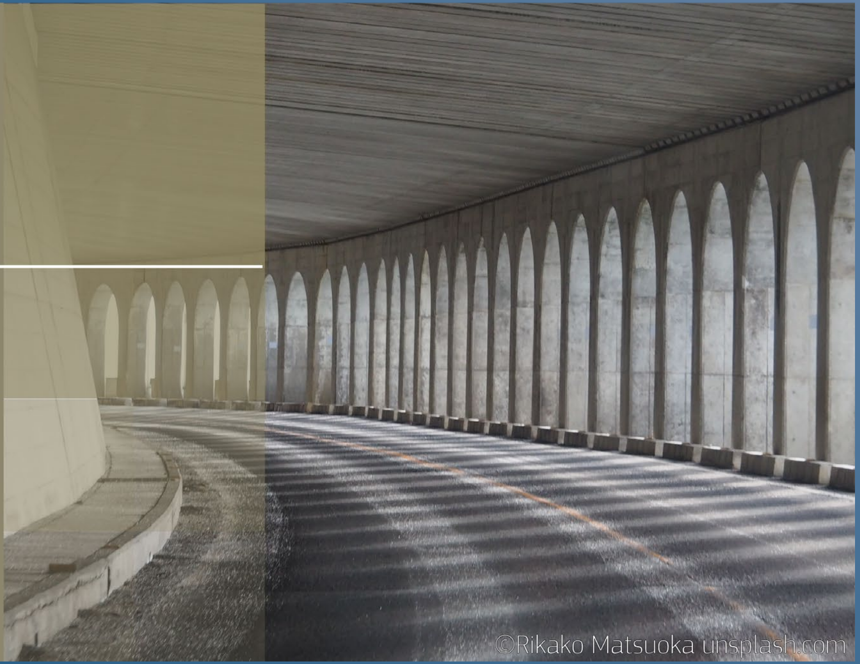
EUROCODES

EN 1992

Design of concrete structures



Hans Rudolf Ganz

EUROCODE Conference I Berlin I 24 May 2023

2023 EURO CODE

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1. Organisation of SC 2 for revision of Eurocode 2

	CEN/TC 250/SC 2 **Chair: Hans Rudolf Ganz** **Secretary: Damir Zorcec**	
CEN/TC 250/SC 2/WG 1 – EN 1992-1-1 **Convenor: Mikael Hallgren**	**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**
CEN/TC 250/SC 2/WG 1/TG 1 Leader: Konrad Zilch		**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		**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	**Ad-Hoc Group Detailing** **Convenor: Charles Goodchild**	
CEN/TC 250/SC 2/WG 1/TG 4 Leader: Josef Hegger	**Ad-Hoc Group Robustness** **Convenor: Aurelio Muttoni / Tony Jones**	
CEN/TC 250/SC 2/WG 1/TG 5 Leader: Fabienne Robert	**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		
CEN/TC 250/SC 2/WG 1/TG 7 Leader: Harald Müller		
CEN/TC 250/SC 2/WG 1/TG 8 Leader: Paul Jackson		
CEN/TC 250/SC 2/WG 1/TG 9 Leader: Giuseppe Mancini		
CEN/TC 250/SC 2/WG 1/TG 10 Leader: Mikael Hallgren		

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
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

2. 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.

2. 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 with provisions for general / regular use
- Annexes with provisions for special topics / less frequent use

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

Clause	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**

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

Sustainability - EN 1992-1-1:

- Reference age 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).

2. 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).			

2. 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. Properties for other, less frequently used materials are given in specific annexes

  - Concrete: Design strength for 12 MPa $\leq f_{ck} \leq$ 100 MPa

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

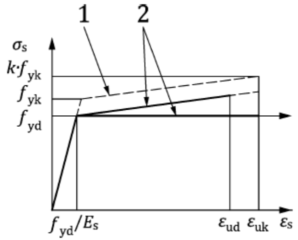
$$\eta_{cc} = \left(\frac{f_{ck,ref}}{f_{ck}}\right)^{\frac{1}{3}} \leq 1{,}0$$

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

  - Reinforcing steel: Extended strength classes up to B700

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.						



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

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

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

2. 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).
- Effect of exposure over time (t) considered with recognised models for carbonation and chloride ingress.
- Resistance of concrete is grouped into Exposure Resistance Classes (ERC):
  - for new types of concrete (without sufficient experience) or all types based on performance testing acc. to EN 12390-xy or national test procedures
  - for known types of concrete (with sufficient experience) can be determined based on deemed-to-satisfy rules

  $\rightarrow$ proof of conformity according to EN 206-100 (under preparation).
- ERC-Concept currently developed for corrosion of reinforcement in carbonated concrete and induced by chlorides (future extension to freeze-thaw, chemical attack, etc.).

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

Clause 6 Durability and concrete cover - EN 1992-1-1 / Exposure-Resistance Classes ERC:

→ Minimum concrete cover for Classes XRC to limit corrosion of reinforcement in carbonated concrete at end of service design life to small, acceptable value: $c_{min} \geq c_{min,dur}$

Table 6.3 (NDP) — Minimum concrete cover $c_{min,dur}$ for carbon reinforcing steel — Carbonation

ERC	Exposure class (carbonation)							
	XC1		XC2		XC3		XC4	
	Design service life (years)							
	50	100	50	100	50	100	50	100
XRC 0,5	10	10	10	10	10	10	10	10
XRC 1	10	10	10	10	10	15	10	15
XRC 2	10	15	10	15	15	25	15	25
XRC 3	10	15	15	20	20	30	20	30
XRC 4	10	20	15	25	25	35	25	40
XRC 5	15	25	20	30	25	45	30	45
XRC 6	15	25	25	35	35	55	40	55
XRC 7	15	30	25	40	40	60	45	60

NOTE 1 XRC classes for resistance against corrosion induced by carbonation are derived from the carbonation depth [mm] (characteristic value 90 % fractile) assumed to be obtained after 50 years under reference conditions (400 ppm CO_2 in a constant 65 %-*RH* environment and at 20 °C). The designation value of XRC has the dimension of a carbonation rate [mm/√(years)].

NOTE 2 The recommended minimum concrete cover values $c_{min,dur}$ assume execution and curing according to EN 13670 with at least execution class 2 and curing class 2.

NOTE 3 The minimum covers can be increased by an additional safety element $\Delta c_{dur,\gamma}$ considering special requirements (e.g. more extreme environmental conditions).

→Table with concrete cover is NDP (reliability index: $\beta \sim 1{,}5$)

→ Similar table for Classes XRDS to limit corrosion of reinforcement induced by chlorides

Design target at end of design service life

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

Clause 6 Durability and concrete cover - EN 1992-1-1 / Verification by designer:

→ **Minimum ERC** as a function of Exposure Class of member, design service life, execution (inspection and curing classes) and chosen concrete cover; or

→ **Minimum concrete cover** as a function of Exposure Class of member, design service life, execution (inspection and curing classes) and specified ERC.

Table 6.3(NDP) — Minimum concrete cover $c_{min,dur}$ for carbon steel — Carbonation

ERC	Exposure class (carbonation)							
	XC1		XC2		XC3		XC4	
	Design service life (years)							
	50	100	50	100	50	100	50	100
XRC 0,5	10	10	10	10	10	10	10	10
XRC 1	10	10	10	10	10	15	10	15
XRC 2	10	15	10	15	15	25	15	25
XRC 3	10	15	15	20	20	30	20	30
XRC 4	10	20	15	25	25	35	25	40
XRC 5	15	25	20	30	25	45	30	45
XRC 6	15	25	25	35	35	55	40	55
XRC 7	15	30	25	40	40	60	45	60

NOTE 1 The designation of XRC classes for resistance against corrosion induced by carbonation is derived from the carbonation depth [mm] (characteristic value 90 % fractile) assumed to be obtained after 50 years under reference conditions (400 ppm CO_2 in a constant 65 %-*RH* environment and at 20 °C). XRC has the dimension of a carbonation rate [mm/√(years)].

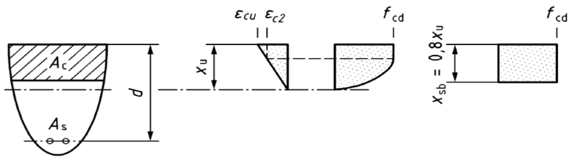
NOTE 2 The recommended minimum concrete cover values $c_{min,dur}$ assume execution and curing according to EN 13670 with at least Execution Class 2 and Curing Class 2.

NOTE 3 The minimum covers can be increased by an additional safety element $\Delta c_{dur,\gamma}$ considering special requirements (e.g. more extreme environmental conditions).

2. 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

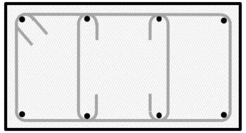
- Simplified strain distributions with unique values ε_{c2} and ε_{cu} for all concrete strengths, optional consideration of confined concrete.

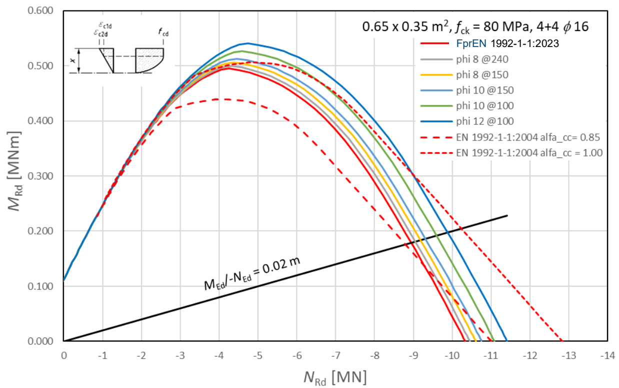


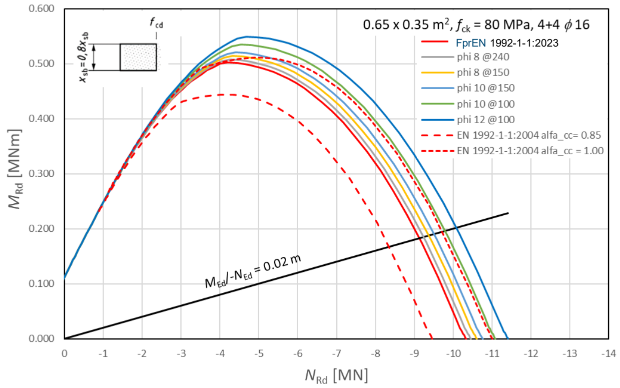
$$f_{cd} = \eta_{cc} \cdot k_{tc} \frac{f_{ck}}{\gamma_C}$$

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

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







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

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

Clause 8 Ultimate limit states - EN 1992-1-1: Shear - General

- Action effects: Consistently presented as shear stress

Beams $$\tau_{Ed} = \frac{V_{Ed}}{b_w \cdot z}$$

Slab $$\tau_{Ed} = \frac{v_{Ed}}{z}$$

- Detailed verification of shear resistance may be omitted: $$\tau_{Rdc,min} = \frac{11}{\gamma_V} \cdot \sqrt{\frac{f_{ck}}{f_{yd}} \cdot \frac{d_{dg}}{d}}$$

N.B.: Consideration of size effect d_{dg} / d

d_{dg} = 16 mm + $D_{lower} \leq$ 40 mm for ($f_{ck} \leq$ 60 MPa) or
d_{dg} = 16 mm + D_{lower} $(60/f_{ck})^2 \leq$ 40 mm for ($f_{ck} >$ 60 MPa)

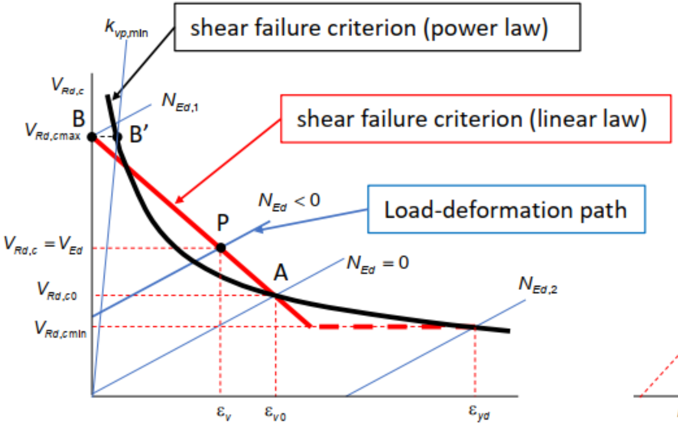
Clause 8 Ultimate limit states - EN 1992-1-1: Shear in members not requiring shear reinforcement

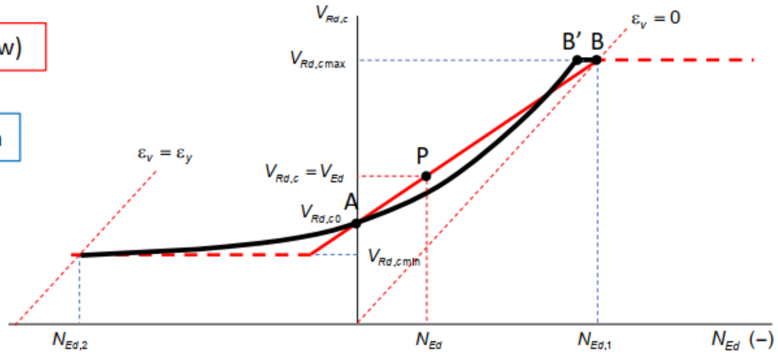
- Critical-Shear-Crack-Theory (CSCT) model
  - power law for detailed verification to 8.2.2(2)-(4) for tension & compression axial forces
  - linear law as alternative for compression axial force to 8.2.2(5).

$$\tau_{Rd,c} = \frac{0{,}66}{\gamma_V} \cdot \left(100\rho_l \cdot f_{ck} \cdot \frac{d_{dg}}{d}\right)^{\frac{1}{3}} \geq \tau_{Rdc,min}$$

$$a_v = \sqrt{\frac{a_{cs}}{4} \cdot d} \qquad a_{cs} = \left|\frac{M_{Ed}}{V_{Ed}}\right| \geq d$$

Effect of axial force: (d or a_v) x $k_{vp} = 1 + \frac{N_{Ed}}{|V_{Ed}|}\frac{d}{3 \cdot a_{cs}} \geq 0{,}1$





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

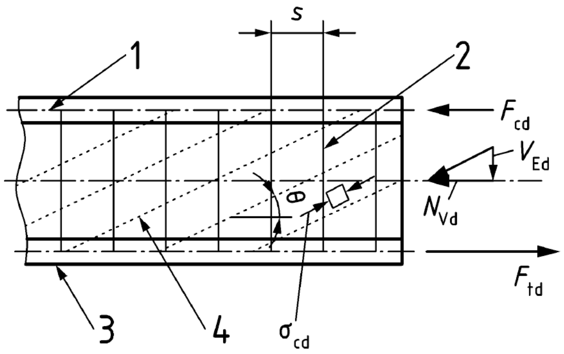
Clause 8 Ultimate limit states - EN 1992-1-1: Shear in members requiring shear reinforcement

- Compression field model

$$\tau_{Rd,sy} = \rho_w \cdot f_{ywd} \cdot \cot\theta \qquad \rho_w = \frac{A_{sw}}{b_w \cdot s}$$

and

$$\sigma_{cd} = \tau_{Ed}(\cot\theta + \tan\theta) \leq \nu \cdot f_{cd}$$



$$1 \leq \cot\theta \leq \cot\theta_{min}$$

— $\cot\theta_{min} = 2{,}5$ for ordinary reinforced members without axial force;

— $\cot\theta_{min} = 3{,}0$ for members subjected to significant axial compressive force (average axial compressive stress $\geq |3\text{ MPa}|$) and provided that the depth of the compression chord x determined from a sectional analysis according to 8.1.1 and 8.1.2 is less than $0{,}25d$. Interpolated values between 2,5 and 3,0 may be adopted for intermediate cases. For very high compressive forces ($x > 0{,}25d$), (11) can apply;

— $\cot\theta_{min} = 2{,}5 - 0{,}1 \cdot N_{Ed}/|V_{Ed}| \geq 1{,}0$ for members subjected to axial tension.

N.B.: Compression field inclinations lower than θ_{min} may be adopted for reinforcement of ductility classes B and C:

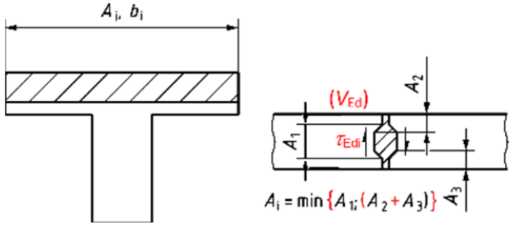
$$\nu = \frac{1}{1{,}0 + 110 \cdot (\varepsilon_x + (\varepsilon_x + 0{,}001) \cdot \cot^2\theta)} \leq 1{,}0$$

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

Clause 8 Ultimate limit states - EN 1992-1-1: Shear at interfaces

- Without and with reinforcement across the interface anchored for f_{yd}

$$\tau_{Rdi} = c_{v1}\frac{\sqrt{f_{ck}}}{\gamma_C} + \mu_v\,\sigma_n + \rho_i\,f_{yd}\,(\mu_v\,\sin\alpha + \cos\alpha) \leq 0{,}30\,f_{cd} + \rho_i\,f_{yd}\,\cos\alpha$$



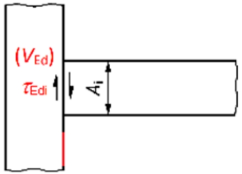


Table 8.2 — Coefficients depending on the roughness of the surface

	Formula (8.76)		Formula (8.77)		
Surface roughness	c_{v1}	μ_v	c_{v2}	k_v	k_{dowel}
very smooth	0,01[a]	0,5	0	0	1,5
smooth	0,08[a]	0,6	0	0,5	1,1
rough	0,15[a]	0,7	0,08[a]	0,5	0,9
very rough	0,19[a]	0,9	0,15[a]	0,5	0,9
keyed[b]	0,37	0,9	—	—	—

[a] When the interface is subjected to tensile stresses caused by external axial force in perpendicular direction: $c_{v1} = 0$ and $c_{v2} = 0$.

[b] The factors for keyed interfaces shall be applied for the area of each key considering its concrete strength.

N.B.: Similar formula given for reinforcement across interface which is anchored for $\sigma_{sd} < f_{yd}$

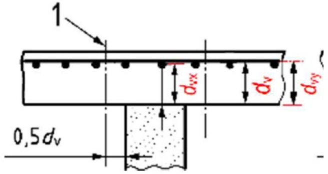
$$\tau_{Rdi} = c_{v2}\frac{\sqrt{f_{ck}}}{\gamma_C} + \mu_v\,\sigma_n + k_v\,\rho_i\,f_{yd}\,\mu_v + k_{dowel}\,\rho_i\,\sqrt{f_{yd}\cdot f_{cd}} \leq 0{,}25 f_{cd}$$

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

Clause 8 Ultimate limit states - EN 1992-1-1: Punching

- Critical-Shear-Crack-Theory (CSCT) model for slabs without shear reinforcement
- Action effects at perimeter $0{,}5d_v$:

$$\tau_{Ed} = \beta_e \frac{V_{Ed}}{b_{0,5} \cdot d_v} \qquad d_v = \frac{d_{vx} + d_{vy}}{2}$$



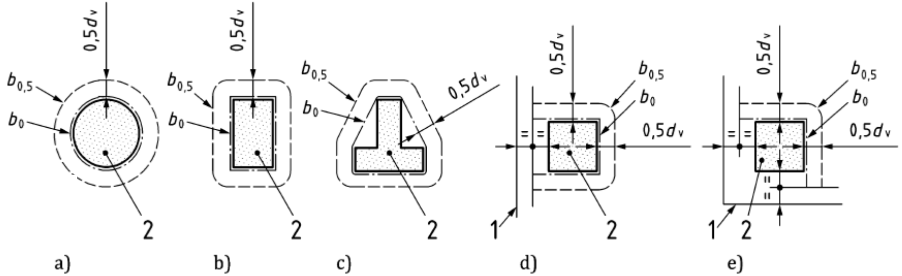


Table 8.3 — Coefficients β_e accounting for concentrations of the shear forces

Support	Approximated	Refined[a]	
internal columns	$\beta_e = 1{,}15$	$\beta_e = 1 + 1{,}1\frac{e_b}{b_b} \geq 1{,}05$	where $e_b = \sqrt{e_{b,x}^2 + e_{b,y}^2}$
edge columns	$\beta_e = 1{,}4$		where $e_b = 0{,}5\lvert e_{b,x}\rvert + \lvert e_{b,y}\rvert$
corner columns	$\beta_e = 1{,}5$		where $e_b = 0{,}27(\lvert e_{b,x}\rvert + \lvert e_{b,y}\rvert)$
ends of walls	$\beta_e = 1{,}4$		
corners of walls	$\beta_e = 1{,}2$		

- Detailed verification of shear strength may be omitted in control perimeter $b_{0,5}$:

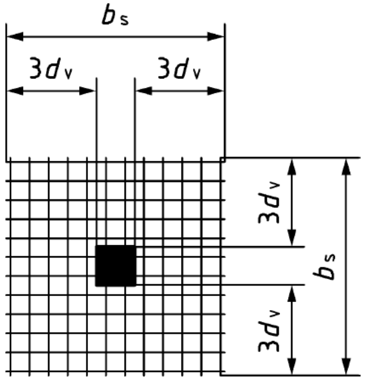
$$\tau_{Ed} \leq \tau_{Rdc,min} = \frac{11}{\gamma_V} \cdot \sqrt{\frac{f_{ck}}{f_{yd}} \cdot \frac{d_{dg}}{d}}$$

Clause 8 Ultimate limit states - EN 1992-1-1: Punching

- Slabs without shear reinforcement

$$\tau_{Rd,c} = \frac{0{,}6}{\gamma_V} \cdot k_{pb} \left(100\, \rho_l \cdot f_{ck} \cdot \frac{d_{dg}}{d_v}\right)^{\frac{1}{3}} \leq \frac{0{,}5}{\gamma_V} \cdot \sqrt{f_{ck}}$$

$$\rho_l = \sqrt{\rho_{l,x} \cdot \rho_{l,y}}$$



k_{pb}: punching shear enhancement coefficient

$$1 \leq k_{pb} = 3{,}6 \sqrt{1 - \frac{b_0}{b_{0,5}}} \leq 2{,}5$$

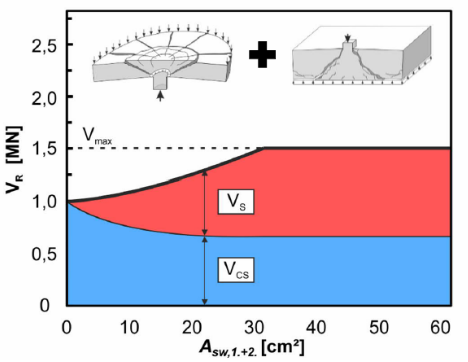
$$a_{pd} = \sqrt{\frac{a_p}{8} \cdot d_v}$$

- Slabs with shear reinforcement:

$$\tau_{Rd,cs} = \eta_c \cdot \tau_{Rd,c} + \eta_s \cdot \rho_w \cdot f_{ywd} \geq \rho_w \cdot f_{ywd}$$

$$\rho_w = \frac{A_{sw}}{s_r \cdot s_t}$$

$$\eta_c = \frac{\tau_{Rd,c}}{\tau_{Ed}} \qquad \eta_s = \frac{d_v}{150\phi_w} + \left(15 \frac{d_{dg}}{d_v}\right)^{1/2} \cdot \left(\frac{1}{\eta_c \cdot k_{pb}}\right)^{3/2} \leq 0{,}8$$



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

Clause 8 Ultimate limit states - EN 1992-1-1: Design with strut-and-tie models and stress fields

- Verification of struts and compression fields:

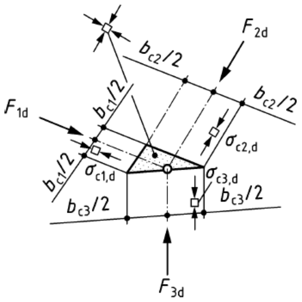
$$\sigma_{cd} \leq \nu \cdot f_{cd}$$

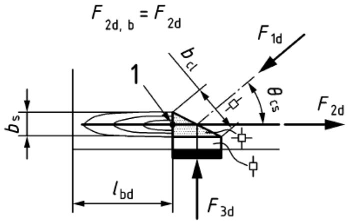
— $20° \leq \theta_{cs} < 30°$ $\nu = 0{,}4$
— $30° \leq \theta_{cs} < 40°$ $\nu = 0{,}55$
— $40° \leq \theta_{cs} < 60°$ $\nu = 0{,}7$
— $60° \leq \theta_{cs} < 90°$ $\nu = 0{,}85$

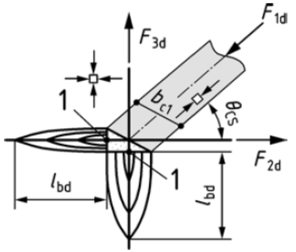
- Verification of ties:

$$F_{td} \leq F_{Rd} = A_s \cdot f_{yd} + A_p \cdot f_{pd}$$

- Verification of nodes: C-C-C C-C-T C-T-T







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

Clause 9 Serviceability limit states - EN 1992-1-1: Crack control

- Following limits apply if control of crack width is required:

Table 9.1 (NDP) — Verifications, stress and crack width limits for appearance

Verification	Calculation of minimum reinforcement according to 9.2.2	Verification of crack width according to 9.2.3	Verification of reinforcement stresses to avoid yielding at SLS
Combination of actions for calculating σ_s	Cracking forces according to 9.2.2	Quasi-permanent combination of actions	Characteristic combination of actions
Limiting value of crack width $w_{lim,cal}$ or stress σ_s	$\sigma_s \leq f_{yk}$	$w_{lim,cal} = 0{,}4$ mm $\sigma_s \leq f_{yk}$	$\sigma_s \leq 0{,}8 f_{yk}$ $\sigma_p \leq 0{,}8 f_{pk}$
NOTE Crack widths are verified at the member surface unless the National Annex gives a different location.			

Table 9.2 (NDP) — Verifications, stress and crack width limits for durability

Exposure Class	Reinforced members and prestressed members without bonded tendons and with bonded tendons with Protection Levels 2 or 3 according to 5.4.1(4)		Prestressed members with bonded tendons with Protection Level 1 according to 5.4.1(4) and pretensioned members.		
	combination of actions		combination of actions		
	quasi-permanent	characteristic	quasi-permanent	frequent	characteristic
X0, XC1	-	-	-	$w_{lim,cal}$= 0,2 mm · k_{surf}	-
XC2, XC3, XC4	$w_{lim,cal}$ = 0,3 mm · k_{surf}		Decom-pression [b]	$w_{lim,cal}$ = 0,2 mm · k_{surf}	
XD1, XD2, XD3 XS1, XS2, XS3		$\sigma_c \leq 0{,}6 f_{ck}$ [a,c]	-	Decompression[b]	$\sigma_c \leq 0{,}6 f_{ck}$ [a,c]
XF1, XF3 XF2, XF4	-				

NOTE 1 Crack widths are verified at the member surface unless the National Annex gives a different location..

NOTE 2 The factor k_{surf} considers the difference between an increased crack width at the member surface and the required mean crack width according to durability performance of the minimum cover: $1{,}0 \leq k_{surf} = c_{act}/(10 \text{ mm} + c_{min,dur}) \leq 1{,}5$.

c_{act} is a specified actual cover $\geq c_{nom}$ due to detailing or execution reasons.

[a] This limitation in serviceability conditions is not necessary for stresses under bearings, partially loaded areas and plates of headed bars.

[b] The decompression limit requires that all parts of the bonded tendons or duct lie at least 25 mm within concrete in compression. The decompression check is only relevant in the direction of the prestressed reinforcement.

[c] The compressive stress σ_c may be increased to $0{,}66 f_{ck}$ if the cover is increased by 10 mm or confinement by transverse reinforcement is provided.

- Refined control of cracking - amended:

NDP

Effect of curvature

$$w_{k,cal} = k_w \, k_{1/r} \, s_{r,m,cal}(\varepsilon_{sm} - \varepsilon_{cm})$$

$$s_{r,m,cal} = 1{,}5 \cdot c + \frac{k_{fl} \cdot k_b}{7{,}2} \cdot \frac{\phi}{\rho_{p,eff}} \leq \frac{1{,}3}{k_w}(h - x)$$

$$\varepsilon_{sm} - \varepsilon_{cm} = \frac{\sigma_s - k_t \frac{f_{ct,eff}}{\rho_{p,eff}}(1 + \alpha_e \rho_{p,eff})}{E_s} \geq (1 - k_t)\frac{\sigma_s}{E_s}$$

Simplified control of cracking moved to Informative Annex

Note: Crack widths are verified at the member surface unless the National Annex gives a different location
→ Level of reinforcement: $k_{1/r}$ = 1,0 ; c = 0

Clause 10 Fatigue - EN 1992-1-1: Simplified methods

- Reinforcing & prestressing steels:

a) reinforcing steel bars (for bent bars footnote a) of Table E.1 (NDP) should be applied):

— $\Delta\sigma_{sd} \leq 90$ MPa unwelded reinforcing bars $\phi \leq 12$ mm;

— $\Delta\sigma_{sd} \leq 73$ MPa unwelded reinforcing bars $\phi > 12$ mm;

— $\Delta\sigma_{sd} \leq 40$ MPa butt and tack welded reinforcing bars $\phi \leq 12$ mm;

— $\Delta\sigma_{sd} \leq 30$ MPa butt and tack welded reinforcing bars $\phi > 12$ mm;

— $\Delta\sigma_{sd} \leq 19$ MPa couplers.

b) prestressing steel for pre-tensioning:

— $\Delta\sigma_{pd} \leq 95$ MPa.

c) prestressing steel for post-tensioning:

— $\Delta\sigma_{pd} \leq 95$ MPa single strands in plastic ducts;

— $\Delta\sigma_{pd} \leq 80$ MPa straight tendons and curved tendons in plastic ducts;

— $\Delta\sigma_{pd} \leq 55$ MPa curved tendons in steel ducts.

NOTE These limits for the design stress ranges (including partial factor γ_{Ff} according to EN 1990) in the reinforcement are based on the S-N curves in Tables E.1 (NDP) and E.2 (NDP) assuming 10^8 load cycles and $\gamma_S = 1{,}15$. Modification of values in Tables E.1 (NDP) and E.2 (NDP) will result in changes of the limits given above.

If limits are not satisfied, refined methods may be used (damage equivalent stresses; Palmgren-Miner rule) → Annex E

- Concrete:

Compression

$$\frac{|\sigma_{cd,max}|}{f_{cd,fat}} \leq 0{,}5 + 0{,}45\frac{|\sigma_{cd,min}|}{f_{cd,fat}} \leq 0{,}90$$

$$f_{cd,fat} = \beta_{cc}(t_0) \cdot \frac{f_{ck}}{\gamma_C} \cdot \eta_{cc,fat}$$

Shear

for $\tau_{Ed,min}/\tau_{Ed,max} \geq 0$:

$$\frac{|\tau_{Ed,max}|}{\tau_{Rd,c}} \leq 0{,}5 + 0{,}45\frac{|\tau_{Ed,min}|}{\tau_{Rd,c}} \leq 0{,}90$$

for $\tau_{Ed,min}/\tau_{Ed,max} < 0$:

$$\frac{|\tau_{Ed,max}|}{\tau_{Rd,c}} \leq 0{,}5 - \frac{|\tau_{Ed,min}|}{\tau_{Rd,c}}$$

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

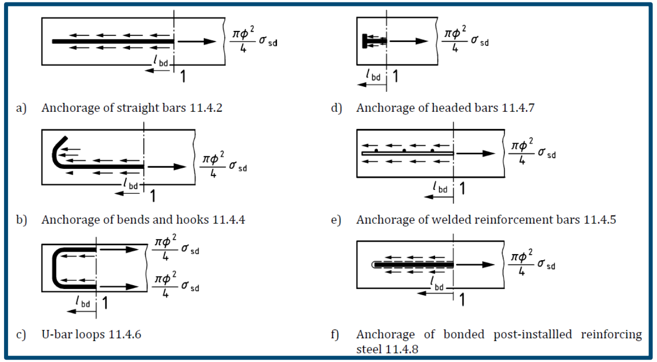
Clause 11 Detailing of reinforcement and PT tendons - EN 1992-1-1:

- Anchorage length of straight bars is given for parameters $\sigma_{sd} = f_{yd}$ and $c_d = 1{,}5\phi$ and good bond conditions in Table 11.1. For general cases, Formula (11.3) applies:

Table 11.1 (NDP) — Anchorage length of straight bars divided by diameter l_{bd}/ϕ

ϕ [mm]	Anchorage length l_{bd}/ϕ							
	f_{ck}							
	20	25	30	35	40	45	50	60
≤ 12	47	42	38	36	33	31	30	27
14	50	44	41	38	35	33	31	29
16	52	46	42	39	37	35	33	30
20	56	50	46	42	40	37	35	32
25	60	54	49	46	43	40	38	35
28	63	56	51	47	44	42	40	36
32	65	58	53	49	46	44	41	38

NOTE The values of Table 11.1 (NDP) are derived from Formula (11.3).



$$l_{bd} = k_{lb} \cdot k_{cp} \cdot \phi \cdot \left(\frac{\sigma_{sd}}{435}\right)^{n_\sigma} \cdot \left(\frac{25}{f_{ck}}\right)^{\frac{1}{2}} \cdot \left(\frac{\phi}{20}\right)^{\frac{1}{3}} \cdot \left(\frac{1{,}5\phi}{c_d}\right)^{\frac{1}{2}} \geq 10\phi \qquad (11.3)$$

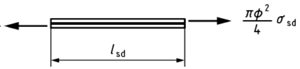
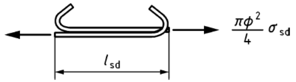
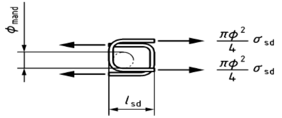
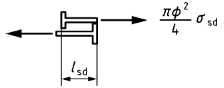
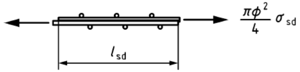
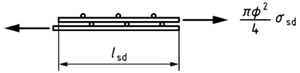
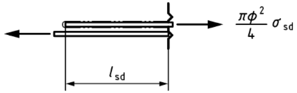
NDPs: $k_{lb} = 50$; $n_\sigma = 1{,}5$
Good bond: $k_{cp} = 1{,}0$
Poor bond: $k_{cp} = 1{,}2$

- Various methods of anchoring bars may be used with corresponding reduction of anchorage length compared with straight bars.

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

- Lap length of straight bars
  $l_{sd} = k_{ls} \times l_{bd}$ with $k_{ls} = 1{,}2$ (NDP)
- Various methods of lapping bars may be used with design lap length according to Table 11.3
- Away from plastic hinge regions:
  - laps with 100% of bars in tension
- In plastic hinge regions:
  - confinement reinforcement; or
  - staggering; or
  - design for $1{,}2\sigma_{sd}$

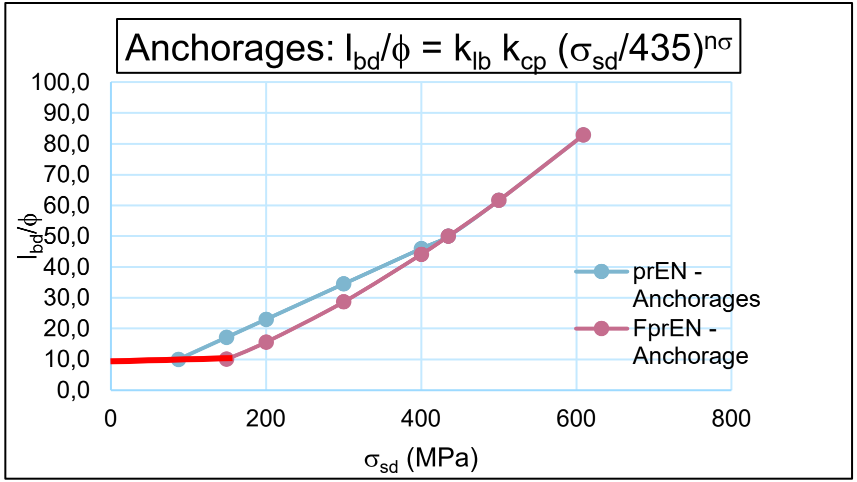
Table 11.3 — Types of laps and design lap lengths l_{sd}

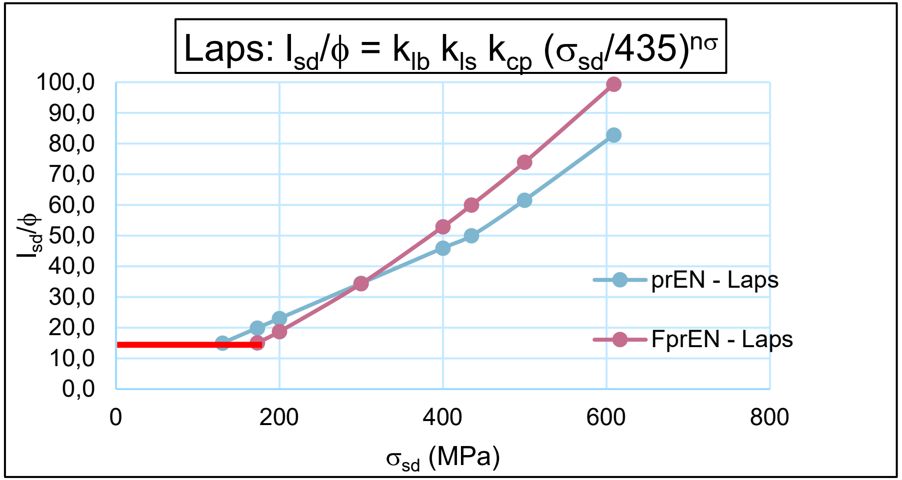
Type of lap splice		Design lap length l_{sd}	
		Tension laps	Compression laps
	straight bars	$l_{sd} = k_{ls} \cdot l_{bd} \geq 15\phi$ where l_{bd} is calculated according to 11.4.2, see also 11.5.3	
	bends and hooks (tension only)	$l_{sd} = k_{ls} \cdot l_{bd} \geq 15\phi$ where l_{bd} is calculated according to 11.4.4	—
	loops (tension only)	l_{sd} is calculated according to 11.5.4, with the limit $l_{sd} \geq \phi_{mand} + 4\phi$	—
	headed bars	l_{sd} is calculated according to 11.5.5	
	intermeshed fabric	$l_{sd} = k_{ls} \cdot l_{bd} \geq \max\{15\phi; 250\text{ mm}\}$ where l_{bd} is calculated according to 11.4.5	
	layered fabric		
	bonded post-installed reinforcement	$l_{sd,pi} = k_{ls} \cdot l_{bd,pi} \geq 15\phi \cdot \alpha_{lb}$ where $l_{bd,pi}$ is calculated according to 11.4.8	

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

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

- Comparison of anchorage and lap lengths of FprEN 1992-1-1:2023 with prEN 1992-1-1:2021.





2. 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 design models in general and for $M_{Ed} \leq M_{cr}$

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

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

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

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 + cotα)
6	Maximum longitudinal spacing of bent-up bars[a]	$s_{bu,max}$	0,6d (1 + cotα)
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.

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

Annex K Bridges - EN 1992-1-1:

- Design provisions in Clauses 4 to 14 and Annexes A to S apply to bridges except for few clauses clearly identified in Annex K.
- Added 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 4 clauses each for bridges with external or unbonded tendons, and for cable stayed, extradosed and suspension bridges.
- Added 3 clauses for precast segmental construction.
- Clarified that NDPs may be given different values for bridges than for buildings.
- Offer option to NSBs to give more restrictive provisions as NDPs - for specific topics in specific clauses and for permissions (i.e. ‘may’ clauses) only.

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

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: 25 → total number = 102.
- 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 FprEN 1992-1-1:2023 with new content by 185pp: → total number = 409pp.
- Provided extensive background document to FprEN 1992-1-1:2023: 878pp.
- Improved navigation in and ease-of-use of FprEN 1992-1-1:2023.

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

General - EN 1992-1-2:

- Harmonised structure of fire part in line with other materials.
- Improved simplified design methods and added analytical determination of temperature profiles.
- Ensured consistency between design provisions in tabulated design data (Clause 6), simplified design methods (Clause 7) and advanced design methods (Clause 8).
- Introduced new topics: Steel-fibre reinforced concrete structures and recycled aggregates concrete structures.
- Added specific rules for spalling of concrete.

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

Review of objectives - EN 1992-1-2:

- Reduced number of NDPs of EN 1992-1-2:2004 by 88% to: 2.
- Introduced new NDPs for new content and materials: 2 $\rightarrow$ total number = 4.
- Reduced volume of content of EN 1992-1-2:2004 (total 97pp) by: $>$ 30%.
- Reduced volume of FprEN 1992-1-2:2023 including new content by 6% to: 91pp.
- Provided extensive background document to FprEN 1992-1-2:2023: 388pp.
- Reduced number of alternative design methods.
- Improved navigation in and ease-of-use of FprEN 1992-1-2:2023.

4. Conclusions

Conclusions:

- FV of FprEN 1992-1-1:2023 and FprEN 1992-1-1:2023 ends 22 June 2023.
- Consider main objectives of Mandate M/515 achieved in terms of reducing number of NDPs and improving ease-of-use for both FprEN 1992-1-1 and FprEN 1992-1-2.
- Failed with objective to restrict volume of FprEN 1992-1-1 to ~ 250 pages mainly due to volume of new topics/materials and extent of Clauses 1-3.
- 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.

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