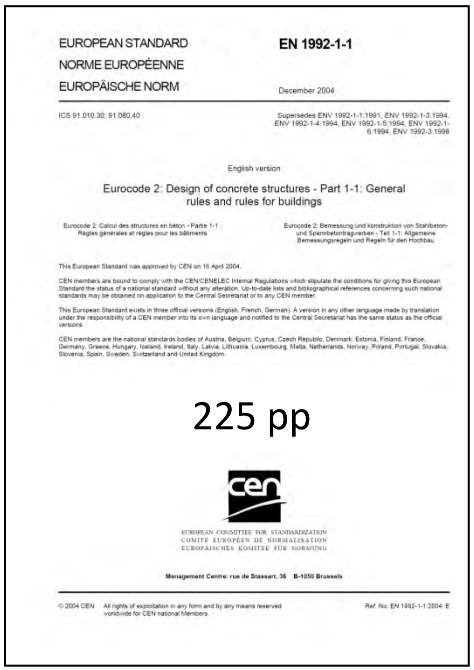
Evolutions in the Eurocodes for Concrete Structures

Hans Rudolf Ganz
Chairman CEN/TC 250/SC 2
(Eurocode 2)

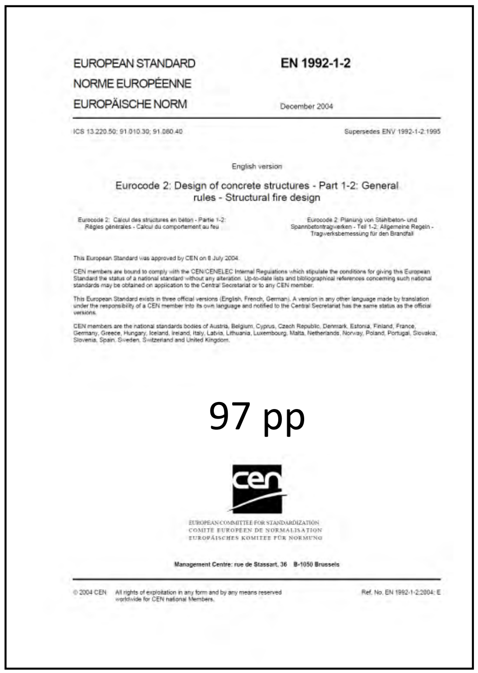
Contents

1. Introduction

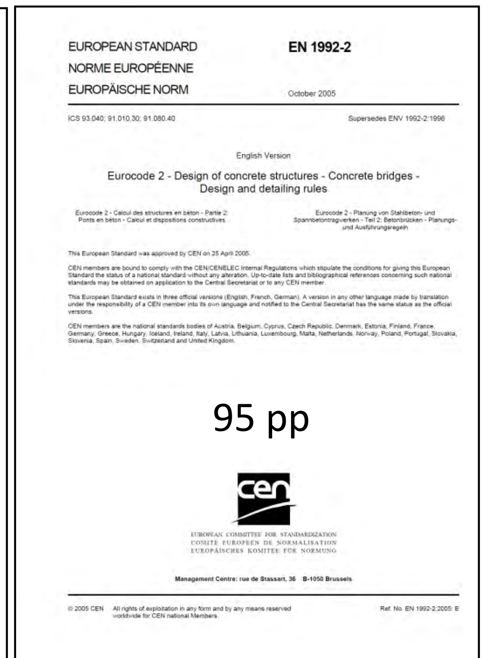
- Eurocode 2 = EN 1992-1-1; EN 1992-1-2; EN 1992-2; EN 1992-3
- Plus National Annexes


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 1992-1-1
December 2004
ICS 91.010.30; 91.080.40
Supersedes ENV 1992-1-1:1991, ENV 1992-1-3:1994, ENV 1992-1-4:1994, ENV 1992-1-5:1994, ENV 1992-1-6:1994, ENV 1992-3:1998
English version
Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

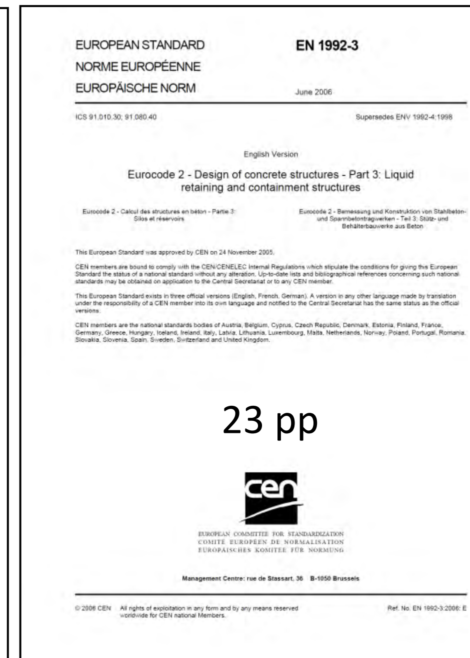
225 pp


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 1992-1-2
December 2004
ICS 13.220.50; 91.010.30; 91.080.40
Supersedes ENV 1992-1-2:1995
English version
Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design

97 pp


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 1992-2
October 2005
ICS 93.040; 91.010.30; 91.080.40
Supersedes ENV 1992-2:1996
English Version
Eurocode 2 - Design of concrete structures - Concrete bridges - Design and detailing rules

95 pp


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM
EN 1992-3
June 2006
ICS 91.010.30; 91.080.40
Supersedes ENV 1992-4:1998
English Version
Eurocode 2 - Design of concrete structures - Part 3: Liquid retaining and containment structures

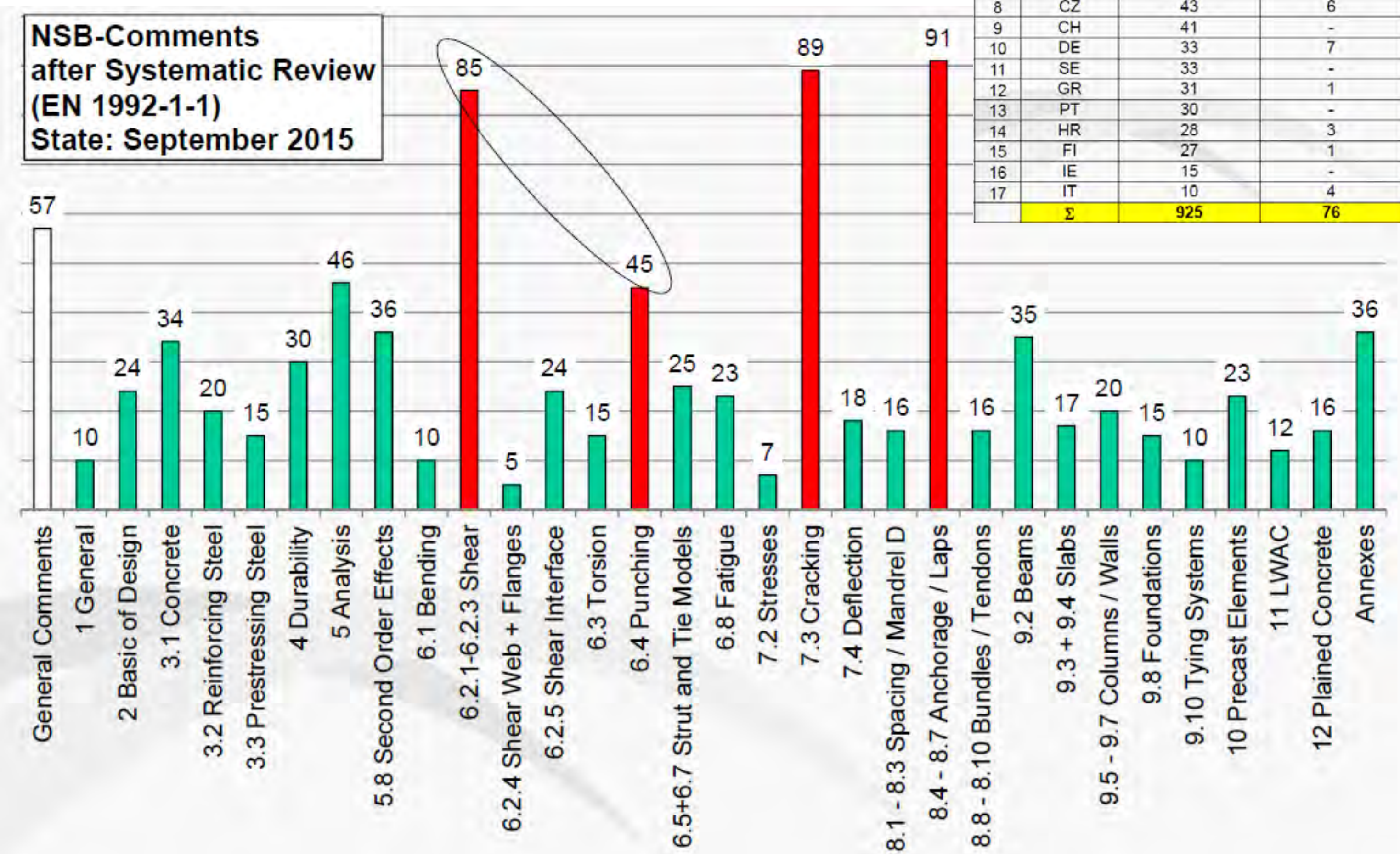
23 pp

N.B.: EN 1992-4 Fastenings has been published in October 2018

1. Introduction

- Systematic Review of EN 1992 (2014):

	NSB	EN 1992-1-1 rev. 11	EN 1992-1-2 rev. 6	EN 1992-2 rev. 9	EN 1992-3 rev. 4
1	UK	174	14	24	11
2	NL	119	2	2	-
3	NO	95	6	1	2
4	BE	74	4	1	10
5	ES	70	7	3	1
6	FR	52	10	27	-
7	DK	50	11	33	1
8	CZ	43	6	39	-
9	CH	41	-	4	-
10	DE	33	7	10	-
11	SE	33	-	3	-
12	GR	31	1	-	-
13	PT	30	-	-	-
14	HR	28	3	5	3
15	FI	27	1	-	9
16	IE	15	-	4	5
17	IT	10	4	-	-
	Σ	925	76	156	42



1. Introduction

- Organisation of CEN/TC 250/ 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	CEN/TC 250/SC 2/WG 2 – EN 1992-4	PT SC2.T1 (2015 – 06/2018) – EN 1992-1-1
Convenor: Mikael Hallgren	**Convenor: Rolf Eligehausen (DE)**	**PT Leader: Aurelio Muttoni**
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**
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**
CEN/TC 250/SC 2/WG 1/TG 3 Leader: Gerrie Dieteren		
CEN/TC 250/SC 2/WG 1/TG 4 Leader: Josef Hegger		
CEN/TC 250/SC 2/WG 1/TG 5 Leader: Fabienne Robert		
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 of WG 1: 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

2. Proposed structure of future EC2 and approach to EoU

- Proposed structure of Eurocode 2:

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1992-1-1

December 2004

ICS 91.010.30; 91.080.40

Supersedes ENV 1992-1-1:1991, ENV 1992-1-3:1994, ENV 1992-1-4:1994, ENV 1992-1-5:1994, ENV 1992-1-6:1994, ENV 1992-3:1998

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

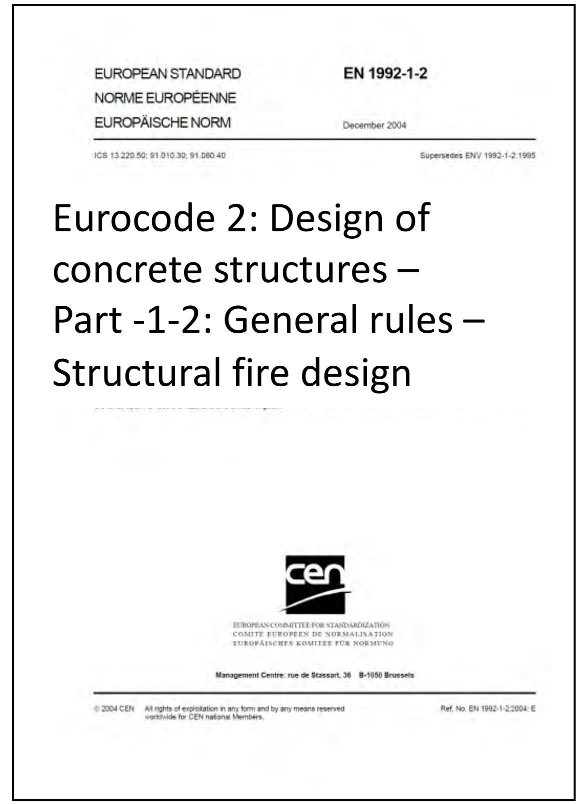
Target 250 pp

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

© 2004 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. EN 1992-1-1:2004: E



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1992-1-2

December 2004

ICS 13.220.50; 91.010.30; 91.080.40

Supersedes ENV 1992-1-2:1995

Eurocode 2: Design of concrete structures – Part -1-2: General rules – Structural fire design

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

© 2004 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. EN 1992-1-2:2004: E

N.B.: Merger of Parts -2 and -3 into -1-1 subject to approval by CEN/TC 250 - pending
N.B.: Plus EN 1992-4 Fastenings published in October 2018

2. Proposed structure of future EC2 and approach to EoU

- Proposed structure of future EN 1992-1-1:

Section	Titel	Responsible	Pages
1; 2; 3	Scope; normative references; terms, definitions and symbols	SC2/WG1	7 / =
4	Basis of design	SC2/WG1	6/ =
5	**Materials**	SC2/WG1, TG1, TG2, TG7	20 / -
6	**Durability (and cover to reinforcement)**	TG10, SC2/WG1	6 / =
7	**Structural analysis**	TG 6, SC2/WG1	30 / -
8	**Ultimate Limit State (ULS)**	SC2/WG1, TG4, TG7, TG8	35 / =
9	**Serviceability Limit State (SLS)**	SC2/WG1, TG10	13 / -
10	**Fatigue**	SC2/WG1, TG8	4
11	**Detailing of reinforcement (and prestressing tendons)**	SC2/WG1	21 / =
12	**Detailing of members and particular rules for various types of structures**	SC2/WG1	20 / =
13	Additional rules for precast concrete elements and structures	SC2/WG1, AHG SC2-TC229	13 / -
14	Plain and lightly reinforced structures	SC2/WG1	6 / -

Total: 181 pp

Note:
- Main text for provisions of common / regular use
- Section with significant changes shown in BOLD

2. Proposed structure of future EC2 and approach to EoU

- Proposed structure of future EN 1992-1-1 - Continued:

Annex	Titel	Responsible	Pages
A	Modification of partial factors for materials	SC2/WG1	2
B	Time dependent behaviour of materials: Creep, shrinkage and elastic strain of concrete and relaxation of prestressing steel	TG7	5
C	Durability and service life design	TG10, SC2/WG1	5
D	Evaluation of early-age and long-term cracking due to restraint	TG7	3
E	Additional rules for fatigue verification	TG8	5-10
F	Non-linear analyses procedures	TG6	2
G	Design of membrane, shell and slab elements at ULS	SC2/WG1	4
H	Guidance on design of concrete structures for water tightness	SC2/WG1	4
I	Assessment of resistance of existing concrete structures	TG3	5-10
J	Strengthening of existing concrete structures with FRP	TG1	5-10
K	Bridges, particular design conditions	TG9	5
L	Fibre reinforced concrete	TG2	5-10
M	Lightweight aggregate concrete structures	SC2/WG1	8 / -
N	Recycled aggregate concrete structures	TG7	2
O	Simplified approaches for second order effects	TG6	6

Note: Annexes for provisions of less frequent use

Total: 66-86 pp

2. Proposed structure of future EC2 and approach to EoU

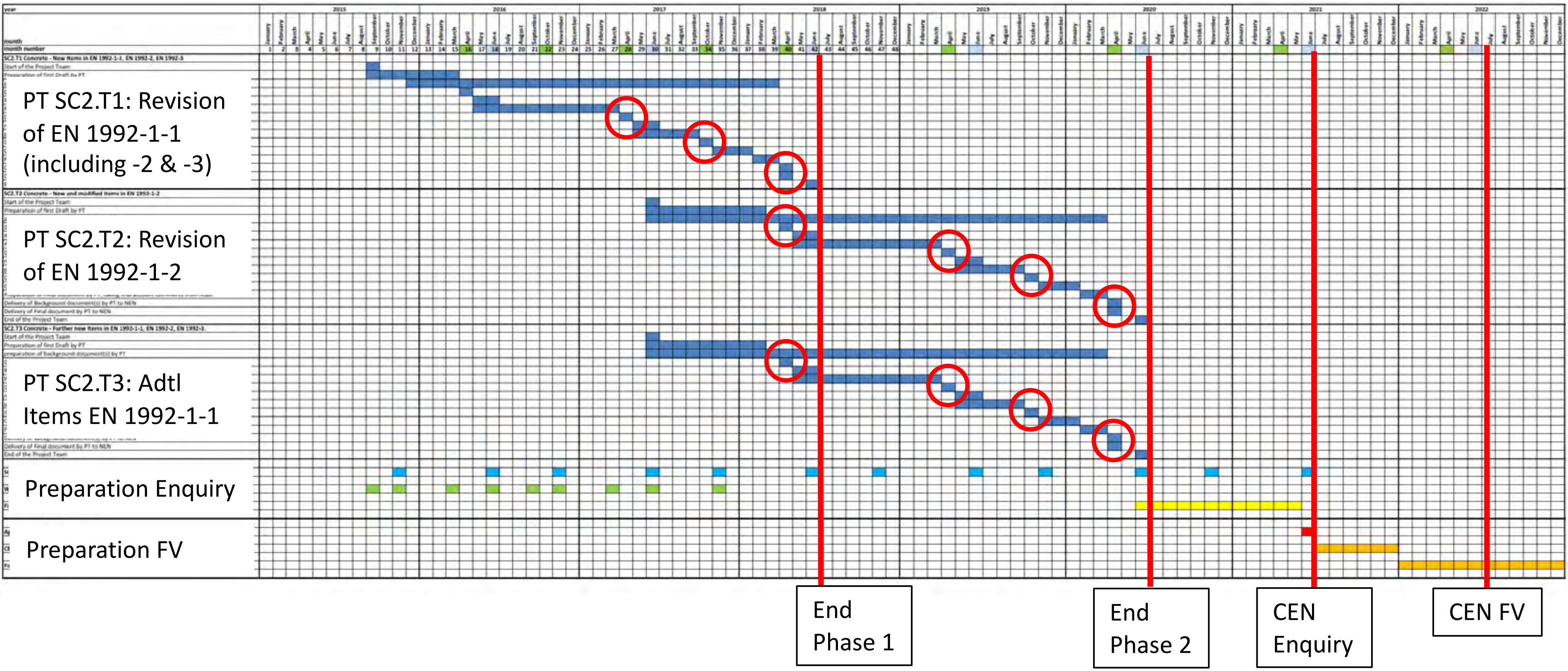
- Scope of PT SC2.T1 for revision of EN 1992-1-1:
  - Reduction in number of NDPs (see CEN/TC 250/N1233 & 1239)
  - Enhance ease of use (see CEN/TC 250/N1493)
  - Durability (input from TG10)
  - Design by non-linear FEM (input from TG6)
  - Size effect (input from TG4)
  - Early age thermo-mechanical design (input from TG7)

→ Avoid member specific design rules whenever possible
→ Merge EN 1992-2 & -3 with EN 1992-1-1
→ Provide design models which are sufficiently comprehensive for existing structures but may be simplified for new construction
→ Provide design models with physical basis which may be used also with new materials (FRP, FRC)
→ Remove rules of little practical use, avoid alternative application rules, shorten standard (reduce current 343pp to approx. 250pp)
→ Improve clarity, avoid repetition, simplify navigation inside standard
→ Start design provisions with a check whether verification is required at all before going into simple and comprehensive verification rules

2. Proposed structure of future EC2 and approach to EoU

- Timetable Project Teams SC2 (T1, T2, T3) for revision of EN 1992

→ Check / amend draft EN 1992-1-1 while waiting for additional items by PT T3



3. Selected proposed changes in EN 1992-1-1

- **Section 5 Materials**:

→ Adapted reference to product standards (concrete, reinforcing and prestressing steels) in accordance with decisions of CEN/TC 250 for interfaces with product standards and compatible with CPR

→ Clearly listed all assumptions for materials which are basis for design according to Eurocode

→ Kept primary materials in main text and moved others (LWAC, recycled aggregate concrete, FRC, FRP, etc.) to Annexes. Provisions in Annexes summarised in tables:

Table M.2: Special provisions for lightweight aggregate concrete

Reference to original clause	Values and terms to be modified for lightweight aggregate concrete	Provisions and expressions for lightweight aggregate concrete
5.1.3(3)	Maximum Class	LC80
Table 5.1	Mean value of concrete cylinder compressive strength f_{cm}	f_{cm} = 17 MPa for LC12; f_{cm} = 22 MPa for LC16; values given in Table 5.1 for $f_{ck} \geq$ LC20
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.

3. Selected proposed changes in EN 1992-1-1

- **5.1 - Concrete**:

→ Reference age for concrete properties: Typical reference age is 28d however, later dates up to 91d are encouraged (sustainability, concretes with slow strength development, etc.)

→ Corrected errors in creep and shrinkage (basic and drying); approximate values of plain concrete given in tables in Section 5.1, detailed information in Annex B (adjustment for reinforced sections where needed)

Table 5.3: Nominal total shrinkage values $\varepsilon_{cs,50y}$ (in ‰) for concrete after a duration of drying of 50 years

Cement [a]	Concrete strength f_{ck} [MPa]	Dry atmospheric conditions (RH = 50 %)				Humid atmospheric conditions (RH = 80 %)			
		Notional size, h_n [mm]							
		100	200	500	1000	100	200	500	1000
L	20	0,56	0,55	0,47	0,35	0,33	0,32	0,28	0,21
	35	0,51	0,50	0,44	0,34	0,33	0,32	0,29	0,23
	50	0,48	0,47	0,42	0,34	0,33	0,32	0,30	0,25
	80	0,46	0,45	0,41	0,35	0,35	0,34	0,32	0,29

[a] L, N and R stand for slowly, normal and rapid hardening cements, respectively.

3. Selected proposed changes in EN 1992-1-1

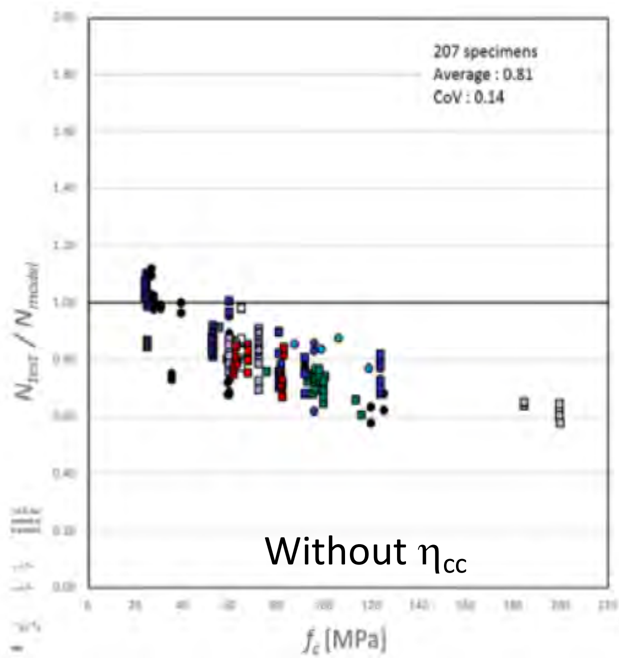
- **5.1 – Concrete, continued**:

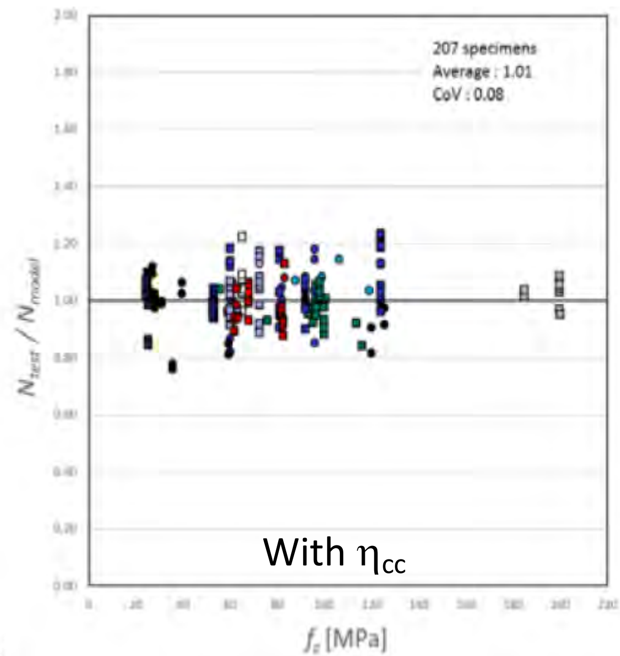
→ Modified design strength: $f_{cd} = \eta_{cc}\, k_{tc}\, f_{ck}/\gamma_C$ where $\eta_{cc} = (40/f_{ck})^{1/3} \leq 1$

Note: η_{cc} accounting for difference between undisturbed compressive strength in cylinder and effective strength in member; k_{tc} for effect of high sustained load, i.e. "Rüsch effect" (recommended value 1,0).

Note: Change provides uniform safety level for column tests; allows single value of ultimate strains independent of strength and avoids different reduction factors η depending on actual stress distribution in axial-bending design

Value of η_{cc} still under discussion!

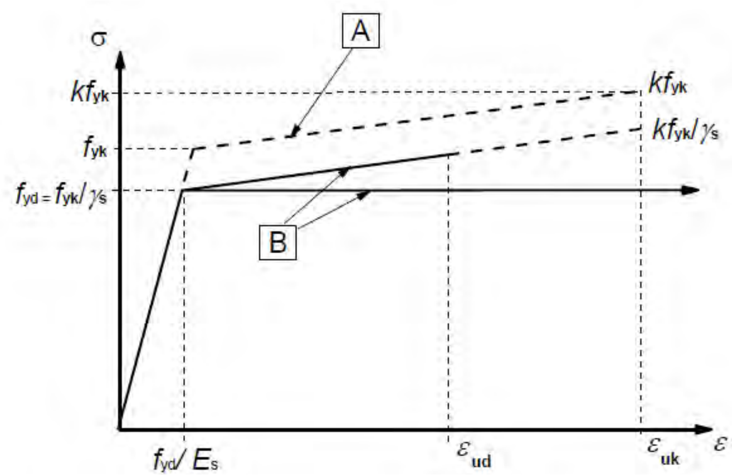




3. Selected proposed changes in EN 1992-1-1

- **5.2 / 5.3 - Reinforcing and prestressing steel:**

→ Introduced indented reinforcing steel up to 14mm diameter
→ Give classes for strength and ductility to permit a rational design procedure
→ Reinforcing steel strength classes B400 to B700 (intermediate classes possible)
→ Prestressing steel strength classes for strands up to Y2060
→ No changes in design assumptions
→ Discussions with ECISS/TC 104: Need fractile value for fatigue strength of reinforcing steel; requested marking of strength and ductility class on reinforcing steel (considered essential for safety – checking incoming materials on site, assessment of existing structures)



3. Selected proposed changes in EN 1992-1-1

- **Section 6 Durability**:

→ Define framework for durability / concrete cover which suits both present national deemed-to-satisfy rules (DtS) and future performance-based rules based on durability testing for carbonation and chloride ingress

→ Input variables for durability design: Exposure class of structure/member; design working life of structure; exposure resistance classes of concrete (ERC)

→ Designer selects required concrete cover as function of ERC for corrosion protection of reinforcement and specifies this for project. N.B.: Similar for deterioration mechanism due to chloride

→ Main objective: Provide method to assess new concrete mixes based on performance testing for which no experience for DtS exists (new cement types)

Exposure Class EC	Concrete Cover: ERC 1		Concrete Cover: ERC 2		Concrete Cover: ERC 3	
	50-years	100-years	50-years	100-years	50-years	100-years
XC1	10	15	10	20	10	20
XC2	10	15	15	20	20	30
XC3	15	20	20	25	25	35
XC4	15	20	20	25	25	35

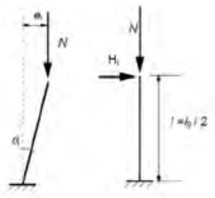
ERC and cover still under discussion!

Note: Background for performance-based durability rules in Annex C

3. Selected proposed changes in EN 1992-1-1

- **Section 7 Structural analysis**:

→ Harmonised geometric imperfections between different Eurocodes
→ Maintained linear-elastic analysis without / with limited redistribution / plastic analysis
→ Permitted use of stress fields (lower bound theorem of theory of plasticity) or FEM-technology to determine force distribution in members which are then designed using partial factor or using global safety factor method
→ General rules for non-linear analysis and design given with reference to EN 1990 and Annex F of EN 1992-1-1 (safety formats)
→ Maintained check whether 2nd order is critical and general method in main text, moved alternative simplified empirical approaches to Informative Annex O
→ Clarified consideration of prestress either on action or resistance side



$$\theta_i = \alpha_h \alpha_m \frac{l}{200} \qquad \alpha_h = 2/\sqrt{l} \begin{cases} \geq 2/5 \\ \leq 1 \end{cases} \qquad \alpha_m = \sqrt{0{,}5\left(1+1/m\right)}$$

3. Selected proposed changes in EN 1992-1-1

- **Section 8 ULS**:

→ Bending with / without axial force: Simplified stress distribution in cross section

→ Introduced provisions for orthogonally reinforced solid slab elements subject to bending and torsional moments

→ Introduced provisions for confined concrete (based on EN 1998)

→ Introduced principal shear in planar members and clarified contributions of tendons and inclined chords to shear strength of members

→ Introduced physical model for shear design without shear reinforcement taking into account size effect

→ Kept same model for shear design with shear reinforcement but amended information for choice of inclination of compression field

→ Added provisions for shear and transverse bending

→ Amended provisions for shear at interfaces

→ Added information for combination of actions and interaction formulae

→ Introduced physical model for punching shear design without shear reinforcement taking into account size effect, moved control perimeter to 0,5d

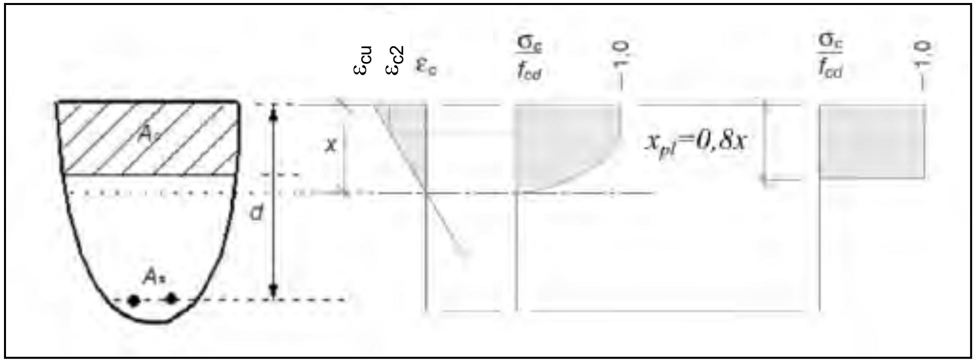
→ Amended provisions for struts and compression fields

3. Selected proposed changes in EN 1992-1-1

- **8.1 – Bending with / without axial force**:

→ Stress distribution in compression zones, change in design strength:
$f_{cd} = \eta_{cc}\, k_{tc}\, f_{ck}/\gamma_C$ where $\eta_{cc} = (40/f_{ck})^{1/3} \leq 1$

Value of η_{cc} still under discussion!



ε_{c2} = 0,002
ε_{cu} = 0,0035

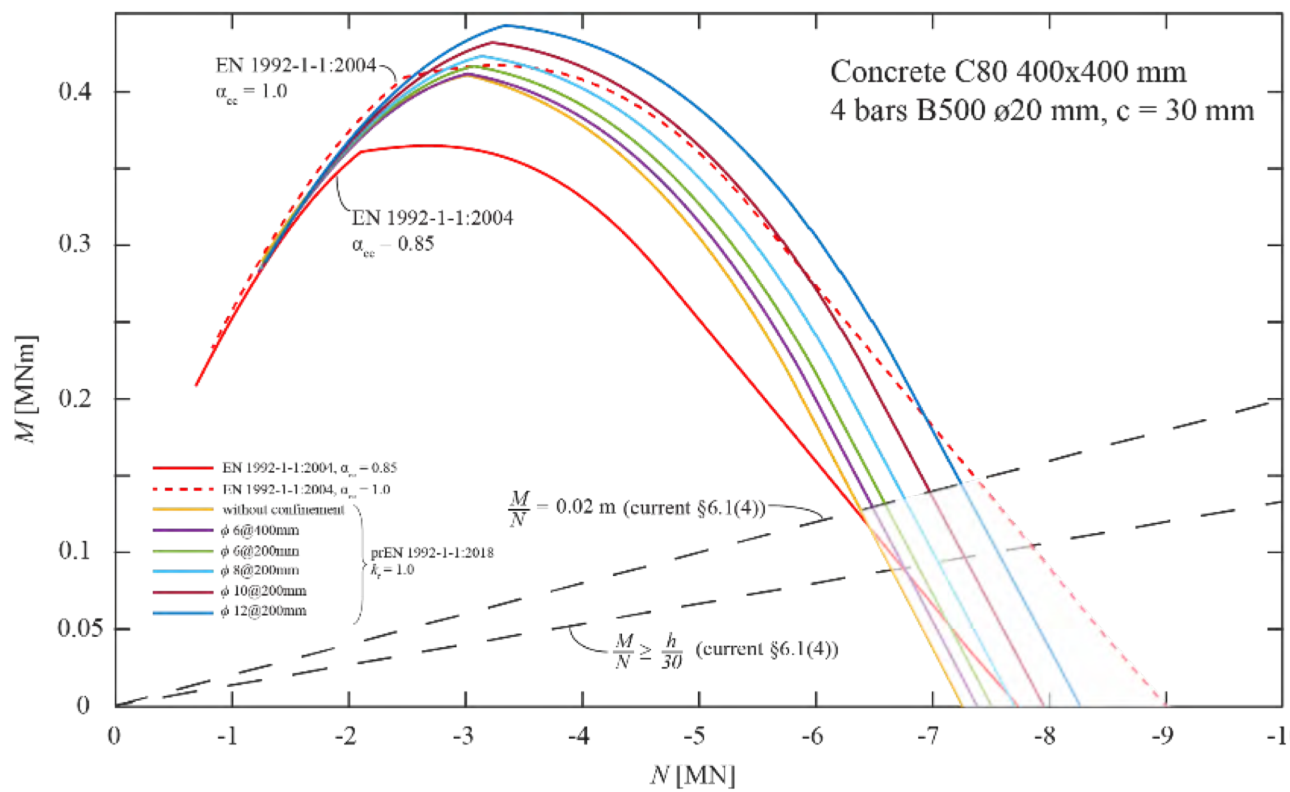
→ Advantages:

- consistent safety level for axial/bending strength for all concrete strengths
- limiting strains ε_{c2} and ε_{cu} independent of concrete strength
- stress blocks independent of concrete strength
- consistent ν-factor for shear design independent of concrete strength
- f_{cd} identical for all ULS design checks

Note: No need for further correction for concrete strength like: [1,0 - (f_{ck} - 50)/200]; [1 - f_{ck}/250]; [0,9 - f_{ck}/200]; etc.

3. Selected proposed changes in EN 1992-1-1

- **8.1 – N-M interaction diagram**: Value of η_{cc} challenged for high strength concretes $\rightarrow$ Comparison of current vs draft provisions without and with consideration of strength increase due to confinement reinforcement shows increase of resistance if α_{cc} = 0,85 and little difference if α_{cc} = 1,0 is used



3. Selected proposed changes in EN 1992-1-1

- **8.1 – Confined concrete**:

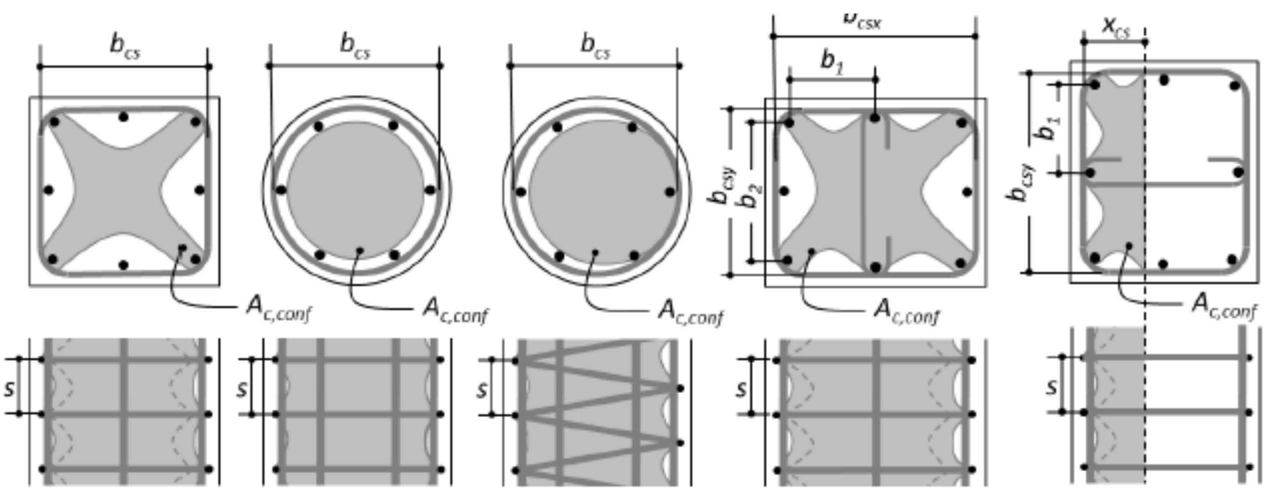
→ provisions for strength increase under transverse confinement stress

→ simplified for $\sigma_{c2d} \leq 0{,}6f_{cd}$: $\Delta f_{cd} = 4\sigma_{c2d}$

→ detailed for $\sigma_{c2d} > 0{,}6f_{cd}$: $\Delta f_{cd} = 3{,}5\sigma_{c2d}^{3/4} f_{cd}^{1/4}$

for $d_{dg} < 32$mm reduce Δf_{cd} by (d_{dg}/32mm)

Note: May be used to compensate reduction of f_{cd} due to η_{cc} with higher strength concrete



$$\sigma_{c2d} = \frac{2A_{s,conf} f_{yd}}{b_{cs} \cdot s}$$

$$\sigma_{c2d} = \frac{2A_{s,conf} f_{yd}}{\max(b_{csx}; b_{csy}) \cdot s}$$

$$\sigma_{c2d} = \min\left(\frac{\Sigma A_{s,confx}}{b_{csy}}; \frac{\Sigma A_{s,confy}}{b_{csx}}\right) \cdot \frac{f_{yd}}{s}$$

$$\sigma_{c2d} = \min\left(\frac{\Sigma A_{s,confx}}{b_{csy}}; \frac{A_{s,confy}}{x_{cs}}\right) \cdot \frac{f_{yd}}{s}$$

3. Selected proposed changes in EN 1992-1-1

- **8.2 – Shear**:

→ (1) check: no detailed investigation is required if $\tau_{Ed} \leq \tau_{Rdc,m}$

$$\tau_{Rdc,\min} = \frac{10}{\gamma_C}\sqrt{\frac{f_{ck}}{f_{yd}} \cdot \frac{d_{dg}}{d}}$$

N.B.: Formula assumes that strain in longitudinal reinforcement is: $\varepsilon_s = \varepsilon_y$

→ (2) detailed: members not requiring shear reinforcement

$$\tau_{Rd,c} = \frac{0,6}{\gamma_C}\left(100\rho_l f_{ck}\frac{d_{dg}}{d}\right)^{1/3} \geq \tau_{Rdc,\min}$$

N.B: for $a_{cs} \leq 4d$: replace $d \rightarrow a_v = (d\, a_{cs}/4)^{1/2}$

with $a_{cs} = M_{Ed}/V_{Ed} \geq d$

and in presence of axial forces

(considers effect of N_{Ed} on strain)

$$a_{cs} = \left|\frac{M_{Ed}}{V_{Ed}}\right| + \frac{N_{Ed}}{|V_{Ed}|}\frac{d}{3} \geq d$$

Note:

d_{dg} : coefficient taking account of concrete type and aggregate properties

d, a_v : taking account of size effect

if prestress is considered on resistance side only modify V_{Ed} , N_{Ed} and M_{Ed} by $P_d \sin\beta$, $P_d\cos\beta$ and $P_d\cos\beta\, e_p$

3. Selected proposed changes in EN 1992-1-1

- **8.2 – Shear, continued**:

→ (3) detailed: members requiring shear reinforcement

- $\cot\theta_{min}$ = 2.5 for ordinary reinforced members without axial force
- $\cot\theta_{min}$ = 3.0 for members subjected to significant axial compressive force (average compressive stress due to N_{Ed} equal to 3 MPa or larger) 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) applies
- $\cot\theta_{min} = 2.5 - 0.1 \cdot N_{Ed}/V_{Ed} \geq 1{,}0$ for members subjected to axial tension

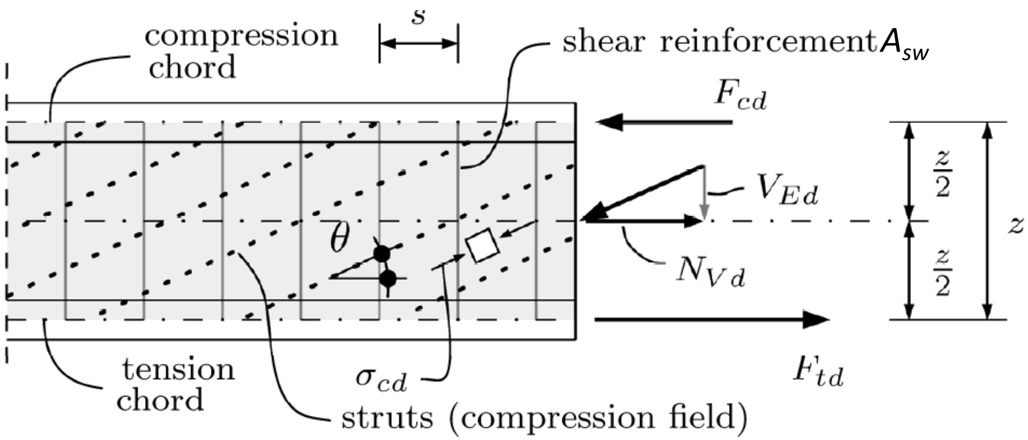
$$\frac{A_{sw}}{s} \geq \frac{V_{Ed}}{z \cdot f_{ywd} \cdot \cot\theta}$$

$$V_{Rd} = \frac{A_{sw}}{s} z \cdot f_{ywd} \cdot \cot\theta \leq b_w \cdot z \frac{\nu \cdot f_{cd}}{2}$$

ν = 0,5 in general

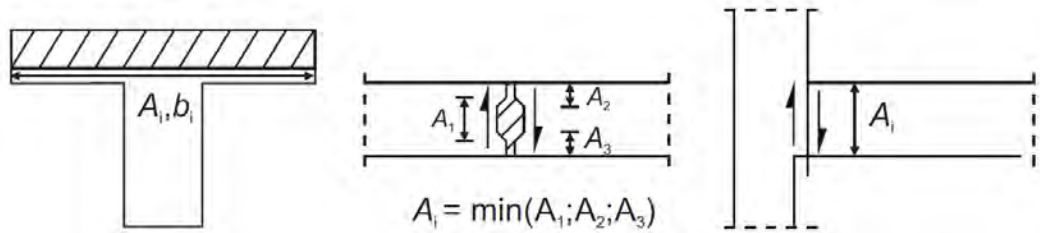
$$\nu = \frac{1}{1.2 + 80 \cdot (\varepsilon_x + (\varepsilon_x + 0.001)\cot^2\theta)} \leq 1{,}0$$

$$\cot\theta_{min} \geq \cot\theta = \sqrt{\frac{\nu \cdot f_{cd} \cdot s \cdot b_w}{A_{sw} \cdot f_{ywd}} - 1} \geq 1$$



3. Selected proposed changes in EN 1992-1-1

- **8.2.6 – Shear at interfaces**:



→ reinforcement across interface sufficiently anchored for yield strength:

$$\tau_{Rdi} = c_{v1} \sqrt{(f_{ck})}/\gamma_C + \mu_v \sigma_n + \rho f_{yd} (\mu_v \sin\alpha + \cos\alpha) \leq \nu f_{cd} \quad (8.55)$$

N.B.: Contribution of $c_{v1}\sqrt{(f_{ck})}/\gamma_c$ corresponds to $c f_{ctd}$ in current EC2

→ reinforcement across interface insufficiently anchored for yield strength:

$$\tau_{Rdi} = c_{v2} \sqrt{(f_{ck})}/\gamma_C + \mu_v \sigma_n + k_t \rho f_{yd} \mu_v + k_f \rho \sqrt{(f_{yd} f_{cd})} \quad (8.56)$$

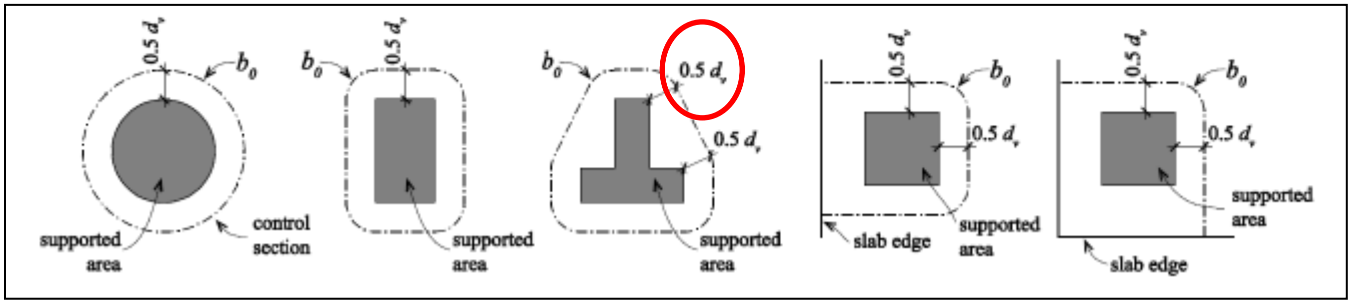
	Equation 8.55		*Equation 8.56*		
Surface roughness	c_{v1}	μ_v	c_{v2}	k_t	k_f
very smooth	0,0095	0,5	0	0	1,5
smooth	0,075	0,6	0	0,5	1,1
rough	0,15	0,7	0,075	0,5	0,9
very rough	0,19	0,9	0,15	0,5	0,9
keyed	0,37	0,9	-	-	-

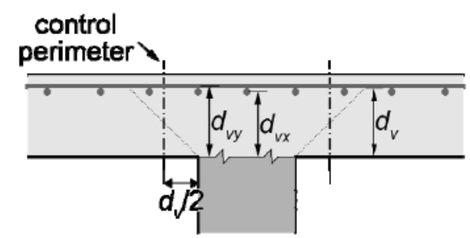
Note: The factors for keyed interfaces shall be applied for the area of each key considering its concrete strength.

3. Selected proposed changes in EN 1992-1-1

- **8.4 – Punching**:

→ typical control perimeter @ 0,5d_v



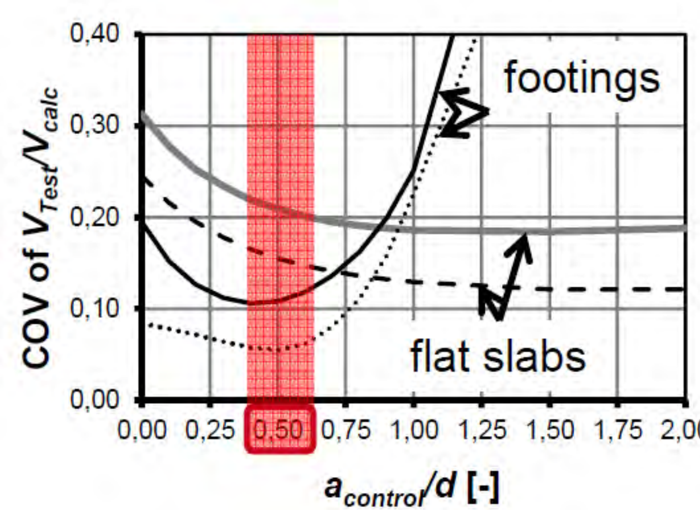


→ punching shear resistance without shear reinforcement

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

Punching shear gradient enhancement coefficient
With μ_p = 8, 4, 2 for internal, edge, corner columns
For axial forces multiply k_{pb} with k_{pp}

$$k_{pb} = \sqrt{5\mu_p \frac{d_v}{b_0}} \leq 2,5$$



Note:
- Control perimeter @ 0,5 d_v results in lowest COV for testing and avoids iteration in footings
- Favourable effect of compression (prestress) is considered by k_{pb}*k_{pp}

3. Selected proposed changes in EN 1992-1-1

- **Section 9 SLS**:

→ Improved structure of section and clarified navigation inside section
→ Amended provisions for effective tension area including for thick planar members
→ Structured crack verification into: (i) minimum reinforcement; (ii) simplified control (equation for bar diameter and spacing instead of diagram); (iii) refined control including effects of restraints
→ Amended tabulated data for cases where deflection calculations may be omitted
→ Provided provisions and equations for simplified calculation of longterm deflections of building members
→ Kept ζ-method as general method for deflection calculation (with reference to rigorous integration of curvatures)
→ Added a clause on vibrations providing suggested values for effective damping ratios

3. Selected proposed changes in EN 1992-1-1

- **9.3 – Crack control**:

→ Added navigation clause for relevant checks

Verification	Calculation of minimum reinforcement for crack control according to 9.2.2	Maximum bar diameter or maximum bar spacing according to 9.2.3 or alternatively Verification of crack width according to 9.2.4	Verification of reinforcement stresses
Combination of actions	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	$\sigma_s \leq f_{yk}$ or $\sigma_s \leq \sigma_{s,lim}$ 2)	$w_{lim,cal} = 0{,}4$ mm 1)	$\sigma_s \leq 0{,}8 \cdot f_{yk}$ $\sigma_p \leq 0{,}8 \cdot f_{pk}$
Note 1: $w_{lim,cal} = 0{,}4$ mm applies unless the National Annex gives different values, more stringent requirements can be defined on a project basis whenever necessary **Note 2:** A lower value $\sigma_s < f_{yk}$ may be needed to satisfy the crack width limits according to the maximum bar size (see Expression (9.6))			

3. Selected proposed changes in EN 1992-1-1

- **9.3 – Crack control, continued**:

→ Table 7.1N of current EC2 updated and amended for protection levels of prestress (new Table 9.2N):

Exposure Class	Reinforced members, prestressed members with unbonded tendons and prestressed members with bonded tendons with Protection Levels 2 or 3 according to 5.4.1(3)		Prestressed members with bonded tendons with Protection Levels 1 according to 5.4.1(3)		
	Quasi-permanent combination of actions	characteristic combination of actions	Quasi-permanent Combination of actions	Frequent Combination of actions	characteristic combination of actions
X0, XC1	–	–		$w_{lim,cal} = 0{,}2$ mm [1]	–
XC2, XC3, XC4	$w_{lim,cal} = 0{,}3$ mm [1]		Decompression [3]	$w_{lim,cal} = 0{,}2$ mm [1]	
XD1, XD2, XD3, XS1, XS2, XS3		$\sigma_c \leq 0.6 f_{ck}$ [2]	–	Decompression [1) 3)]	$\sigma_c \leq 0.6 f_{ck}$
XF1, XF2, XF3, XF4	–				

Note 1: the National Annex may give different values for use in a Country

Note 2: No limitation in serviceability conditions is necessary for stresses under bearings and anchorages through mechanical devices

Note 3: The decompression limit requires that all parts of the bonded tendons or duct lie at least 25 mm within

Table 9.2 still remains to be discussed and agreed (task of TG10)

3. Selected proposed changes in EN 1992-1-1

- **Section 11 – Detailing of reinforcement**

→ Provisions for checking mandrel diameter still pending

→ Added navigation clause where to find provisions for different methods of tension anchorage

→ Adopted fib MC2010 model for required anchorage length and as a consequence removed bond stress / bond strength concept

→ Added provisions for anchorage of headed bars

→ Lap length taken as equal as anchorage length for lapping up to 100% of bars if laps are provided away from sections where plastic hinges or maximum effects are expected to occur

→ Added provisions for laps using U-bar loops

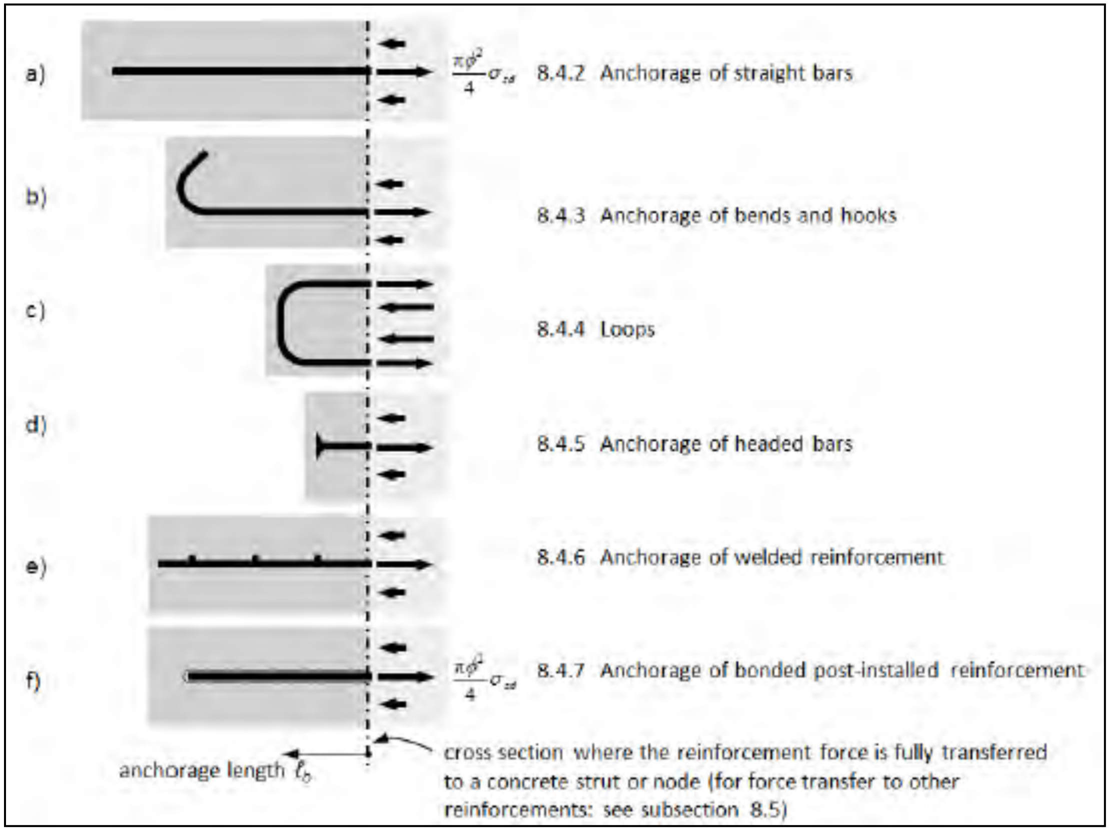
→ Moved provisions for pretensioning tendons to Section 13 “Precast concrete elements and structures”

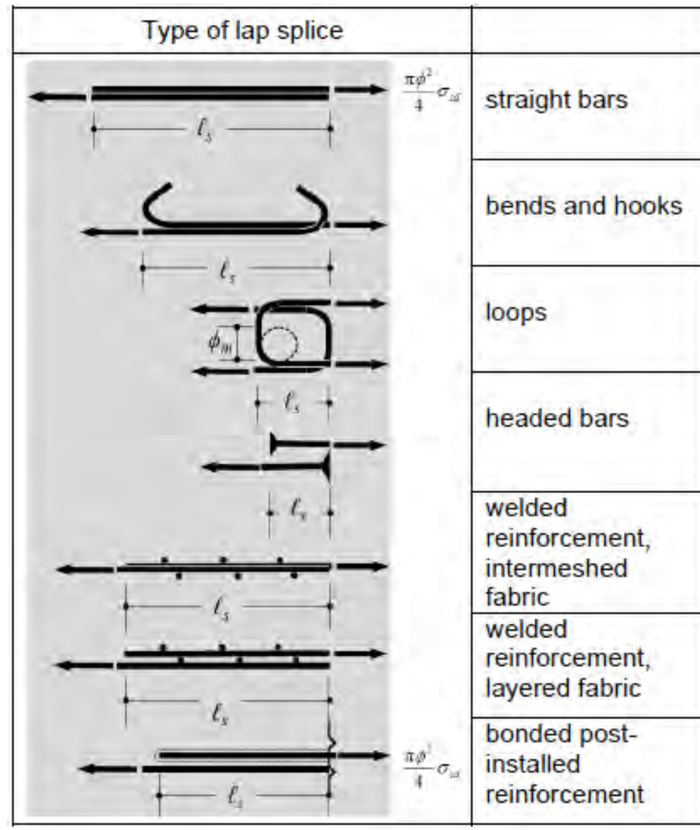
→ Added provisions for minimum radius of curvature of post-tensioning tendons

→ Added provisions for detailing for deviation forces due to curved tensile and compressive chords

3. Selected proposed changes in EN 1992-1-1

- **Section 11**: Covering various types of anchorages and laps

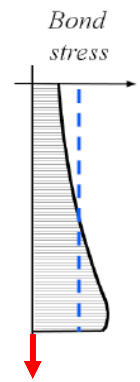


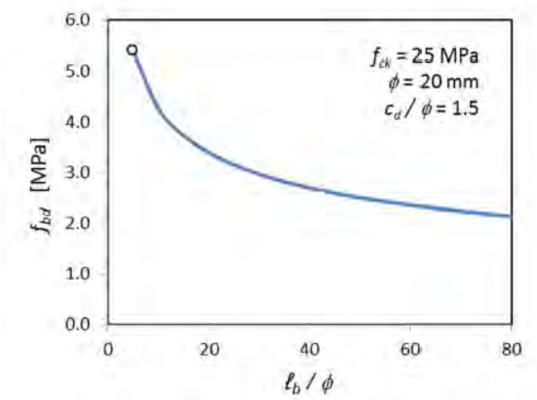


3. Selected proposed changes in EN 1992-1-1

- **11.4 – Anchorage of reinforcing steel bars:**

→ Adopted/modified fib MC2010 model for required anchorage length; due to non-linear character do not use bond strength anymore





→ simplified verification: $\ell_{bd} = k_{lbs} \cdot \phi$

valid for $\phi \leq 20$ mm, with $f_{ck} \geq 25$ MPa, $c_d \geq 1.5 \cdot \phi$

Table 11.1: Coefficient k_{lbs} as a function of the design stress σ_{sd} for $\gamma_C = 1.5$

σ_{sd} [MPa]	$\sigma_{sd} \leq 200$	$200 < \sigma_{sd} \leq 250$	$250 < \sigma_{sd} \leq 300$	$300 < \sigma_{sd} \leq 350$	$350 < \sigma_{sd} \leq 390$	**$390 < \sigma_{sd} \leq 435$**	$435 < \sigma_{sd} \leq 480$	$480 < \sigma_{sd} \leq 520$	$520 < \sigma_{sd} \leq 610$
k_{lbs}	16	22	29	36	43	**50**	58	65	83

k_{lbs} still remains to be agreed

3. Selected proposed changes in EN 1992-1-1

- **11.4 – Anchorage of reinforcing steel bars, continued:**

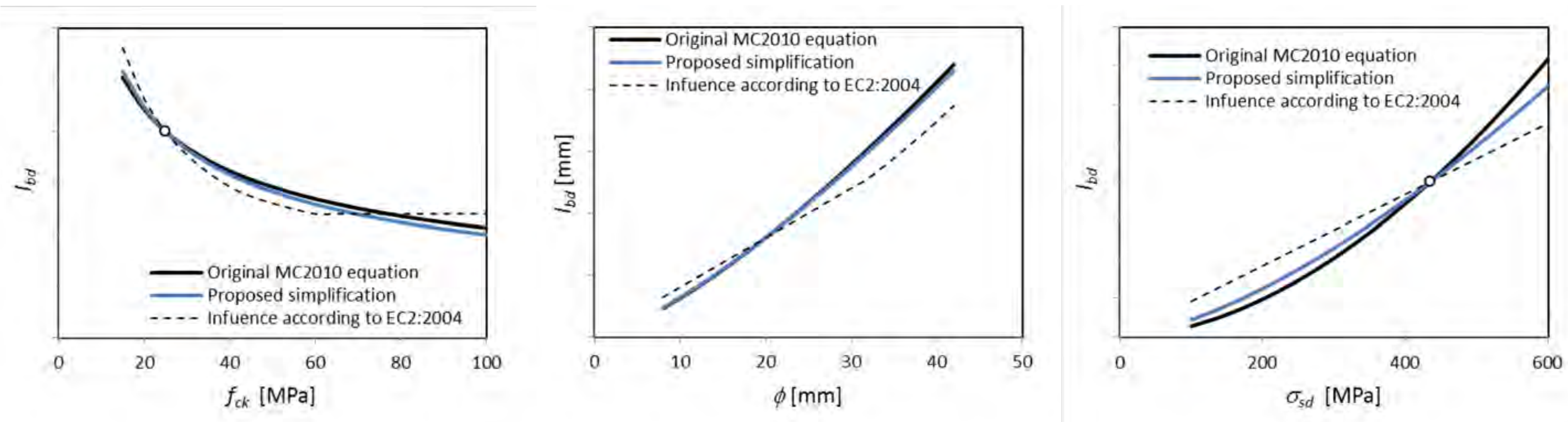
$\rightarrow$ detailed verification:

$$\ell_{bd} = k_{lbs} \cdot \phi \left(\frac{25\text{ MPa}}{f_{ck}} \right)^{\frac{1}{2}} \left(\frac{\phi}{20\text{ mm}} \right)^{\frac{1}{3}} \left(\frac{1.5\phi}{c_d} \right)^{\frac{1}{2}} \geq 15\phi$$

$$k_{lbs} = 50 \left(\frac{\sigma_{sd}}{435\text{ MPa}} \cdot \frac{\gamma_C}{1.5} \right)^{\frac{3}{2}}$$

k_{lbs} still remains to be agreed

N.B.: ratios ϕ / 20 mm and 1.5ϕ / c_d shall not be taken smaller than 0.6 and 0.4, respectively.



3. Selected proposed changes in EN 1992-1-1

- **11.5.2 – Robustness rules for anchorages and laps:**

→ Design lap length is set equal to design anchorage length

→ Considering need for deformation capacity and residual strength in laps located in zones where plastic hinges are assumed to develop in structural analysis

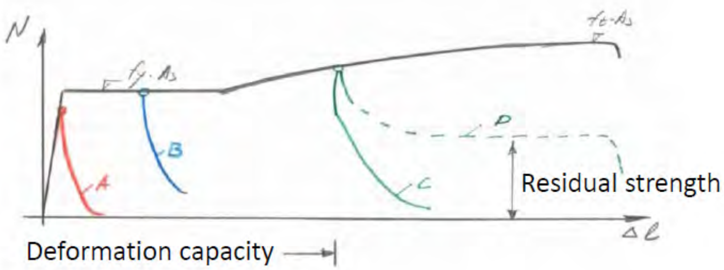
(3) Away from plastic hinges and sections where maximum effects are expected to occur, tension laps may be detailed with up to 100% of bars lapped at any section and laps may be designed for the maximum value of the reinforcement design stress σ_{sd} .'

(4) If tension laps have to be located near plastic hinges or sections where maximum effects are expected to occur, tension laps may be designed for σ_{sd} if :

- a confinement reinforcement is arranged according to 11.5.3(2) or
- if they are staggered so that the area of lapped bars ≤ 35% of the total cross-section area of the reinforcement in linear members (beams and columns) or ≤ 50% in planar members (slabs, walls and shells).

Otherwise, tension laps should be designed for $1.2 \cdot \sigma_{sd}$.

All bars in compression may be lapped in one section and designed for σ_{sd} .



Concept still under discussion

3. Selected proposed changes in EN 1992-1-1

- **Section 12 – Detailing of members:**

→ Introduced clause on minimum reinforcement for robustness (design resistance of section equal or larger than effects when section cracks). However, subject still under discussion and likely to be amended for smaller reinforcing ratios

→ Good practice detailing rules for specific members given in table format for ease of use; rules considered outdated or of little practical use removed

→ Rules considered representing limits of validity of design models moved to ULS

→ Tying systems for buildings maintained mostly

N.B.: Work on Section 12 to be continued. Intent is to more specifically identify types of detailing requirements, clearly indicate what the intent of each of the provisions is, i.e. limitations of design models; good practice; robustness; etc.

3. Selected proposed changes in EN 1992-1-1

- **Annexes:**

→ Annex D: Evaluation of early-age and long-term cracking due to restraint. Annex added to cover parts of current EN 1992-3 Containment structures

→ Annex G: Design of membrane, slab and shell elements for ULS.

→ Annex H: Guidance on design of concrete structures for water tightness. Annex added to cover parts of current EN 1992-3 Containment structures

→ Annex K: Bridges, particular design conditions. Annex summarises aspects which are in current EN 1992-2 and not yet covered in main part of draft EN 1992-1-1 (clauses on analysis of cable stayed structures to be moved to EN 1993-1-11)

→ Annex M: Modifications of design provisions for LWAC structures

→ Annex N: Modifications of design provisions for recycled aggregate concrete structures

→ Annex O: Simplified approaches for second order effects (Informative)

N.B.: Open draft for new materials (FRC, FRP, stainless steel) cautiously

4. Way forward to publication of future EC2

→ M/515, Phase 2 PT SC2.T3 is preparing provisions for further new items by mid 2020 to be integrated into future EN 1992-1-1: FRP (externally bonded for strengthening and embedded reinforcement); FRC; Existing Structures; Stainless Steel

→ NSBs are invited to perform trial calculations with final document EN 1992-1-1 and to report back to CEN/TC 250/SC 2 by end 2019 any errors, excessive differences in results to current practice or problems of understanding

→ SC 2 formed a Coordinating & Drafting Group which will make editorial changes to draft and integrate provisions from PT SC2.T3. Any proposed technical changes to final document EN 1992-1-1 will be proposed by SC 2/WG 1 and reviewed and approved by SC 2 before integration into prEN 1992-1-1 to be submitted for CEN enquiry to CEN/TC 250 by mid 2021

→ Controversial provisions will be reviewed during this process also in order to build consensus prior to CEN enquiry and formal vote

→ List of NDPs will have to be reviewed (final document has 38 clauses with NDPs versus 165 clauses in current EN 1992-1-1, -2, -3)

4. Way forward to publication of future EC2

→ Maintain concise and consistent draft while adding new and amending existing provisions

→ Background for main changes given in commentary to draft (right hand column) or in specific background document to draft

→ Draft is considered a modern design standard for concrete structures which is easy to use with simplified design models for new construction but permits to use sufficiently comprehensive models for existing structures to avoid unnecessary rehabilitation

→ Draft standard is written for competent engineers / practitioners and is considered well adapted for preliminary design, for detailed design by hand or with software both with linear and non-linear methods as well as for verification of computer results by hand-calculations