INVITED CONFERENCE

The scope and main changes in the new Eurocode 2

Hans R. Ganz

EUROCODES

EN 1992

Design
of concrete
structures

2nd generation of Eurocode 2 on concrete structures

Madrid, October 17th, 2023

ACHE
Asociación Española de
Ingeniería Estructural

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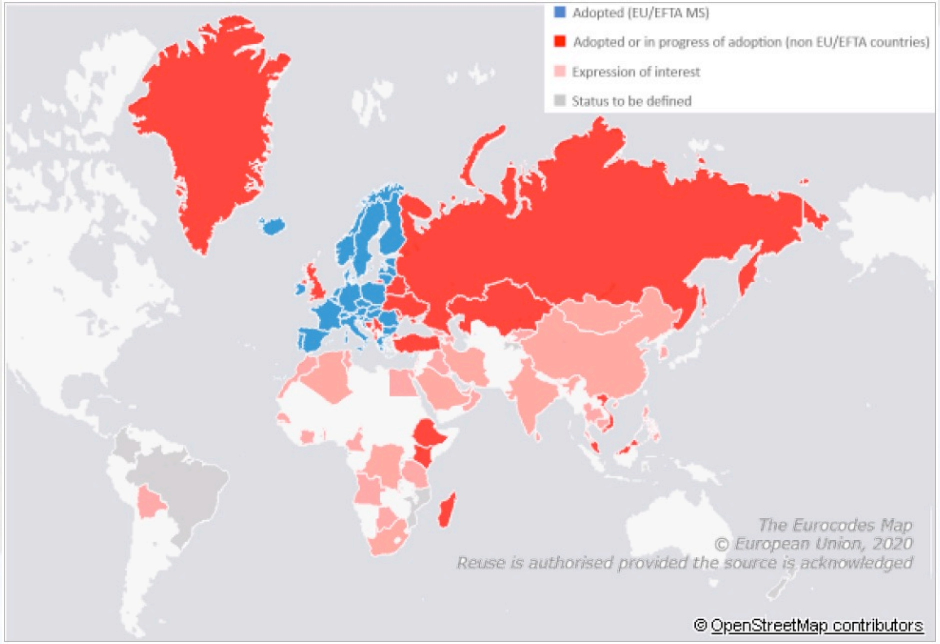
Contents

1. Introduction to revision of Eurocodes

Eurocodes 1st Generation:

- *Eurocode suite EN 199x (1990, 1991, 1992, …, 1997, 1998, 1999)*
- *10 Eurocodes with total 59 parts: 5000 pages and 1055 NDPs *)*
- *Publication as ENV as of 1992*
- *Publication as EN between 2002-2007, withdrawal of conflicting national standards 2010*
- *N.B.: Relevance of Eurocodes*
  - *500'000 engineers*
  - *65 Mia.€ design contracts*
  - *34 countries in CEN*
  - *+ other countries*

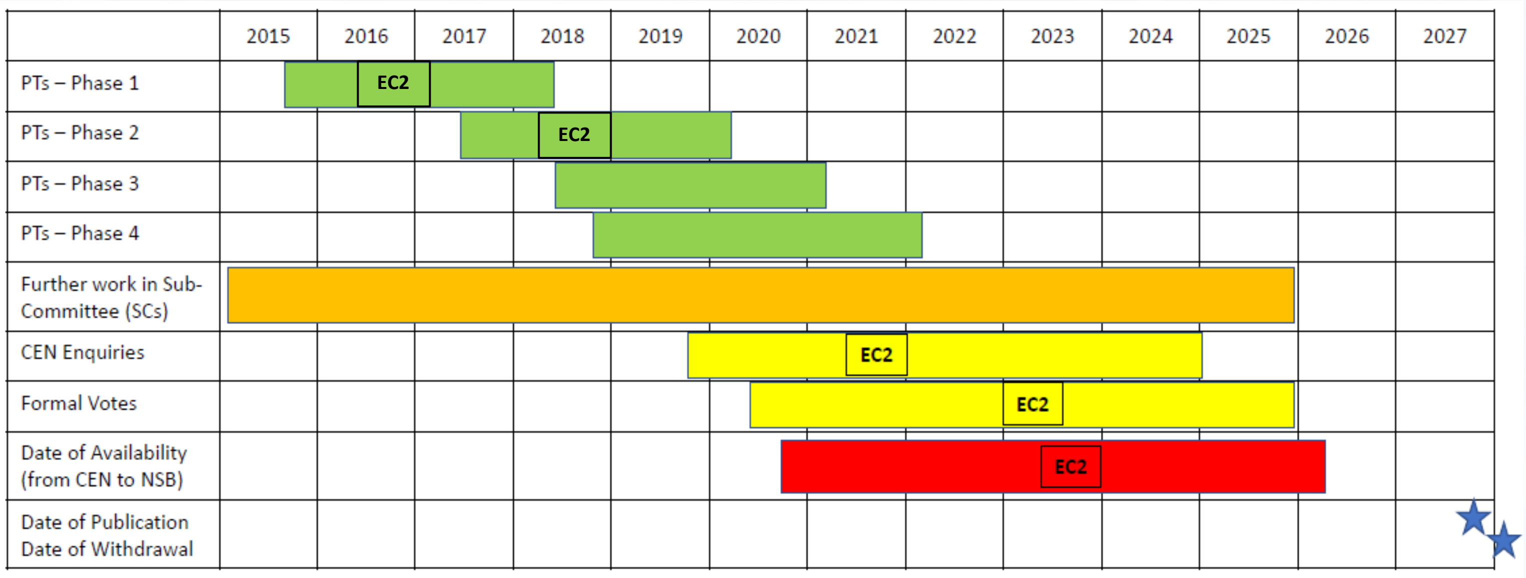


**) NDP = Nationally Determined Parameter: Parameters for which a country can set values. If nothing is said, the recommended values in Eurocodes apply*

1. Introduction to revision of Eurocodes

2012 EU/EFTA Mandate M/515 to CEN for Revision of Eurocodes → CEN/TC 250:

- Drafting of standards by 73 Project-Teams (PTs) in 4 Phases : 2015 – End 2021
- Objectives: Improve Ease of Use; Reduce number of NDPs



→ Date of Publication / Date of Withdrawal are latest possible dates for countries / NSBs → ***EN 1992: October 2023***
→ At «Date of Withdrawal» current Eurocodes will have an age of 20 years

2. Organisation of CEN/TC 250/SC 2 for revision of Eurocode 2

Plus National Mirror Committees for input, reviews, comments, and voting

	CEN/TC 250/SC 2 **Chair: Hans Rudolf Ganz** **Secretary: Damir Zorcec** J. Rodriguez J. M. Arrieta	
CEN/TC 250/SC 2/WG 1 – EN 1992-1-1 **Convenor: Mikael Hallgren** J. M. Arrieta J. Rodriguez	**CEN/TC 250/SC 2/WG 2 – EN 1992-4** **Convenor: Rolf Eligehausen (DE)**	**PT SC2.T1 (2015 – 06/2018) – EN 1992-1-1** **PT Leader: Aurelio Muttoni; M/515 – Phase 1** A. P. Caldentey
CEN/TC 250/SC 2/WG 1/TG 1 Leader: Konrad Zilch E. Oller		**PT SC2.T2 (2017 – 06/2020) – EN 1992-1-2** **PT Leader: Fabienne Robert; M/515 – Phase 2**
CEN/TC 250/SC 2/WG 1/TG 2 Leader: Marco di Prisco G. Ruiz		**PT SC2.T3 (2017 – 06/2020) – EN 1992-1-1 Items** **PT Leader: Craig Giaccio; M/515 – Phase 2**
CEN/TC 250/SC 2/WG 1/TG 3 Leader: Gerrie Dieteren C. Andrade	**Ad-Hoc Group Detailing** **Convenor: Charles Goodchild** A. P. Caldentey	
CEN/TC 250/SC 2/WG 1/TG 4 Leader: Josef Hegger A. Caldera; A. Mari; P. Miguel; M.A. Fernandez	**Ad-Hoc Group Robustness** **Convenor: Aurelio Muttoni / Tony Jones** A. P. Caldentey	
CEN/TC 250/SC 2/WG 1/TG 5 Leader: Fabienne Robert S. Carrascon	**Ad-Hoc Group Cracking** **Convenor: Alejandro Perez Caldentey**	**Coordinating & Drafting Group (CDG)** **Convenor: Mikael Hallgren**
CEN/TC 250/SC 2/WG 1/TG 6 Leader: Simon Wijte A. P. Caldentey		
CEN/TC 250/SC 2/WG 1/TG 7 Leader: Harald Müller A. P. Caldentey		
CEN/TC 250/SC 2/WG 1/TG 8 Leader: Paul Jackson C. Rios; F. Dias		
CEN/TC 250/SC 2/WG 1/TG 9 Leader: Giuseppe Mancini A. M. Cutillas		
CEN/TC 250/SC 2/WG 1/TG 10 Leader: Mikael Hallgren C. Andrade; D. Izquierdo		

CEN/TC 250/SC 2: Strategic guidance, supervision, decision taking
CEN/TC 250/SC 2/WG 1: Coordination & editorial work for revision of Eurocode 2, technical discussions
Task Groups (TGs): Providing technical input for work of PTs
Project Teams: Preparing drafts of future EN 1992-1-1 (T1 & T3) and EN 1992-1-2 (T2) under Mandate M/515
CDG: Editorial work to prepare documents for ENQ and FV

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Contents - EN 1992-1-1:

Clause	Title	Pages (FprEN)
	Title page, Table of contents, European foreword, Introduction	20
1; 2; 3	Scope; normative references; terms, definitions and symbols	46
4	Basis of design	4
5	Materials	12 + Annex C
6	Durability	12
7	Structural analysis	19 + Annex O
8	Ultimate Limit State (ULS)	52
9	Serviceability Limit State (SLS)	14 + Annex S
10	Fatigue	4 + Annex E
11	Detailing of reinforcement and post-tensioning tendons	24
12	Detailing of members and particular rules	22
13	Additional rules for precast concrete elements and structures	12
14	Plain and lightly reinforced structures	6
	Total main part	**247**

- Main part (Clauses 1 – 14) with provisions for general / regular use
- Annexes with provisions for special topics / less frequent use

this presentation

other presentations

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex	Title	Pages (FprEN)
A	Adjustment of partial factors for materials (Normative → Informative)	9
B	Time dependent behaviour of materials (Normative)	11
C	Requirements to materials (Normative)	9
D	Evaluation of early-age and long-term cracking due to restraint (Informative)	5
E	Additional rules for fatigue verification (Normative)	5
F	**Non-linear analyses procedures (Informative)**	5
G	Design of membrane, shell and slab elements at ULS (Normative)	7
H	Guidance on design of concrete structures for water tightness (Informative)	3
I	**Assessment of existing structures (Informative)**	19
J	**Strengthening of existing concrete structures with CFRP (Informative)**	20
K	Bridges (Normative)	16
L	**Steel fibre reinforced concrete structures (Informative)**	14
M	Lightweight aggregate concrete structures (Normative)	3
N	**Recycled aggregates concrete structures (Informative)**	3
O	Simplified approaches for second order effects (Informative)	8
P	Alternative cover approach for durability (Informative)	4
Q	**Stainless steel reinforcement (Normative)**	4
R	**Embedded FRP reinforcement (Informative)**	11
S	Minimum reinforcement for crack control and simplified control of cracking (Informative)	4
	Bibliography	2
	Total Annexes	162
	Total FprEN 1992-1-1	**409**

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

General - EN 1992-1-1:

- Design provisions based on physical models; independent of type of member; sufficiently detailed for existing structures; simplified for new structures.
- General, regularly used provisions given in main part Clauses 4 - 14; provisions for special members and materials in Annexes. Example: Simplified verification for fatigue in Clause 10; detailed verification in Annex E.
- Integration of bridge part (EN 1992-2:2005) into EN 1992-1-1, with provisions specific to bridges only in Annex K.
- Integration of containment part (EN 1992-3:2006) into EN 1992-1-1, with provisions for restraints / cracking at early age in Annex D and for leak tightness in Annex H.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Sustainability - EN 1992-1-1:

- Reference age t_{ref} for definition of concrete strength is 28 days, in general, but may be increased up to 91 days, to better exploit potential of concretes with slow strength development («green concretes»).
- Introduction of «Exposure Resistance Concept» for durability assessment of concretes, applicable both for common/well-known but primarily for new concretes («green concretes») with little experience → Clause 6.
- Introduction of provisions for recycled aggregates concrete structures → Annex N (Informative).
- Introduction of provisions for assessment of existing structures → Annex I (Informative).
- Introduction of provisions for adaptation of partial material factors by NSBs to consider enhanced quality requirements and better knowledge of material and geometry to make more efficient use of materials → Annex A (Informative).

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 4 Basis of design - EN 1992-1-1:

- Clause 4 gives general provisions as basis of design as well as all partial factors for materials and concrete specific actions in compact tabular format (β = 3,8)
  - partial factors for prestressing actions at ULS
  - partial factors for materials (new: γ_V for shear resistance of concrete).

Table 4.2 (NDP) — Partial factors for prestress action for ultimate limit states

Factor for prestress	Value	Applied to	ULS verification type
$\gamma_{P,fav}$	1,00	Prestress force for bonded and unbonded tendons	Verifications where an increase in prestress would be favourable
$\gamma_{P,unfav}$	1,20		Verifications where an increase in prestress would be unfavourable
$\gamma_{\Delta P,sup}$	0,80	Change in stress in unbonded tendons	Verifications where increase in stress would be favourable
$\gamma_{\Delta P,inf}$	1,20		Verifications where increase in stress would be unfavourable
$\gamma_{\Delta P,sup}$ $\gamma_{\Delta P,inf}$	1,0		Verifications where linear analysis with uncracked sections, i.e. assuming a lower limit of deformations, is applied

Table 4.3 (NDP) — Partial factors for materials

Design situations — Limit states	γ_S for reinforcing and prestressing steel	γ_C and γ_{CE} for concrete	γ_V for shear and punching resistance without shear reinforcement
Persistent and transient design situation	1,15	1,50[a]	1,40
Fatigue design situation	1,15	1,50	1,40
Accidental design situation	1,00	1,15	1,15
Serviceability limit state	1,00	1,00	—

NOTE The partial factors for materials correspond to geometrical deviations of Tolerance Class 1 and Execution Class 2 in EN 13670.

[a] The value for γ_{CE} applies when the indicative value for the elastic modulus according 5.1.4(2) is used. A value γ_{CE} = 1,3 applies when the elastic modulus is determined according to 5.1.4(1). *)

*) 5.1.4(1): Specifying E_c or determined by testing

- Adjustment of partial factors for materials given in Annex A → Presentation: *J.M. Arrieta*

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 5 Materials - EN 1992-1-1:

- Clause 5 gives material properties for the design with commonly used materials. Other properties and those for less frequently used materials are given in specific annexes

- Concrete: Extended strength classes to 12 MPa $\leq f_{ck} \leq$ 100 MPa

Strength: Specified at time t_{ref} typically 28 days but may be taken between 28-91 days

Design strength: → Presentation: *J.M. Arrieta*

$$\boxed{f_{cd} = \eta_{cc} \cdot k_{tc} \frac{f_{ck}}{\gamma_C}} \quad \boxed{\eta_{cc} = \left(\frac{f_{ck,ref}}{f_{ck}}\right)^{\frac{1}{3}} \leq 1{,}0}$$

$0{,}85 \leq k_{tc} \leq 1{,}00$; $f_{ck,ref}$ = 40MPa (NDP)

Creep: Values $\varphi(50y, t_0)$ given in Table 5.2 for CS, CN, CR*) and selected t_0 and h_0 based on formulae given in Annex B (MC 2010) → values close to EN 1992-1-1:2004

Shrinkage: Nominal total values $\varepsilon_{cs,50y}$ given in Table 5.3(NDP) for CS, CN, CR *) and selected t_0 and h_0 based on formulae given in Annex B (MC 2010) → values significantly higher than EN 1992-1-1:2004.

*) *Concretes with Slow, Normal, Rapid hardening*

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 5 Materials - EN 1992-1-1:

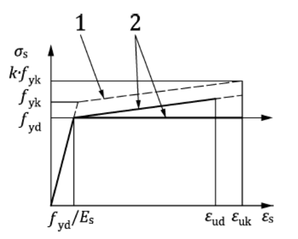
- Clause 5 gives material properties for the design with commonly used materials. Other properties and those for less frequently used materials are given in specific annexes

- Reinforcing steel: Extended strength classes to 400MPa $\leq f_{yk} \leq$ 700MPa

Table 5.4 — Strength classes of reinforcing steel

Properties for stress-strain-diagram (Fig. 5.2)	Reinforcing steel strength class					
	B400	B450	B500	B550	B600	B700
characteristic value f_{yk} [MPa]	400	450	500	550	600	700

NOTE All strength classes apply unless a National Annex excludes specific classes. Intermediate strength classes can be used, if included in a National Annex.



$$\boxed{\varepsilon_{ud} \leq \varepsilon_{uk}/\gamma_S}$$

- Prestressing steel: Wire, strand (up to Y2060), bar

Stress ratio: $k = (f_p/f_{p0,1})_k \geq 1{,}1 \rightarrow$ same as recommended value in EN 1992-1-1:2004

N.B.: Reference to «relevant standards» for reinforcing & prestressing steel which can be specified in National Annex (similar for post-tensioning systems).

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 6 Durability and concrete cover - EN 1992-1-1:

- Clause 6 introduces new performance-based approach for durability design: Effects of exposure of member (t) $\leq$ Exposure-resistance of member (t) as f(β).

$\rightarrow$ Presentation: *Carmen Andrade*

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 7 Structural analysis - EN 1992-1-1:

- Harmonised global imperfections between different material Eurocodes.
- Methods of analysis

- Linear elastic analysis with redistribution – without explicit check of rotation capacity:

New formula for ratio δ_M "moment after redistribution / elastic bending moment":

$$\delta_M \geq \frac{1}{1 + 0{,}7\varepsilon_{cu} \cdot E_s / f_{yd}} + \frac{x_u}{d}$$

$\geq$ 0,7 (Class B or C reinforcement); $\geq$ 0,8 (Class A)

prestressed members: replace f_{yd} by f: $f = \frac{(f_{pd} - \sigma_{pm,\infty})A_p + f_{yd}A_s}{A_p + A_s}$

- Linear elastic analysis with redistribution – with explicit check of rotation capacity:

$$\theta_{Ed} \leq \quad \theta_{Rd} = \frac{1{,}3d}{\gamma_\theta}\left(\left(\frac{1}{r}\right)_{u,m} - TS_{My}\frac{\varepsilon_{yd}}{d-x}\right)$$

- Non-linear analysis: Reference to EN 1990; ULS verification see Annex F

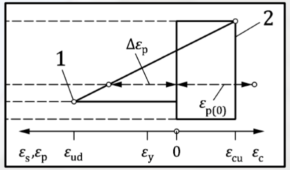
- Second order analysis: General method; simplified methods given in Annex O.

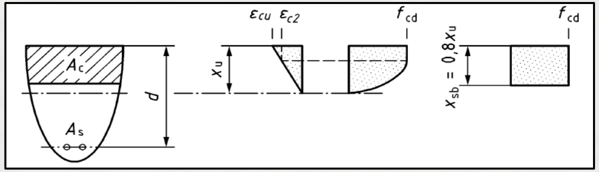
- Clarified how to consider effects of prestress (action vs resistance) in analysis and design.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 8 Ultimate limit states - EN 1992-1-1: Bending with or without axial force

- Simplified strain distributions in compression, use unique values ε_{c2} and ε_{cu} for all concrete strengths, optional consideration of confined concrete.

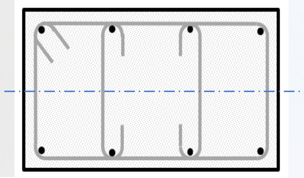


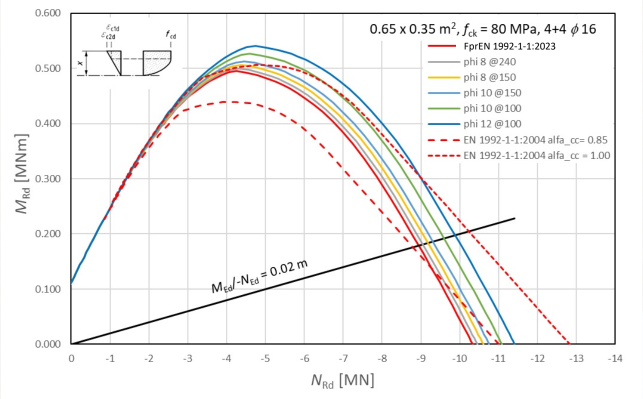


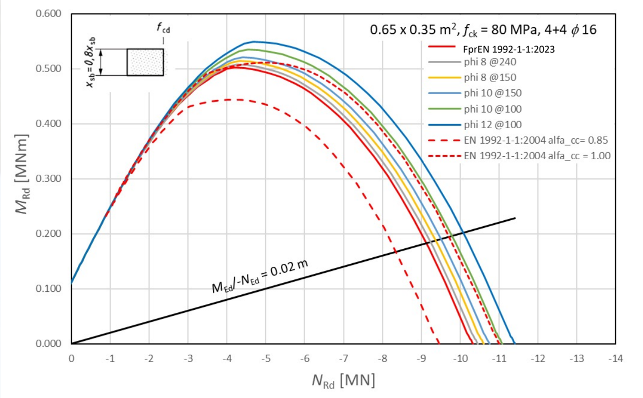
$$f_{cd} = \eta_{cc} \cdot k_{tc} \frac{f_{ck}}{\gamma_C}$$

$$\varepsilon_{c2} = 0{,}002$$

$$\varepsilon_{cu} = 0{,}0035$$







Note consistency between capacity based on parabola-rectangle and based on stress block

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 8.1 Ultimate limit states - EN 1992-1-1: Bending with or without axial force

- Amended provisions for confined concrete:

- Strength increase under uniform confining stress σ_{c2d}:

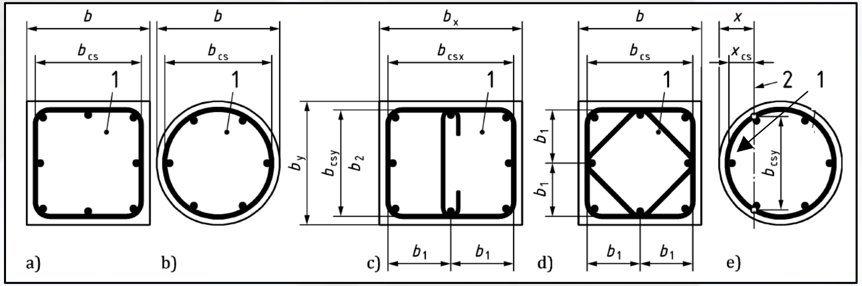
$$\Delta f_{cd} = 4 \cdot \sigma_{c2d} \qquad \text{for } \sigma_{c2d} \leq 0{,}6 f_{cd}$$

$$\Delta f_{cd} = 3{,}5 \cdot \sigma_{c2d}^{3/4} \cdot f_{cd}^{1/4} \qquad \text{for } \sigma_{c2d} > 0{,}6 f_{cd}$$

- Average value of increased strength $f_{cd,c}$ smeared over compression zone of section:

$$f_{cd,c} = f_{cd} + k_{conf,b} \cdot k_{conf,s} \cdot \Delta f_{cd}$$

- $k_{conf,b}$ and $k_{conf,s}$ given in Table 8.1 for Figure 8.3, a) to e)



N.B.: Effect of confinement on the strain limits in concrete may be considered according to Formulae (8.16) and (8.17) but exclude concrete areas outside confining reinforcement

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clauses 8.2 – 8.4 Ultimate limit states - EN 1992-1-1: Shear and punching shear

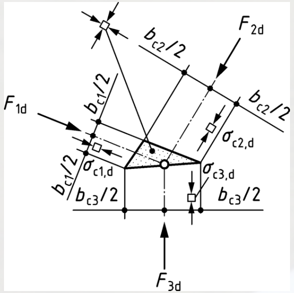
- Action effects and resistance: Consistently presented as shear stress.
- Detailed verification for members without shear reinforcement: New model "Critical-Shear-Crack-Theory (CSCT)".
- Members with shear reinforcement: Refined compression field model.
- Added "In-plane shear and transverse bending".
- Amended "Shear at interfaces", added case where reinforcement across the interface is anchored to develop only $\sigma_s < f_{yd}$.
- Amended interaction formulae for combined actions.

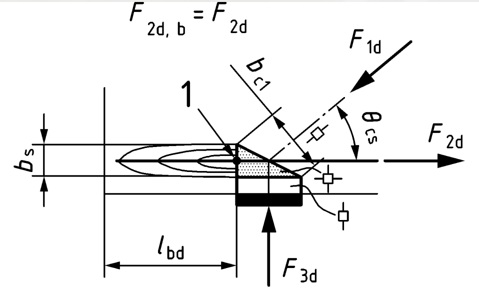
→ Presentations: *Aurelio Muttoni and Pedro Miguel / Miguel Angel Fernandez*

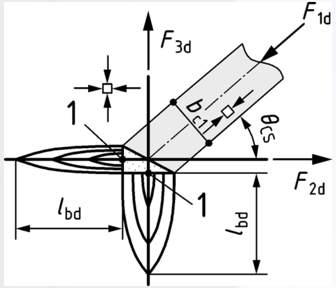
3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 8.5 Ultimate limit states - EN 1992-1-1: Design with strut-and-tie models and stress fields

- Verification of struts and compression fields:
- Verification of ties:
- Verification of nodes: C-C-C C-C-T C-T-T







→ Presentation: *Miguel Fernandez Ruiz*

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

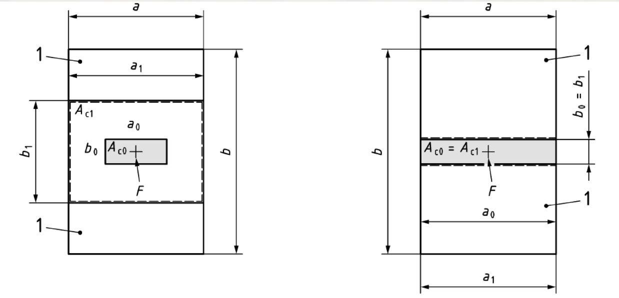
Clause 8.6 Ultimate limit states - EN 1992-1-1: Partially loaded areas

- Partially loaded areas without horizontal forces:

- Design resistance: $$\boxed{\sigma_{Rdu} = f_{cd}\sqrt{\frac{A_{c1}}{A_{c0}}} \leq \nu_{part} f_{cd}}$$ ν_{part} = 3,0 unless justified by refined analysis including tensile stresses due to load or restraint.

- Loaded area A_{c0}: a_0 x b_0

- New definition of contributing area A_{c1}: a_1 x b_1 where a_1 = a length of block parallel to a_0
$b_1 = \min\{b_0 + (a_1 - a_0); b\}$



a) 3-dimensional load distribution   b) 2-dimensional load distribution

- Options to consider beneficial effect of confinement reinforcement, and refined methods.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 9 Serviceability limit states - EN 1992-1-1: Cracking, deflections, vibrations

- Stress and crack width limits for appearance and for durability given in tables.
- Minimum reinforcement areas to avoid yielding.
- Refined control of cracking amended. Simplified control of cracking moved to Informative Annex S.
- Deflection control amended.
- Vibrations added.

→ Presentation: *Alejandro Perez*

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 10 & Annex E Fatigue - EN 1992-1-1: Simplified and refined methods

- Simplified verifications of reinforcing & prestressing steels, concrete under compression and under shear, shear at interfaces: Clause 10

- Refined methods (damage equivalent stresses; Palmgren-Miner rule): Annex E

  N.B.: Damage equivalent values for bridges → Annex K

→ Presentation: *Juan Carlos Lancha and Carlos Rios*

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 11 Detailing of reinforcement and PT tendons - EN 1992-1-1:

- Minimum mandrel diameter:

- Avoid damage to reinforcing steel:

— $\phi_{\mathrm{mand,min}} = 4\phi$ for $\phi \leq 16$ mm;

— $\phi_{\mathrm{mand,min}} = 7\phi$ for $\phi > 16$ mm.

- Avoid failure of concrete inside bend of bar:

$$\sigma_{\mathrm{sd}} \leq 0{,}65 f_{\mathrm{cd}} \frac{\phi_{\mathrm{mand}}}{\phi} + \frac{\sqrt{f_{\mathrm{ck}}}}{\gamma_C} \left(\frac{d_{\mathrm{dg}}}{\phi}\right)^{1/3} \left(\frac{c_{\mathrm{d}}}{\phi} + \frac{1}{2}\right) \left(k_{\mathrm{bend}} + 0{,}7 \cdot \frac{\phi_{\mathrm{mand}}}{\phi}\right)$$

  and conditions for which verification may be omitted

- Anchorages and laps. → Presentation: *John Cairns*

- Post-tensioning tendons: New recommendations for minimum radius of curvature and straight length of tendons adjacent to anchorages (fib MC 2010). Compliance with requirements of system documentation but not smaller than recommended values unless demonstrated by testing to relevant standard.

- Deviation forces due to curved tensile and compressive chords: New provisions.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 12 Detailing of members and particular rules - EN 1992-1-1:

- Specification of minimum reinforcement for validity of ULS design models
  in general and for $M_{Ed} \leq M_{cr}$

$$M_{\mathrm{R,min}}\,(N_{\mathrm{Ed,min}}) \geq M_{\mathrm{cr}}(N_{\mathrm{Ed,min}})$$

$$M_{\mathrm{Rd,min}}(N_{\mathrm{Ed}}) = k_{\mathrm{dc}} \cdot M_{\mathrm{Ed}}$$

- Detailing rules for members given in compact table format (beams, slabs, columns, walls and deep beams) – all NDPs since practice in NSBs varies widely.
- Tying systems for robustness of buildings (Clause 12.9).
- General provisions for supports, bearings, joints (Clause 12.10).

Table 12.1 (NDP) — Detailing requirements for reinforcement in beams

	Description	Symbol	Requirement
1	Minimum longitudinal reinforcement, in those parts of the section where tension may occur	$A_{s,min}$	12.2(2), see also 12.2(3), 12.2(6)
2	Minimum shear and transverse torsional reinforcement, when required. Minimum torsion reinforcement should be provided to the full perimeter including features not counted part of the thin walled section	$\rho_{w,min}$	12.2(4)
3	Minimum bottom reinforcement at inner supports taking account of unforeseen effects leading to positive moments at the support, e.g. unforeseen settlement, or load reversal due to explosion		0,25 $A_{s,req\ span}$
4	Minimum bottom reinforcement for end supports		0,25$A_{s,req\ span}$
5	Maximum longitudinal spacing of shear assemblies/stirrups[a]	$s_{l,max}$	0,75d $(1 + \cot\alpha)$
6	Maximum longitudinal spacing of bent-up bars[a]	$s_{bu,max}$	0,6d $(1 + \cot\alpha)$
7	Maximum transverse spacing of shear legs[a]	$s_{tr,max}$	0,75$d \leq 600$ mm
8	Minimum ratio of shear reinforcement in the form of stirrups with respect to the required reinforcement ratio (taking account of unforeseen effects e.g. compatibility torsion)	$\rho_{w,stir}$	$\geq 0{,}5\rho_{w,req}$
9	Minimum ratio of torsion reinforcement in the form of closed stirrups with respect to the required reinforcement ratio	$\rho_{w,stir}$	$\geq 0{,}2\rho_{w,req}$
10	Maximum spacing for torsion assemblies/stirrups (u defined in 8.3.2(2))	$s_{stir,max}$	$u/8 \leq \min\{b; h\}$
11	Minimum area and spacing of longitudinal surface reinforcement in beams with downstand ≥ 600 mm to avoid coarse cracks in SLS	$A_{s,web}$ $s_{l,surf,max}$	9.2.2(4) 300 mm
12	Minimum transverse reinforcement in flanges (those part of flanges where tension in the transverse direction may occur)	$A_{st,min}$	12.2(2) see 8.2.5, Figure 8.13

[a] These spacings are consistent with the shear model in 8.2.3. Where alternative models are used alternative spacings may be required.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 13 Additional rules for precast concrete elements & structures - EN 1992-1-1:

- Clause 13 corresponds mostly to Clause 10 of EN 1992-1-1:2004.
- Provisions for design & detailing of pre-tensioned tendons integrated into Clause 13. However, use of verification of shear resistance of precast members without shear reinforcement based on principal stress:

$$\sigma_{1\mathrm{Ed}}(y) \leq \frac{f_{\mathrm{ctk,0,05}}}{\gamma_{\mathrm{C}}}$$

$$\sigma_{1\mathrm{Ed}} = \frac{\sigma_{\mathrm{x,Ed}}(y)}{2} + \sqrt{\left(\frac{\sigma_{\mathrm{x,Ed}}(y)}{2}\right)^2 + \tau_{Ed}^2(y)}$$

  limited to effective depth ≤ 500 mm unless size effect is considered by refined analysis.
- Provisions for tying systems for robustness in buildings applicable to all buildings moved to Clause 12.9.
- General provisions for supports, bearings, joints moved to Clause 12.10.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Clause 14 Plain and lightly reinforced concrete structures - EN 1992-1-1:

- Clause 14 corresponds mostly to Clause 12 of EN 1992-1-1:2004
- Simplified design method for walls and columns modified to have creep explicitly considered in formula for Φ, and declared partial factor γ_{CE} = 1,20 assumed in formula:

$$N_{Rd} = b \cdot h \cdot f_{cd,pl} \cdot \Phi$$

$$\Phi = \frac{1 - \left(2{,}1 + 0{,}02\frac{l_0}{h}\right)\frac{e_{tot}}{h}}{1 + \left(\frac{l_0}{h}\right)^2 \left(0{,}9 + 6\frac{e_{tot}}{h}\right)\left(\frac{0{,}8 + \varphi_{eff}}{1000}\right)\left(\frac{f_{cd,pl}}{20}\right)^{0{,}6}}$$

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex C (normative) Requirements for materials - EN 1992-1-1:

- Properties of main materials (concrete, reinforcing steel, prestressing steel, prestressing systems) required for design are given in Clause 5.
- Annex C gives additional provisions for material properties with minimum or maximum values or an interval of values for which the design provisions of the Eurocode apply:
  - Concrete: Reference to EN 206;
  - Reinforcing steel: Fatigue stress range tested in air; minimum relative rib area; ratio “actual/nominal tensile strength”; bendability; strength of welds;
  - Prestressing steel: Fatigue stress range tested in air; bendability; relaxation; stress-corrosion resistance;
  - Couplers: Minimum capacity & elongation; maximum slip; resistance to fatigue in air;
  - Headed bars: Connection of heads to bar; size of head; resistance to fatigue in air;
  - Post-installed reinforcing steel systems: Required mean minimum bond strength.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex K (normative) Bridges - EN 1992-1-1 (replaces current EN 1992-2):

- Design provisions in Clauses 4 to 14 and Annexes A to S apply to bridges except for few clauses clearly identified in Annex K as "*shall not be applied*".
- In addition, integrated selected clauses from current EN 1992-2:
  - 2 clauses each for durability and serviceability;
  - Added provisions for fatigue verification using damage equivalent stress range;
  - Added minimum reinforcement rules to avoid brittle failure of bridges;
  - Added 3 clauses for precast segmental construction.
- In addition, added 4 clauses each for bridges with external or unbonded tendons, and for cable stayed, extradosed and suspension bridges.
- Confirmed that NDPs may be given different values for bridges than for other structures.
- Offer option to NSBs to give more restrictive provisions - for specified topics in specific clauses set-out in Annex K, in the form of NDPs - *intended for clauses expressed as permissions (i.e. 'may' clauses) only*.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex M (normative) Lightweight aggregate concrete structures - EN 1992-1-1:

- Provisions mostly identical or very similar to EN 1992-1-1:2004, Clause 12.
- Changes compared to normal weight concrete provisions are listed in Table M.2 by reference to each clause with a change
(*Note: only parts of Table M.2 shown here*).

Table M.2 — Special provisions for LWAC

Reference to original clause	Values and terms to be modified for lightweight aggregate concrete	Provisions and formulae for lightweight aggregate concrete
5.1.3(3)	Maximum compressive strength	$f_{ck} \leq 80$ MPa
Table 5.1	Mean value of concrete cylinder compressive strength f_{cm}	$f_{cm} = 17$ MPa for $f_{ck} = 12$ MPa; $f_{cm} = 22$ MPa for $f_{ck} = 16$ MPa; values given in Table 5.1 for $f_{ck} \geq 20$ MPa.
Table 5.1	Concrete tensile strength f_{ctm}, $f_{ctk,0,05}$, $f_{ctk,0,95}$	The tensile strength may be obtained by multiplying the values given in Table 5.1 by coefficient $\eta_{lw,fct}$ given in Table M.1.
5.1.4	Modulus of elasticity E_{cm}	An estimate of the mean values of the secant modulus E_{cm} may be obtained by multiplying the values for normal density concrete according to 5.1.4 by coefficient $\eta_{lw,Ec}$ given in Table M.1.
5.1.5(2), Table 5.2	Creep coefficient	The creep coefficient φ may be assumed equal to the value of normal density concrete multiplied by: — $1{,}3 \cdot \eta_{lw,Ec}$ for $f_{ck} \leq 16$ MPa; — $\eta_{lw,Ec}$ for $f_{ck} \geq 20$ MPa.
5.1.5(4), Table 5.3	Nominal total shrinkage values $\varepsilon_{cs,50y}$	Shrinkage values may be obtained by multiplying the value for normal density concrete in Table 5.3 by: — 1,5 for $f_{ck} \leq 16$ MPa; — 1,2 for $f_{ck} \geq 20$ MPa.
5.1.6(1)	Design value of concrete compressive strength f_{cd}	The influence of the increased brittleness of lightweight concrete on the design strength f_{cd} shall be accounted by replacing Formula (5.4) by : $\eta_{cc} = \left(\eta_{lw,fc}\frac{f_{ck,ref}}{f_{ck}}\right)^{1/3} \leq 1$ where coefficient $\eta_{lw,fc}$ is given in Table M.1
5.1.6(6)	Linear coefficient of thermal expansion	Unless more accurate information is available, the linear coefficient of thermal expansion may be taken equal to $8 \cdot 10^{-6}\ ^{\circ}C^{-1}$

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex N (informative) Recycled aggregate concrete structures - EN 1992-1-1:

- New design provisions not currently contained in EN 1992-1-1:2004.
- Reinforced concrete:
  - Substitution rate $\alpha_{RA} \leq 0{,}20$: Same properties as normal weight concrete without recycled aggregates;
  - Substitution rate $0{,}20 \leq \alpha_{RA} \leq 0{,}40$: Values of properties in Table N.1 or values determined by testing should be used;
  - Substitution rate $\alpha_{RA} > 0{,}40$: Values of properties in Table N.1 should be determined by testing using identified batch of aggregates.
- Prestressed concrete:
  - Substitution rate $0 \leq \alpha_{RA} \leq 0{,}20$: Values of properties in Table N.1 or values determined by testing should be used;
  - Substitution rate $\alpha_{RA} > 0{,}20$: Values of properties in Table N.1 should be determined by testing using identified batch of aggregates.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex N (informative) Recycled aggregate concrete structures - EN 1992-1-1:

- Changes compared to normal weight concrete and formulae to account for moderate substitution rates are listed in Table N.1 by reference to each clause with a change.

Reference to original clause	Values and terms to be modified for recycled aggregates concrete	Provisions and formulae for recycled aggregates concrete a)
Table 9.3	Simplified deflection control by span/depth-ratio	Span/depth ratios should be multiplied by the coefficient $1/(1 + 0.12 \cdot \alpha_{RA})$.
9.3.4(3)	General method for deflection calculations	$\zeta = 1 - \beta_{tRA}\left(\frac{\sigma_{sr}}{\sigma_s}\right)^2 \geq 0$ with $\beta_{tRA} = 1{,}0$ for a single short term loading and $\beta_{tRA} = 0{,}25$ for sustained loads or many cycles of repeated loading.
B.5(1)	Creep coefficient	Determine by testing if relevant. Alternatively the creep coefficient for basic and drying creep should be multiplied by a factor $\eta_{ccRA} = 1 + 0{,}6 \cdot \alpha_{RA}$ (high dispersion of the results).
B.6(1)	Shrinkage strain	Determine by testing if relevant. Alternatively the basic and drying shrinkages should be multiplied by a factor $\eta_{shRA} = 1 + 0{,}8 \cdot \alpha_{RA}$ (high dispersion of the results).

a In Formulae is α_{RA} the substitution rate of recycled concrete aggregates (varying from 0 to 1):

$$\alpha_{RA} = \frac{\text{quantity of fine and coarse recycled aggregates}}{\text{total quantity of aggregates}}$$

Table N.1 — Special provisions for recycled aggregates concrete

Reference to original clause	Values and terms to be modified for recycled aggregates concrete	Provisions and formulae for recycled aggregates concrete a)
5.1.6(5)	Density	$\rho_c = 2500 - 220\alpha_{RA}$
5.1.3(3)	Maximum compressive strength	$f_{ck} \leq 50$ MPa
Table 5.1	Concrete tensile strength f_{ctm}, $f_{ctk,0,05}$, $f_{ctk,0,95}$	Determine by testing if relevant. Alternatively may be used: $f_{ctm} = 0{,}3 \cdot f_{ck}^{2/3}$
5.1.4	Modulus of elasticity E_{cm}	Determine by testing if relevant. Alternatively may be used the following: $E_{cm} = \eta_{ERA} \cdot f_{cm}^{1/3}$ where $\eta_{ERA} = k_E \cdot (1 - 0{,}25 \cdot \alpha_{RA})$
5.1.5(2), Table 5.2	Creep coefficient	Determine by testing if relevant. Alternatively the creep coefficient for basic and drying creep should be multiplied by a factor $\eta_{cRA} = 1 + 0{,}6 \cdot \alpha_{RA}$.
5.1.5(4), Table 5.3	Shrinkage strain	Determine by testing if relevant. Alternatively the basic and drying shrinkages should be multiplied by a factor $\eta_{shRA} = 1 + 0{,}8 \cdot \alpha_{RA}$.
Table 6.3 (NDP), Table 6.4 (NDP)	Minimum clear cover $c_{min,dur}$ due to durability requirement	Determine ERC by testing if relevant. For concrete including recycled aggregate, the same minimum cover depth for durability $c_{min,dur}$ applies provided the material pertains the same exposure resistance class (ERC) as concrete including natural aggregate only. Adaptation of the limiting values and/or performance thresholds ensuring compliance with ERCs for concrete including recycled aggregate are given in EN 206 complemented by the provisions valid in the place of use. If the ERC is not determined, the values of $c_{min,dur}$ given in 6.5.2.2 should be increased by +5 mm in case of exposure classes XC2, XC3 and XC4, and by +10 mm in case of all XD/XS-exposure classes.
5.1.6(3)	Stress-strain relationship	Multiply in 5.1.6(3), Formulae (5.9) and (5.10) the values ε_{c1} and ε_{cu1} respectively, by $\eta_{\varepsilon c} = 1 + 0{,}33 \cdot \alpha_{RA}$: $\varepsilon_{c1}(‰) = \eta_{\varepsilon c}\left(0{,}7 f_{cm}^{\frac{1}{3}}\right) \leq 2{,}8$ ‰ $\varepsilon_{cu1}(‰) = \eta_{\varepsilon c}\left(2{,}8 + 14\left(1 - \frac{f_{cm}}{108}\right)^4\right) \leq 3{,}5$ ‰
8.2.1(4) 8.2.2(2)	Shear resistance of members not requiring design shear reinforcement	Shear strength without shear reinforcement: Multiply in 8.2.1(4), Formula (8.20) and in 8.2.2(2), Formula (8.27) by $\eta_\tau = 1 - 0{,}2 \cdot \alpha_{RA}$.

3. Evolution and key changes in Eurocode 2, EN 1992-1-1

Annex Q (normative) Stainless reinforcing steel - EN 1992-1-1:

- New design provisions not currently contained in EN 1992-1-1:2004.
- For ease-of-use, selected properties of stainless reinforcing steel permitted to be assumed identical to non-alloyed (carbon) reinforcing steel when effect on performance were considered negligible: Modulus of elasticity (ULS), coefficient of thermal expansion.
- Stress-strain diagram with inclined post-elastic branch used with strain limit $\varepsilon_{ud} \leq \varepsilon_{uk}/\gamma_S$ and a maximum stress of $k \cdot f_{0,2k}/\gamma_S$ (Note: ε_{uk} according to Table 5.5).
- Fatigue verification: Same design values as given in Clause 10 and Annex E for non-alloyed reinforcing (carbon) steel may be used for stainless reinforcing steel complying with requirements of Annex C.
- Cover for durability → Presentation: *Carmen Andrade*.

4. Conclusions

Review of objectives - EN 1992-1-1:

- Reduced number of clauses with NDPs of content of current EN 1992 by 52% to: 77.
- Introduced new NDPs for new content and materials: 24 $\rightarrow$ total number = 101.
- Reduced volume of contents of EN 1992-1-1:2004, EN 1992-2:2005 and EN 1992-3:2006 (total 343pp) by: 35%.
- Increased total volume of EN 1992-1-1:2023 with extended Clauses 1 - 3 and new content by 185pp: $\rightarrow$ total number = 409pp.
- Improved navigation in and ease-of-use of EN 1992-1-1:2023.
- Provided extensive background document to EN 1992-1-1:2023: 878pp.
- Further background documents by national mirror groups: See monographic issue published by Hormigon y Acero
- Conferences organised by national groups: See Eurocode Conference DIBt; ACHE

4. Conclusions

Conclusions:

- FV of FprEN 1992-1-1:2023 and FprEN 1992-1-2:2023 ended 22 June 2023 – both standards approved, publication expected in October 2023.
- Consider main objectives of Mandate M/515 achieved in terms of reducing number of NDPs and improving ease-of-use for both EN 1992-1-1 and EN 1992-1-2.
- Have up-to-date standard which covers sufficiently wide scope and provides sufficiently simple rules for design of new concrete structures.
- Have up-to-date standard which gives sufficiently advanced methods for verification of existing structures to avoid unnecessary strengthening and leaves adequate room for experienced designers to innovate and apply their expertise.
- Have introduced new topics which will support evolution in construction market and help improving sustainability of concrete structures.

Thank you for your attention

Hans R. Ganz