column face
a_i	Amplitude of buckling shape to be considered as an imperfection for buckling analysis of arches
a_l	Distance by which moment curve is shifted to account for shear effect
a_N	Exponent governing the shape of the simplified skew bending interaction diagram
a_p	Distances between the centre of the support area and the point of contraflexure in slabs under concentrated loads
a_{pd}	Parameter for calculating the punching shear resistance based on a_p
$a_{p,x}, a_{p,y}$	Maximum distances from the centre of the support area to the two points (on the x - and on the y -axis, respectively) where the bending moments $m_{Ed,x}$, respectively $m_{Ed,y}$, are zero
a_q	Distance between concentrated forces pushing against each other

$a_{s,min}$	Minimum interface reinforcement along edges of composite slabs
a_v	Mechanical shear span
$a_{v,0}$	a_v without considering effect of prestressing or external load
a_x	Distance from concrete surface to the centre of the outer reinforcement layer in the x direction
a_y	Distance from concrete surface to the centre of the outer reinforcement layer in the y direction
a, b	Dimensions of load introduction block
a_0, b_0	Dimensions of loaded area A_{c0}
$a_{0,red}, b_{0,red}$	Reduced dimensions of loaded area due to eccentrically applied load
a_1, b_1	Dimensions of contributing area A_{c1}
a_h, b_h	Dimensions of rectangular head of headed bars
α_δ	Deformation parameter considered which may be, for example, a strain, a curvature, or a rotation or even a deflection
α_I, α_{II}	Value of α_δ calculated for uncracked and fully cracked conditions, respectively
b	Overall width of a cross-section, or actual flange width in a T or L beam
b_0	Length of control perimeter at face of supporting area
$b_{0,5}$	Length of control perimeter at a distance of $0,5d_v$ from column edge
$b_{0,5,s}$	Control perimeter placed at the location of the shear reinforcement perimeter
$b_{0,5out}$	b_0 for the verification outside the shear reinforced area
b_b	Geometric mean of the minimum and maximum overall widths of the control perimeter
b_c	Width of a strut
b_{cs}	Maximum width of the confined concrete core at confinement reinforcement
b_{csx}, b_{csy}	Value of b_{cs} in the x and y-directions, respectively
b_e	Width of element
b_{eff}	Effective width of flange in T, L or box sections
$b_{ef,hog}$	Effective width for consideration of hogging reinforcement in flat slabs
b_i	Distance between longitudinal reinforcement bars fixed by confinement reinforcement
b_s	Width of the support strip
b_w	Minimum width of the cross-section between tension and compression chords and neutral axis
$b_{w,nom}$	Nominal web width due to the disturbance of ducts
c	Concrete cover of reinforcement (to the surface of the bar, $\geq c_{nom}$). In 9.2 it refers to the bar which is closest to the concrete surface
$c_{1/r}$	Factor considering curvature distribution
c_{act}	Actual concrete cover
c_d	Nominal value of the concrete cover for designing the anchorage length

$c_{d,conf}$	Nominal value of c_d in presence of confinement
c_{min}	Minimum concrete cover c provided to ensure sufficient bond strength and protection against corrosion
$c_{min,b}$	Minimum concrete cover c due to bond requirement
$c_{min,dur}$	Minimum concrete cover c due to durability requirement
c_{nom}	Nominal value of the concrete cover c which is specified in drawings and is basis for calculating fire resistance
Δc_{abr}	Additional minimum cover for abrasion
Δc_{dev}	Allowance in design for deviation of the concrete cover
$\Delta c_{dur,red1}$, $\Delta c_{dur,red2}$	Reduction of minimum cover for use of additional concrete protection
Δc	Additional reduction or addition to cover
$\Delta c_{min,30}$	Reduction of minimum cover for structures with design life of 30 years
$\Delta c_{min,exc}$	Reduction of minimum cover for superior compaction or curing
$\Delta c_{min,p}$	Additional minimum cover for prestressing tendons
c_s	Clear distance between parallel reinforcement bars
c_u	Effective width of concrete area carrying tensile forces due to the deviation of curved chords
c_v	Parameter to determine $d_{v,out}$
c_{v1} , c_{v2}	Coefficients for the shear resistance at interfaces
$c_{v1,fat}$	Coefficients for the shear resistance at interfaces under fatigue action
c_x , c_y , c_{yb}	Concrete covers to reinforcement measured in x and y direction and at bends, respectively
d	Effective depth of a cross-section
d_d	Design value of the effective depth
d_{dg}	Size parameter describing the crack and the failure zone roughness taking account of concrete type and its aggregate properties
d_{key}	Height of shear key
d_{nom}	Nominal value of the effective depth determined on the basis of c_{nom}
d_p	Effective depth of the prestressed reinforcement
d_s	Effective depth of the ordinary reinforcement
d_v	Shear-resisting effective depth of the reinforcement at the first and second shear reinforcement perimeter
$d_{v,out}$	d_v outside of the second reinforced perimeter
d_{vx} , d_{vy}	Shear-resisting effective depth of the reinforcement in x and y direction, respectively
d_x , d_y	Effective depth of the reinforcement in x and y direction, respectively
e	Eccentricity
e_a , e_b	Eccentricity of applied load in partially loaded area

e_0	First order eccentricity
e_2	Second order eccentricity
e_b	Eccentricity of the resultant of shear forces with respect to the centroid of the control perimeter
$e_{b,x}, e_{b,y}$	Components of e_b in x and y direction, respectively
$e_{d,min}$	Minimum eccentricity due to uncertainties related to modelling and analysis
e_i	Additional eccentricity covering the effects of geometrical imperfections
e_p	Eccentricity of the axial forces related to the centroid of the section at control section, positive when the eccentricity is on the side of the flexural reinforcement in tension
e_{tot}	Total eccentricity
e_y', e_z'	Dimensionless eccentricity along the y -axis and z -axis, respectively
f_{bcd}	Design resistance of bedding material
$f_{bm,req}$	Required minimum mean bond strength of post-installed bar
f_c	Compressive strength of concrete
f_{cd}	Design value of concrete compressive strength
$f_{cd,c}$	Design value of strength of confined concrete
$f_{cd,fat}$	Design value of concrete fatigue strength
$f_{cd,pl}$	Design value of plain concrete compressive strength
Δf_{cd}	Design value of strength increase due to transverse compressive stress or confinement
f_{ck}	Characteristic concrete cylinder compressive strength at age t_{ref}
$f_{ck,ref}$	Value of f_{ck} at reference age t_{ref}
$f_{ck,28}$	Value of f_{ck} at reference age of 28 days
f_{cm}	Mean concrete cylinder compressive strength at age t_{ref}
$f_{cm}(t)$	Mean concrete cylinder compressive strength at age t
f_{cmp}	Mean compressive strength of concrete after heat curing
f_{ct}	Tensile strength, highest stress reached under concentric tensile loading
f_{ctd}	Design value of the tensile strength of concrete
$f_{ctd,pl}$	Design value of plain concrete tensile strength
$f_{ct,eff}$	Mean value of the tensile strength of the concrete effective at the time when cracking may first be expected to occur;
$f_{ctk;0,05}$	Characteristic axial tensile strength of concrete (5 % fractile)
$f_{ctk;0,95}$	Characteristic axial tensile strength of concrete (95 % fractile)
f_{ctm}	Mean axial tensile strength of concrete at age t_{ref}
$f_{ctm,fl}$	Mean flexural tensile strength of concrete
f_p	Actual tensile strength of prestressing steel
f_{pd}	Design yield strength of prestressing steel
f_{pk}	Characteristic tensile strength of prestressing steel

$f_{p0,1k}$	Characteristic 0,1 % proof-stress of prestressing steel
f_r	Relative flexibility of rotational restraints at the ends of a support
f_R	Minimum relative rib area of reinforcing steel
f_{Rd}	Design value of bearing strength
$f_{s,eff}$	Tensile stress in reinforcement when M_{Rd} is reached
f_t	Tensile strength of reinforcement
f_{tdx}, f_{tdy}	Tensile strength provided by reinforcement in membrane elements in x- and y-directions, respectively
f_y	Yield strength of reinforcement
f_{yd}	Design yield strength of reinforcement
f_{yk}	Characteristic value of yield strength of reinforcement or, if yield phenomenon is not present, the characteristic value of 0,2 % proof strength
f_{ywd}	Design yield strength of shear reinforcement
$f_{0,2k}$	Characteristic 0,2 % proof-stress of reinforcement
h	Overall depth of a cross-section or of a part of a cross-section
h_{col}	Largest side length of column
$h_{c,eff}$	Height of the effective concrete area around reinforcement
h_D	Hydrostatic head
h_F	Foundation depth;
h_f	Thickness of a flange at the junction with the web
h_n	Notional size of concrete member
i	Radius of gyration
i_s	Radius of gyration of total group of reinforcement
i_y, i_z	Radius of gyration with respect to y-axis and z-axis, respectively
k	Coefficient; Factor
k	Ratio related to strain hardening of reinforcement
$k_b, k_{b,simpl}$	Coefficient for bond conditions
k_{bend}	Parameter accounting for the bend angle α_{bend}
$k_{b,pi}$	Bond efficiency factor
k_c	Coefficient reflecting the extent of cracking and the effect of non-linear material properties in the bracing system
k_{cip}	Factor considering increased uncertainty and variability in γ_c for concrete geotechnical members
$k_{conf,b}, k_{conf,s}$	Effectiveness factor for confinement
k_{cp}	Coefficient accounting for casting effect on bond conditions
$k_{c,pl}$	Coefficient to determine the design compressive strength of plain concrete
k_{dc}	Coefficient for moment resistance depending on ductility class of reinforcement

k_{dowel}	Factor depending on the roughness of the interface
k_{duct}	Coefficient for calculating the nominal web width due to the disturbance of ducts
k_E	an adjusting factor for the modulus of elasticity of concrete considering the type of aggregates.
k_{f1}, k_{f2}	Stress exponent in $S-N$ curves
$k_{fl}, k_{fl,simpl}$	Coefficient for type of loading (axial versus flexure)
k_h	Coefficient which allows for the effect of non-uniform self-equilibrating stresses, which lead to a reduction of the apparent tensile strength
k_{int}	Coefficient to calculate resistance for robustness
k_I	Coefficient to accounting for the effect of cracking, for tension stiffening and for the fact that creep deformations are less than proportional to the creep coefficient in cracked sections
k_{lb}	Factor for calculating the design anchorage length
k_{ls}	Factor to increase anchorage to lap length
k_N	Coefficient to consider beneficial effect of eccentric tendons on punching shear resistance in prestressed slabs
k_p	Exponent to model the evolution of relaxation with time
k_{pb}	Shear gradient enhancement coefficient for punching
k_{pp}	Coefficient accounting for the influence of axial forces on the shear slenderness of slabs submitted to concentrated forces
k_r	In the context of second order effects, correction coefficient for equilibrium curvature depending on axial force
k_s	Coefficient accounting for the effect of cracking on the shrinkage deflection
k_{st}	Resistance factor of the transverse reinforcement in laps using U-bar loops and headed bars
k_{surf}	Factor considering effect or ratio of actual cover / minimum cover
k_t	Coefficient accounting for the effect of the nature and duration of the load on tension stiffening effects for cracking
k_{tc}	Coefficient considering the effect of high sustained loads on concrete compressive strength
k_{Temp}	Coefficient accounting for the reduction in temperature from t_1 to t_2
$k_{t,pl}$	Coefficient to determine the design tensile strength of plain concrete
k_{tt}	Coefficient considering the effect of high sustained loads on concrete tensile strength
k_v	Factor depending on roughness of interface
k_{vp}	Coefficient considering effect of axial force
k_w	Factor converting the mean crack width into a design crack width
k_1	Factor considering effect of axial force and eccentricity
$k_{1/r}, k_{1/r,simpl}$	Coefficient accounting for increase of crack width due to curvature
k_μ	Unintentional angular displacement for internal tendons (per unit length)

k_{σ}	Ratio of concrete stress to $0,4f_{cm}$, used to account for non-linear creep
$k_{\sigma 1}, k_{\sigma 2}$	Coefficient for determining $\sigma_{s,lim}$
k_{φ}	In the context of second order effects, correction coefficient for equilibrium curvature accounting for creep
l (or L)	Length; span
l_0	Effective length of the member
l_{0b}	Distance l_{0b} between points of zero moment
l_{0t}	Distance between torsional restraints
l_{aw}	Half wavelength of the buckling mode with the lowest buckling load
l_{bd}	Design value of anchorage length of reinforcing steel
l_{bdn}	Part of the anchorage length in the nodal region
$l_{bd,pi}$	Design anchorage length of post-installed reinforcing steel
$l_{bd,tot}$	Design anchorage length measured along the centre line of bars with bends and hooks in tension
l_{bpd}	Anchorage length of pretensioning tendon
l_{disp}	Dispersion length of effect of pretensioning tendon
l_{pt}	Transmission length of pretensioning tendon
l_s	Actual lap length
l_{sd}	Design value of lap length of reinforcing steel
l_w	Clear height of the member
$l_{w,p}$	Length of passing crack
m	Number of load bearing members in one storey that bear a significant part of the vertical load
m_{Ed}	Design value of the applied internal bending moment per unit width in planar members
m_{Edx}, m_{Edy}	Value of m_{Ed} in the x and y -directions, respectively
m_{Edxy}	Design value of the applied internal torsion moment per unit width in planar members
m_{Rd}	Design value of the flexural strength per unit width of a planar member resisting positive moments
m_{Rd}'	Design value of the flexural strength per unit width of a planar member resisting negative moments (value positive)
m_{Rdx}, m_{Rdy}	Value of m_{Rd} in the x and y -directions, respectively (without the influence of torsion moments)
m_{Rdx}', m_{Rdy}'	Value of m_{Rd}' in the x and y -directions, respectively (without the influence of torsion moments)
n	Non-dimensional axial force
n_b	Number of anchored bars or pairs of lapped bars in the potential splitting failure surface
n_c	Number of legs of confinement reinforcement crossing the potential splitting failure surface

n_i	Number of acting stress cycles for stress level i
n_s	Number of storeys
n_{st}	Proportion of traffic crossing bridge simultaneously
n_{trans}	Number of transverse bars in the bend
n_1	Number of layers with bars anchored at the same point in the member
n_2	Number of bars anchored in each layer
n_σ	Exponent to consider effect of steel stress on anchorage length
p	Water pressure
p_{Rd}	Maximum transverse bearing stress on tendon
Δp	Water pressure difference between the ends of a passing crack
q	Leakage rate through cracks
q_d	Distributed load
q_{ed}	Design value of variable load
r	Radius of curvature
r_{inf}	Factor to account for variation in prestress in serviceability and fatigue verifications when prestressing is favourable
r_m	Ratio of end moments $ r_m \leq 1,0$
r_{sup}	Factor to account for variation in prestress in serviceability and fatigue verifications when prestressing is unfavourable
$1/r$	Curvature at a particular section
s	Spacing of the shear reinforcement or confinement reinforcement measured along the longitudinal axis of the member
s_c	Spacing of the confinement reinforcement along the bar to be anchored
s_f	Spacing of transverse reinforcement
s_0	Distance from the column face to the axis of the first perimeter of punching reinforcement
s_1	Spacing between shear links in radial direction
s_c	Coefficient for different early strength development of concrete and concrete strength
s_L	Spacing of longitudinal ribs
s_T	Spacing of transverse ribs
s_l	Centre-to-centre spacing of longitudinal bars
$s_{l,surf,max}$	Maximum spacing of surface reinforcement in beams with downstand
$s_{bu,max}$	Maximum longitudinal spacing of bent-up bars
$s_{max,col}$	Maximum spacing of transverse reinforcement along the column
$s_{l,max}$	Maximum longitudinal spacing of shear assemblies/stirrups
$s_{slab,max}$	Maximum spacing of bars for slabs
$s_{stir,max}$	Maximum spacing for torsion assemblies / stirrups

$s_{tr,max}$	Maximum transverse spacing of shear legs
s_r	Spacing of shear links in the radial direction
$s_{r,m,cal}$	Calculated mean crack spacing when all cracks have formed or where not all cracks have formed, the maximum length along which there is slip between concrete and steel adjacent to a crack
$s_{r,m,cal,x}, s_{r,m,cal,y}$	Calculated mean crack spacing in the x direction and in the y direction, respectively
s_t	Average spacing of shear links in the tangential direction at the investigated control perimeter; spacing of transverse reinforcement along the bar to be anchored
s_x	Bar spacing in a group of headed bars
t	Thickness of a strut; length over which the support reaction is distributed
t	Time being considered, age of the concrete
Δt	Time interval
t_{eff}	Effective wall thickness
t_{eq}	Equivalent time to consider effect of heat treatment loss of prestress
t_{fac}	Tensile force in horizontal ties to walls
t_p	Duration of heat curing
t_0	Age of concrete when the event under consideration occurs (prestressing, settlement, start of drying, loading age)
$t_{0,adj}$	Concrete age at loading adjusted for strength class of cement and temperature
$t_{0,T}$	Temperature-adjusted concrete age at loading
t_1	Time when the maximum concrete temperature due to heat hydration is reached
t_2	Time when concrete starts to develop tensile stresses
t_c	Age of concrete when support conditions change
t_{crit}	Critical time for early-age cracking. Time at which thermal equilibrium with the restraining structure is achieved (within 2 °C) and the greater part of basic shrinkage has already developed
t_{dor}	Dormant time, e.g. time from concreting until stresses begin to develop
t_{ref}	Age of concrete at which the concrete strength is determined in days
t_s	Age of concrete at the beginning of drying
t_T	Temperature-adjusted concrete age in days
u	Perimeter of concrete cross-section, having area A_c
V_{Ed}	Principal out of plane shear force per unit width in planar members
$V_{Ed,x}, V_{Ed,y}$	Out of plane shear force in planar members on the cross-sections perpendicular to the x and y direction, respectively
$w_{k,cal}$	Calculated crack width
$w_{k,cal,1}$	Crack width at end of a through-crack, where the crack is wider
$w_{k,cal,2}$	Crack width at end of a through-crack, where the crack is thinner
$w_{k,cal,e}$	Equivalent width of a passing crack, of variable width

$w_{k,lim,1}$	Limiting crack width for water-tightness
$w_{lim,cal}$	Limiting crack width to be compared with the calculated crack width $w_{k,cal}$
x	Depth of the neutral axis at serviceability limit state
Δx	Length under consideration for shear transfer
x_{cs}	Distance between the neutral axis and the axis of confinement reinforcement
x_g	Depth of neutral axis of uncracked section
x, y, z	Coordinates
x_{min}	Minimum depth of the compression zone to guarantee water-tightness in elements subjected to flexure
x_{sb}	Depth of the compression zone assuming a stress block
x_u	Depth of the neutral axis at ultimate limit state
z	Inner lever arm of internal forces for shear design
z_{cp}	Distance between the centroid of the concrete section and the tendons
z_{red}	Reduced depth of section at segment joint due to joint opening

3.2.3 Greek letters

α	Angle; ratio
α	Inclination of reinforcement across interface
α_{bend}	Bend angle
α_{bs}	Coefficient accounting for the effect of the strength class of cement on basic shrinkage
α_c	Function to determine tangent modulus of elasticity of concrete
$\alpha_{c,th}$	Coefficient of thermal expansion of concrete
α_{ds}	Coefficients accounting for the effect of the strength class of cement on drying shrinkage
α_e	Modular ratio, $\alpha_e = E_s/E_c$
$\alpha_{e,ef}$	Modular ratio, $\alpha_{e,ef} = E_s/E_{c,eff}$
α_{fcm}	Coefficient accounting for the effect of concrete strength on time evolution of drying creep
α_h	Reduction coefficient for length or height
α_{lb}	Factor accounting for cracks along post-installed bar
α_m	Reduction coefficient for number of members
$\alpha_{NDP,b}, \alpha_{NDP,d}$	Coefficient to determine basic shrinkage and drying shrinkage, respectively
α_R	Sensitivity factor for the reliability of the resistance
α_{RA}	Substitution rate of recycled concrete aggregates
α_{SC}	Exponent accounting for the strength class of cement on the adjusted loading age
$\alpha_{s,th}$	Coefficient of thermal expansion of reinforcement
α_v	Angle between the principal shear force and the x-axis

α_w	Angle between shear reinforcement and the member axis perpendicular to the shear force
α_1, α_2	Coefficients for determination of transmission length
α_3	Coefficient for determination of anchorage length considering type of verification (fatigue or other)
α_μ	Sum of the absolute values of angular displacements over a distance for the calculation of prestressing losses due to friction
β_{tgt}	Target value of reliability index
β_{new}	Ratio of longitudinal force in new concrete due to composite action
β_{incl}	Angle of inclined cross-sections for determining the shear resistance in case of direct strutting in deep beams or in presence of concentrated loads near to the support
$\beta_{bc, fcm}$	Coefficient accounting for the effect of concrete strength on the basic creep coefficient
$\beta_{bc, t-t_0}$	Coefficient describing the evolution with time of basic creep and accounting for age of loading
$\beta_{bs, t}$	Coefficient describing the evolution with time of basic shrinkage
β_c	Coefficient which depends on the distribution of 1 st and 2 nd order moments
$\beta_{cc}(t)$	Coefficient for determining the compressive concrete strength which depends on the age of the concrete t
$\beta_{dc, fcm}$	Coefficient accounting for the effect of concrete strength on the drying creep coefficient
$\beta_{dc, RH}$	Coefficient accounting for the effect of relative humidity on the drying creep coefficient
β_{dc, t_0}	Coefficient accounting for the effect of age of loading on the drying creep coefficient
$\beta_{dc, t-t_0}$	Coefficient describing the evolution with time of drying creep and accounting for the effect of notional size and age at loading
$\beta_{ds, t-t_s}$	Coefficient describing the evolution with time of drying shrinkage and accounting for the effect of notional size
β_e	Coefficient accounting for concentrations of the shear forces along a control perimeter
β_{Eul}	Euler coefficient
β_{fck}	Coefficient accounting for concrete strength and slenderness, used in the nominal curvature method
β_h	Coefficient accounting for the effect of notional size and concrete strength on the time development of drying creep
β_p	Angle between the tendon and the axis of the member, for the sign, the angle indicated in Figure 8.4 is positive
β_{RH}	Coefficient accounting for the effect of relative humidity on drying shrinkage
β_t	Coefficient to account for duration of loading or of repeated loading on average strain
γ	Partial factor (safety and serviceability)
$\gamma(t_{0, adj})$	Exponent accounting for the influence of age of loading in the time development of drying creep
γ_c	Partial factor for concrete