Ny generation af Eurocode 2

Dansk Betondag 2021

Linh C. Hoang, DTU Byg

Linh C. Hoang, Background

Professor of Concrete Structures, DTU (since 2013)

Member of DS/S-1992 (since 2007)

Member of CEN/TC250/SC2 (since 2007)

Agenda

1. Mandate & Organization

2. Overview of results

3. Examples of revised/new content

4. Time schedule and work plan toward implementation

Scope & Mandate (M515 from 2012)

Mandate includes: …. State-of-the-art; Encourage innovation, New materials and methods; Improved efficiency & harmonization; Sustainability;……

Specific mandate of CEN/TC250/SC2:

- Enhanced ease-of-use
- Reduction in number of National determined parameters (NDPs)
- New durability concept
- Size effects
- Design by non-linear FEM
- Early age thermomechanical design
- Stainless reinforcing steel
- Fibre reinforced concrete
- Assessment of existing structures
- Strengthen with FRP
- Fire resistance

Organization of SC2 (Structural Eurocodes)

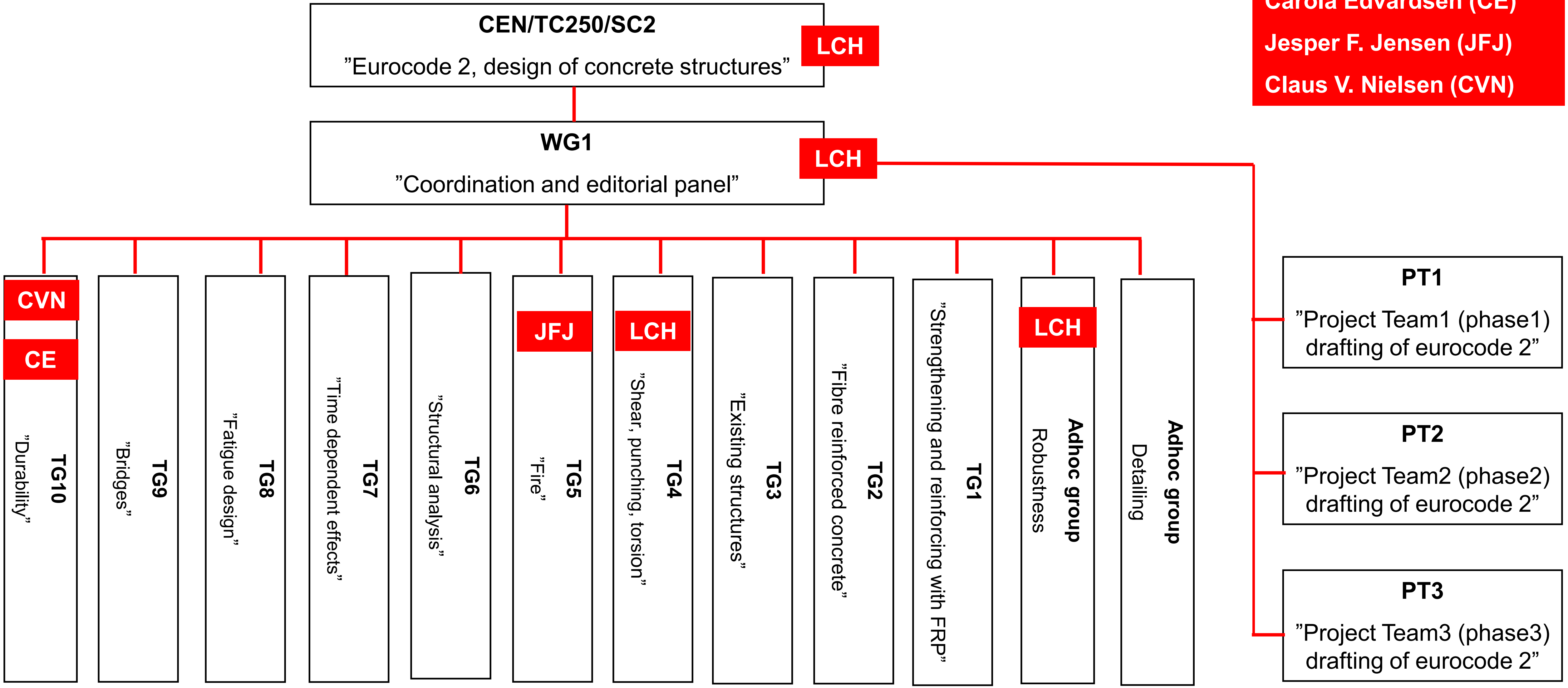
Danish participation:

Linh C. Hoang (LCH)

Carola Edvardsen (CE)

Jesper F. Jensen (JFJ)

Claus V. Nielsen (CVN)



Overview – Enquiry Versions of EN 1992-1-1 & -2

PT1 & PT3

New & revised Items in:

- EN-1992-1-1 (General rules / buildings)
- EN-1992-2 (Bridges)
- EN-1992-3 (Liquid retaining structures)

Future EN-1992-1-1

General rules - Buildings, bridges & civil engineering structures

PT2

New Items & revised items in:

- EN-1992-1-2 (Structural fire design)

Future EN-1992-1-2

Structural fire design

Background documents

~ 1300 pages

Future EN-1992-1-1. Reinforcement classes & materials

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.						

Table 5.5 — Ductility classes of reinforcing steel

Properties for stress-strain-diagram (Fig. 5.2)	Reinforcing steel ductility class		
	A	B	C
Characteristic value of $k = (f_t/f_y)_k$	1,05	1,08	1,15 to 1,35
Characteristic strain at maximum force ε_{uk}	2,5 %	5,0 %	7,5 %

Future EN-1992-1-1. Reinforcement classes & materials

Annex J
(informative)

Strengthening of Existing Concrete Structures with CFRP

Annex JA
(informative)

Embedded FRP Reinforcement

Annex L
(informative)

Steel Fibre Reinforced Concrete Structures

Annex Q
(normative)

Stainless reinforcing steel

Future EN-1992-1-1. Compression strength for structural calculations

(2) The value for t_{ref}

(i) should be taken as 28 days in general or

(ii) may be taken between 28 and 91 days when specified for a project.

(3) The compressive and tensile strength characteristics necessary for design should be taken from Table 5.1.

Table 5.1 — Compressive and tensile strength of concrete [MPa]

f	Strength classes for concrete [EN 206]															Analytical formulae
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60	C55/67	C60/75	C70/85	C80/95	C90/105	C100/115	
f_{ck}	12	16	20	25	30	35	40	45	50	55	60	70	80	90	100	–
f_{cm}	20	24	28	33	38	43	48	53	58	63	68	78	88	98	108	$f_{cm} = f_{ck} + 8$ MPa
f_{ctm}	1,6	1,9	2,2	2,6	2,9	3,2	3,5	3,8	4,1	4,2	4,3	4,5	4,7	4,9	5,1	$f_{ctm} = 0{,}3 f_{ck}^{2/3}$ ($f_{ck} \leq 50$ MPa) $f_{ctm} = 1{,}1 f_{ck}^{1/3}$ ($f_{ck} > 50$ MPa)
$f_{ctk;0,05}$	1,1	1,3	1,5	1,8	2,0	2,2	2,5	2,7	2,9	2,9	3,0	3,2	3,3	3,5	3,6	$f_{ctk;0,05} = 0{,}7 f_{ctm}$ (5 %-fractile)
$f_{ctk;0,95}$	2,0	2,5	2,9	3,3	3,8	4,2	4,6	4,9	5,3	5,4	5,6	5,9	6,2	6,4	6,6	$f_{ctk;0,95} = 1{,}3 f_{ctm}$ (95 %-fractile)

Future EN-1992-1-1. ULS, members in compression

8.1.4 Confined concrete

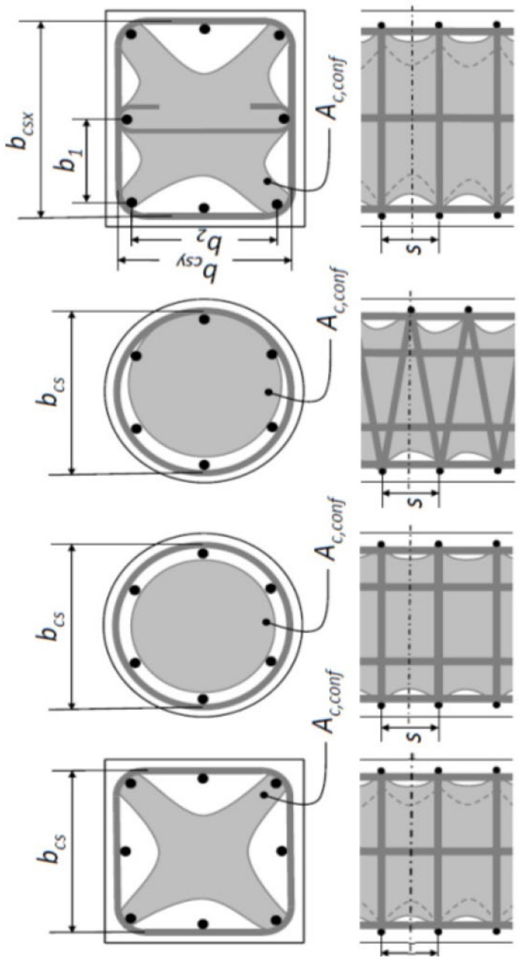
(1) The concrete compressive design strength may be enhanced by the favourable effect of confinement reinforcement or of triaxial compressive stresses.

(2) The compressive strength increase of a concrete with $d_{dg} \geq 32$ mm due to a transverse compressive stress σ_{c2d} may be calculated according to:

$$\Delta f_{cd} = 4 \cdot \sigma_{c2d} \qquad \text{for } \sigma_{c2d} \leq 0{,}6 f_{cd} \qquad (8.6a)$$

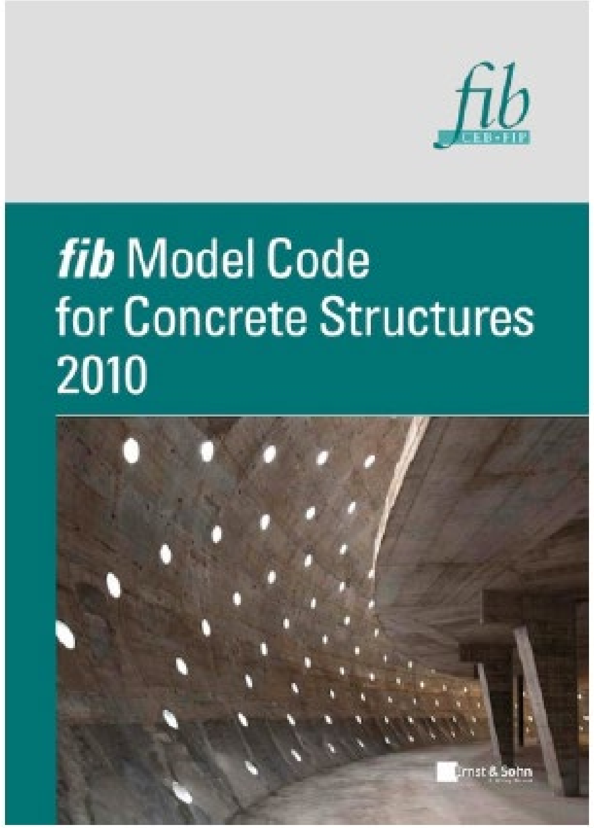
$$\Delta f_{cd} = 3{,}5 \cdot \sigma_{c2d}^{3/4} \cdot f_{cd}^{1/4} \qquad \text{for } \sigma_{c2d} > 0{,}6 f_{cd} \qquad (8.6b)$$

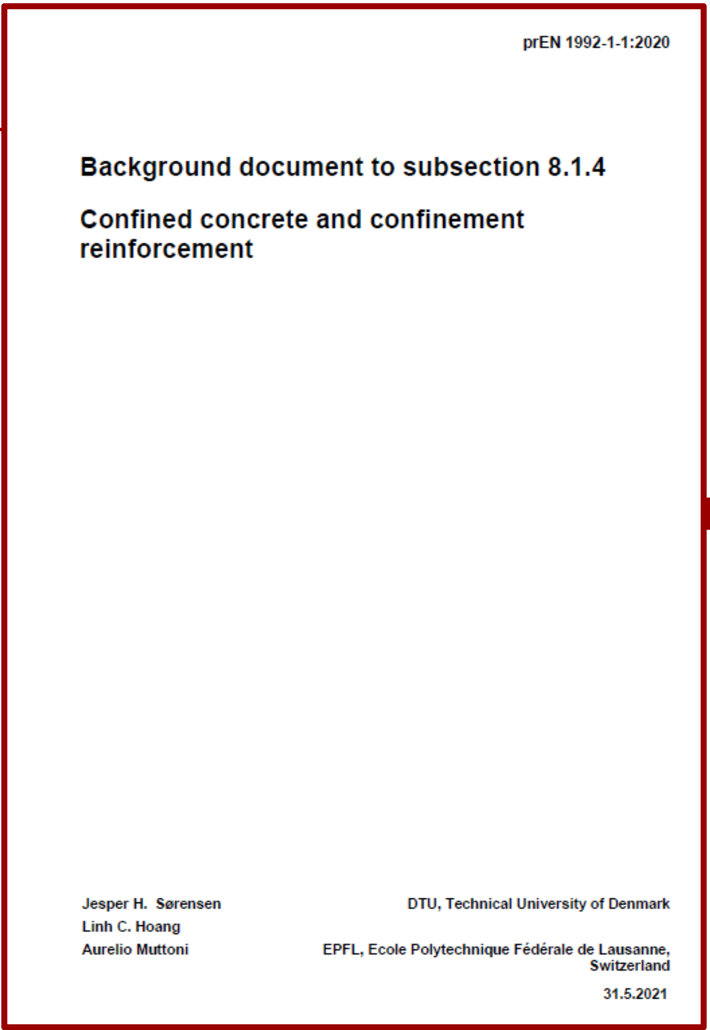
In case of concrete with $d_{dg} < 32$ mm, the strength increase Δf_{cd} according to Formulae (8.6) shall be reduced by factor $d_{dg}/32$ mm.



Future EN-1992-1-1. ULS, members in compression

fib MC2010





prEN 1992-1-1:2020

Background document to subsection 8.1.4

Confined concrete and confinement reinforcement

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31.5.2021

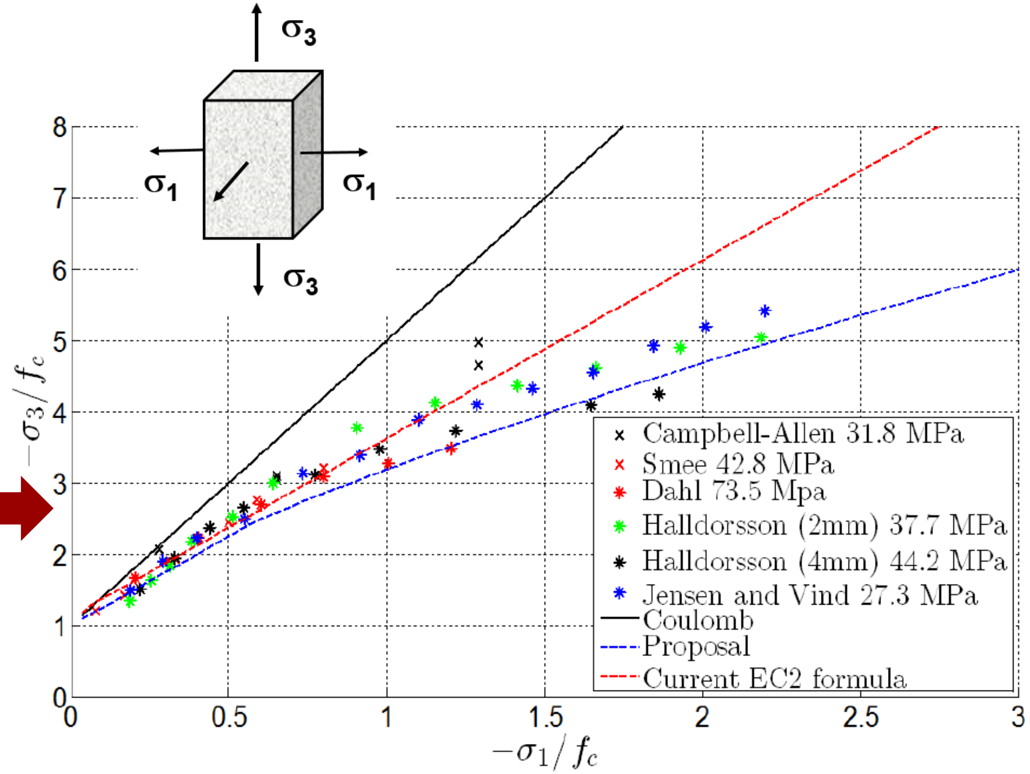
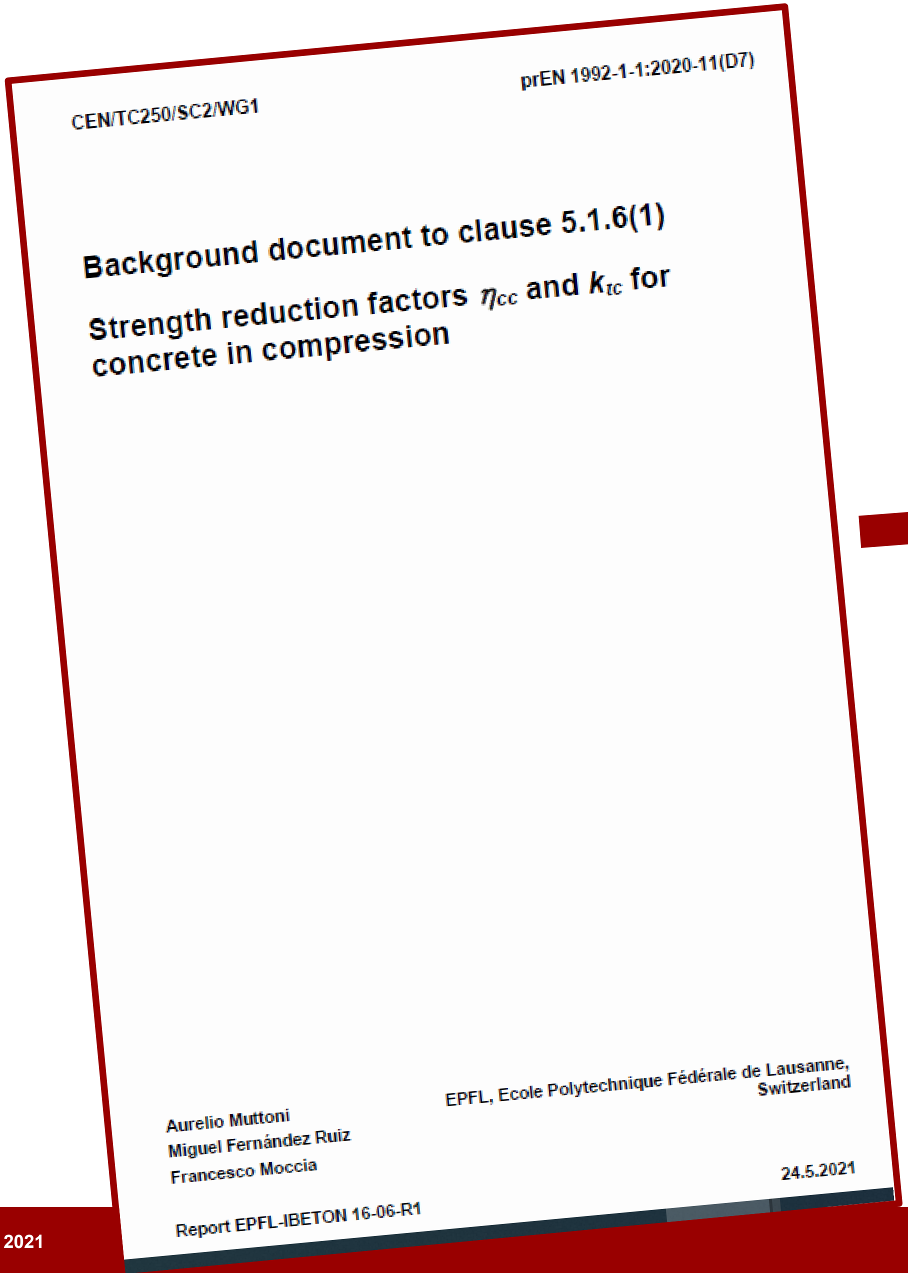


Figure C8.1.4: *Comparison to test results from literature, mortar with $D_{max} \leq 4.75$ mm*

x - Specimens of size 150x300 mm

** - Specimens of size 100x200 mm*

Future EN-1992-1-1. ULS, members in compression



CEN/TC250/SC2/WG1

prEN 1992-1-1:2020-11(D7)

Background document to clause 5.1.6(1)

Strength reduction factors η_{cc} and k_{tc} for concrete in compression

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24.5.2021

Report EPFL-IBETON 16-06-R1

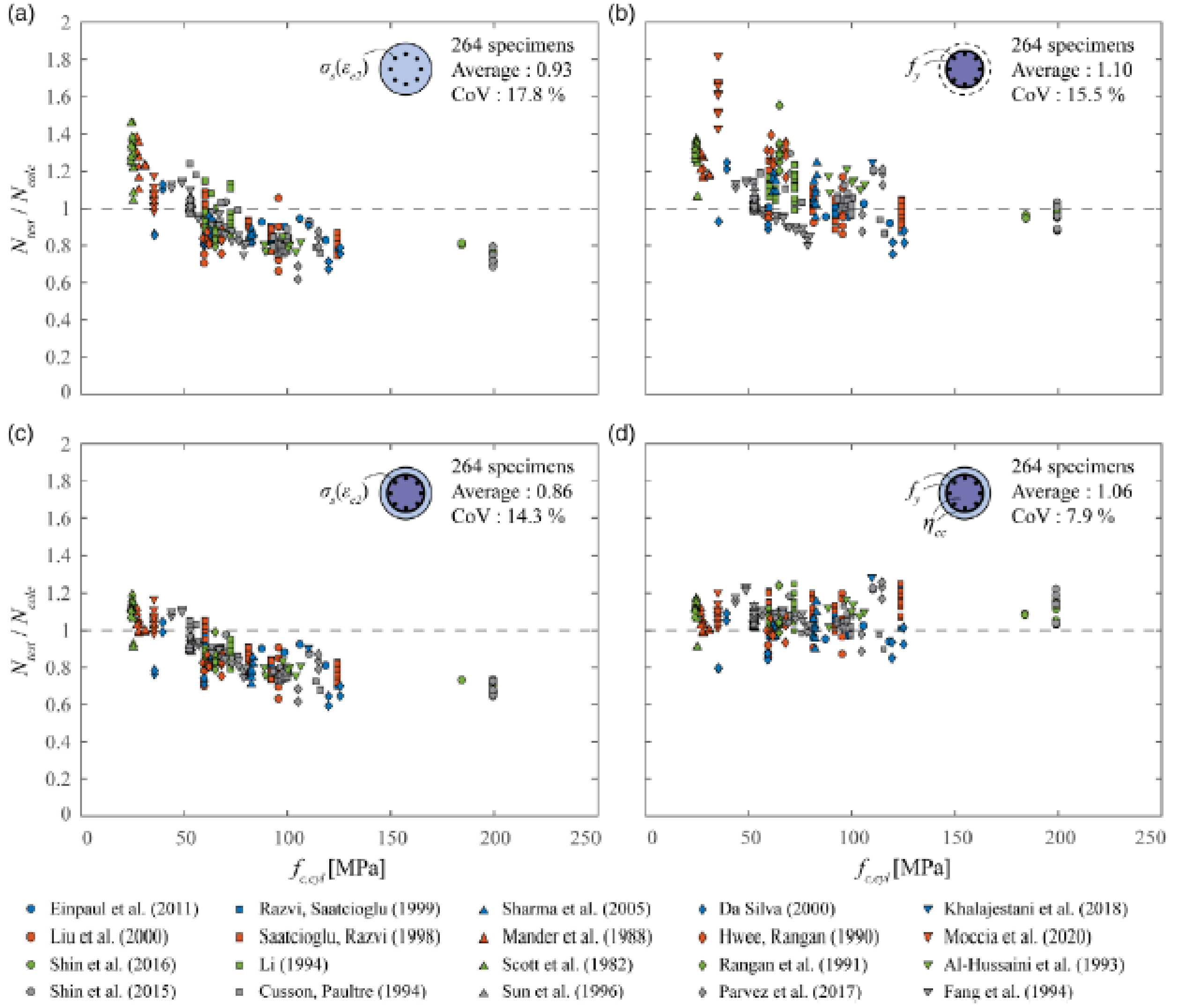


Figure C5.3 : Ratio between the measured failure load and the calculated axial load of centrically loaded column specimens as a function of the cylinder compressive strength of concrete $f_{c,cyl}$, for the definition of the 4 cases, see text below (from [Moccia et al., 2020])

Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems

Current EC2

Section 6
ULS – member design

6.1
M & (M,N)-interaction

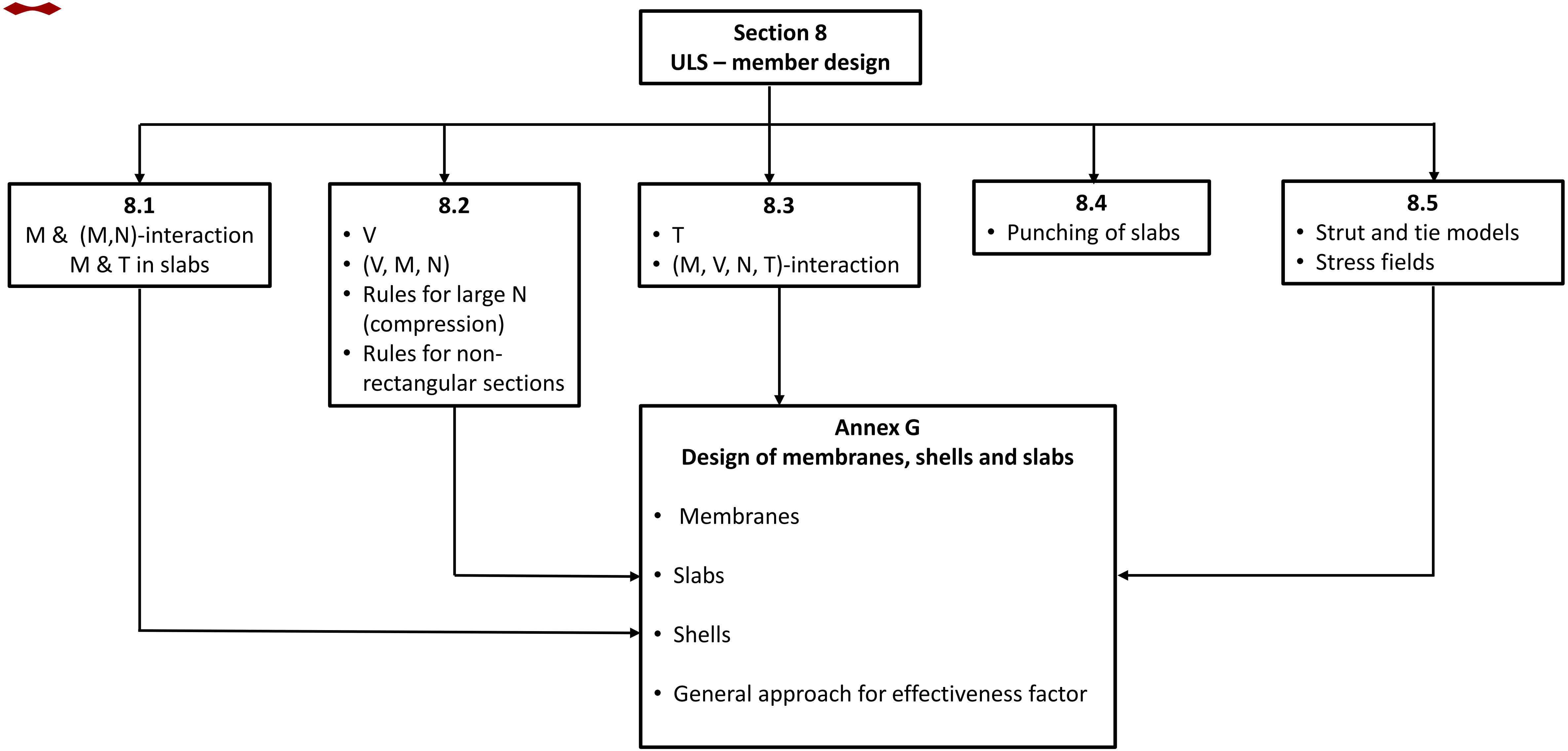
6.2
- V
- (V, M, N)

6.3
- T

6.4
- Punching of slabs

6.5
- Strut and tie models

Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems



Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems

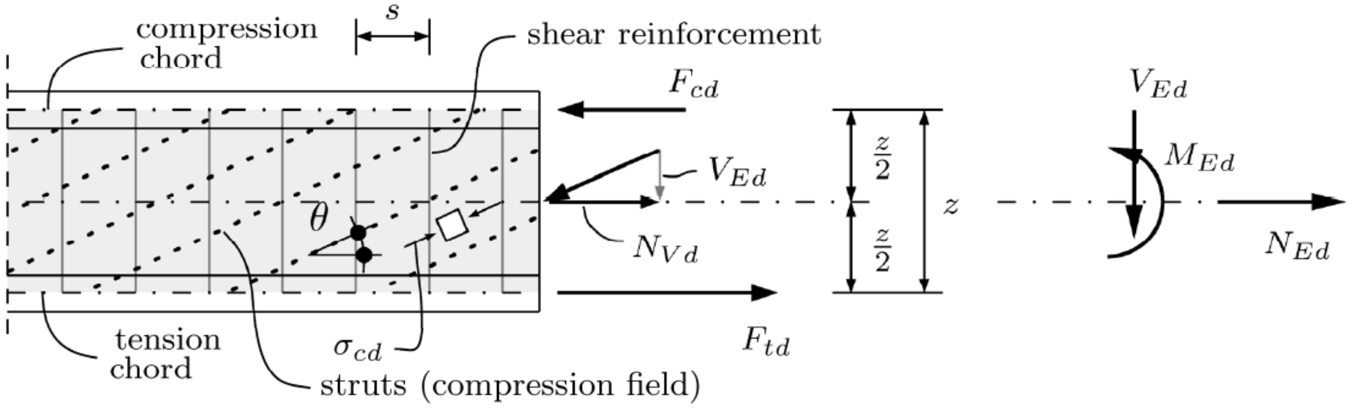


Figure 8.9: Model and notation for shear reinforced members

Simplified approach →

(5) A value $\nu = 0{,}5$ may be adopted when using the angles of the compression field given in (3).

(6) Angles of the compression field inclination to the member axis lower than θ_{min} given in (3) or values of factor ν higher than according to (5) may be adopted provided that the ductility class of the reinforcement is B or C and that the value of factor ν is calculated on the basis of the state of strains of the member according to:

Semi-general approach →

$$\nu = \frac{1}{1{,}0 + 110 \cdot (\varepsilon_x + (\varepsilon_x + 0{,}001) \cdot \cot^2\theta)} \leq 1{,}0 \quad (8.32)$$

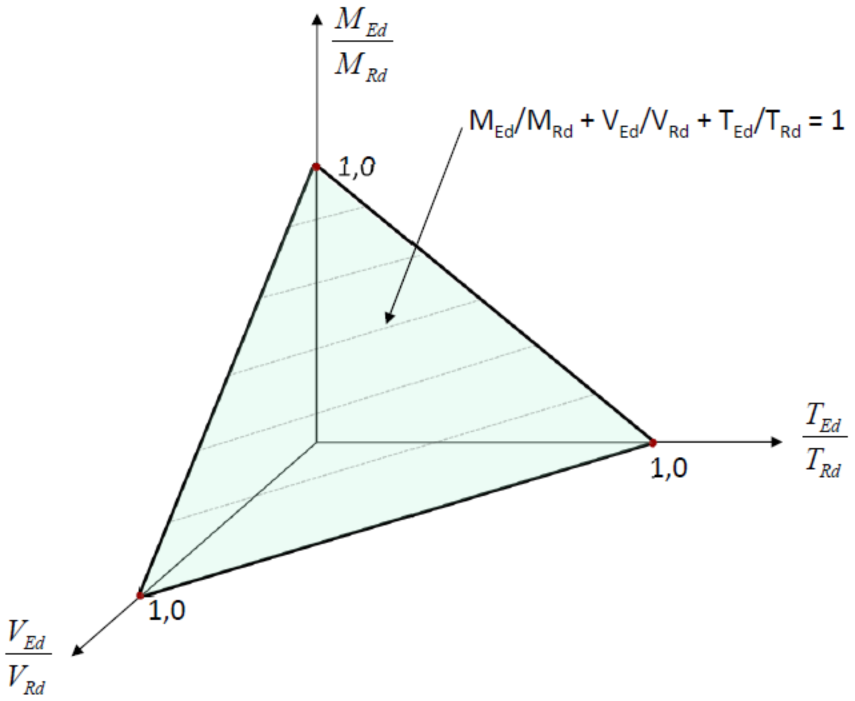
A more refined calculation of the reduction factor of concrete may be performed using:

General approach →

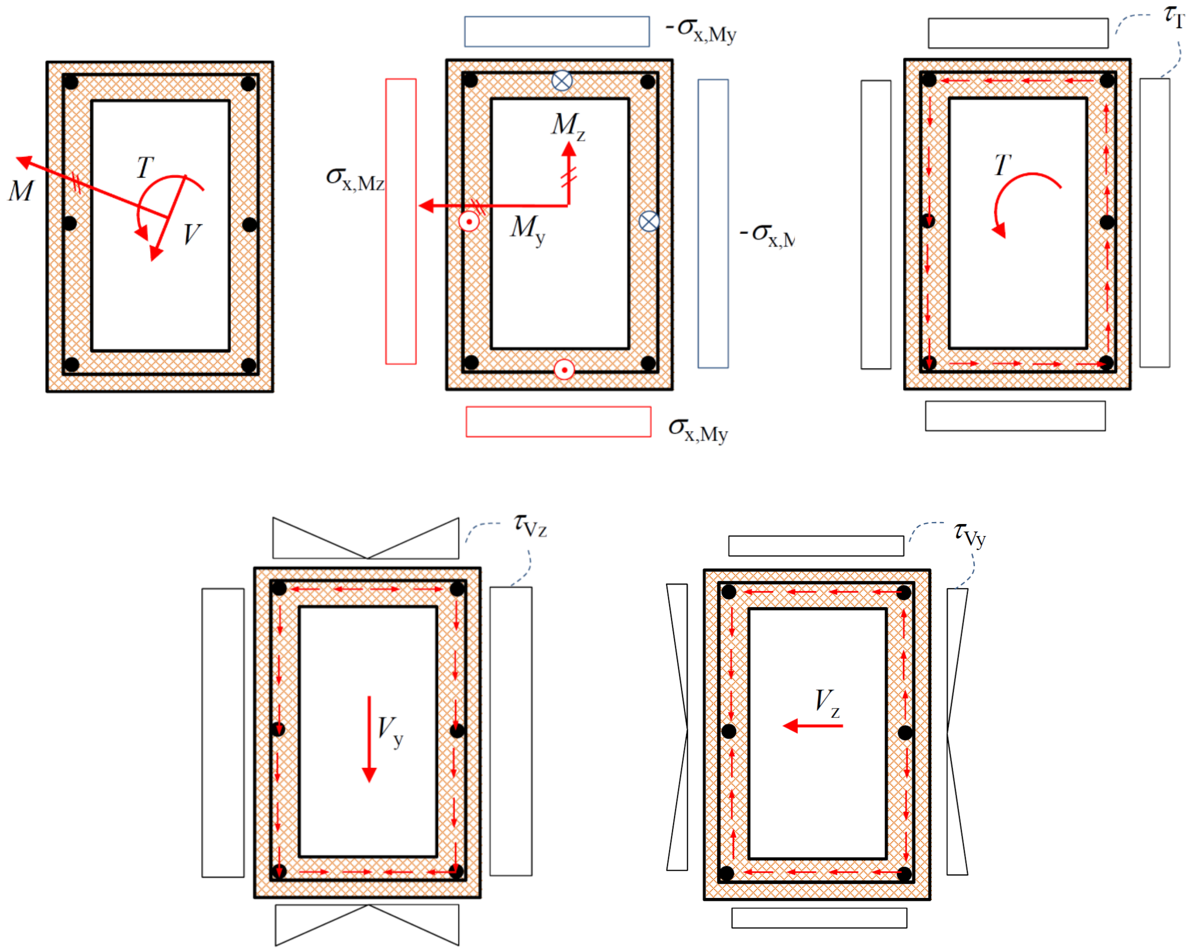
$$\nu = \frac{1}{1{,}0 + 110 \cdot \varepsilon_1} \leq 1{,}0 \quad (G.9)$$

Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems

Combined action, Simple approach:



Combined action, general approach based on Annex G:



Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems

Design by stringer method & general stress fields will be allowed.

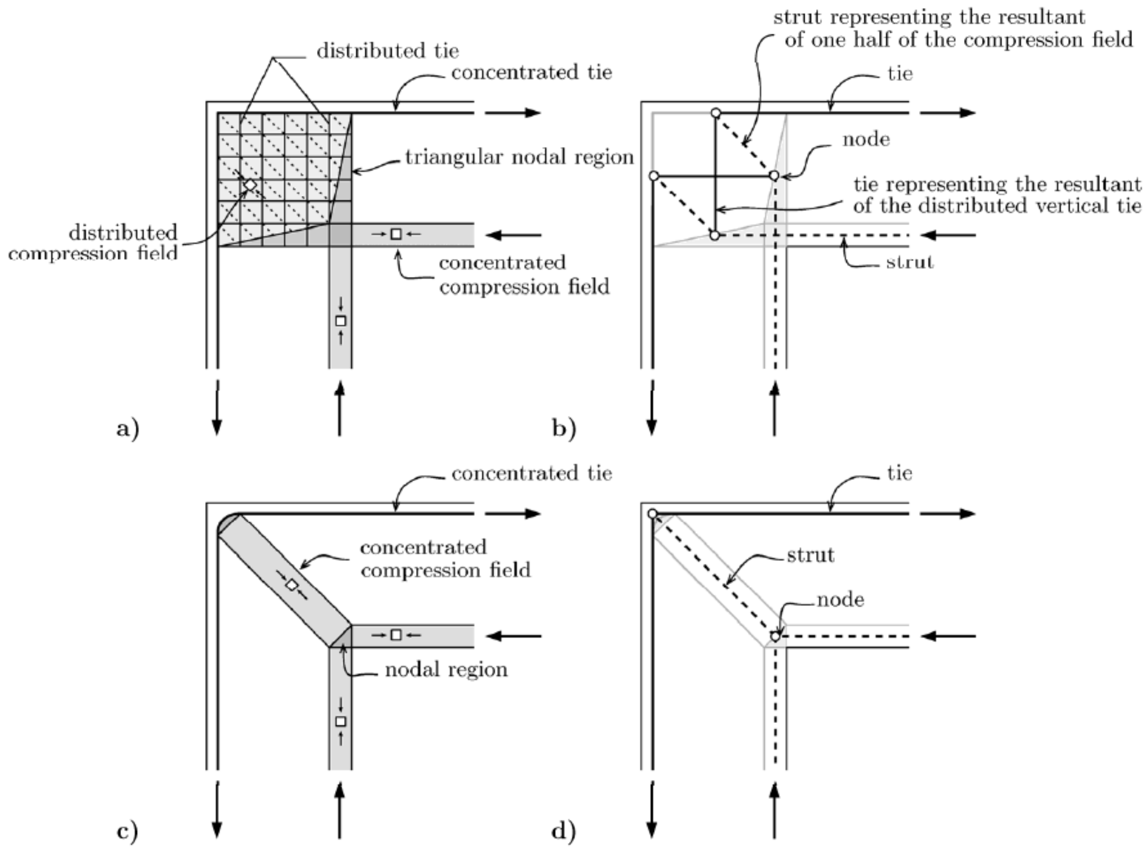


Fig. 8.25: Examples of stress fields and strut-and-tie models: (a) distributed stress field, (b) corresponding strut-and-tie model; (c) concentrated stress field; and (d) corresponding strut-and-tie model

Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems

Verification of shear and punching in slabs will be based on The Critical Shear Crack Theory

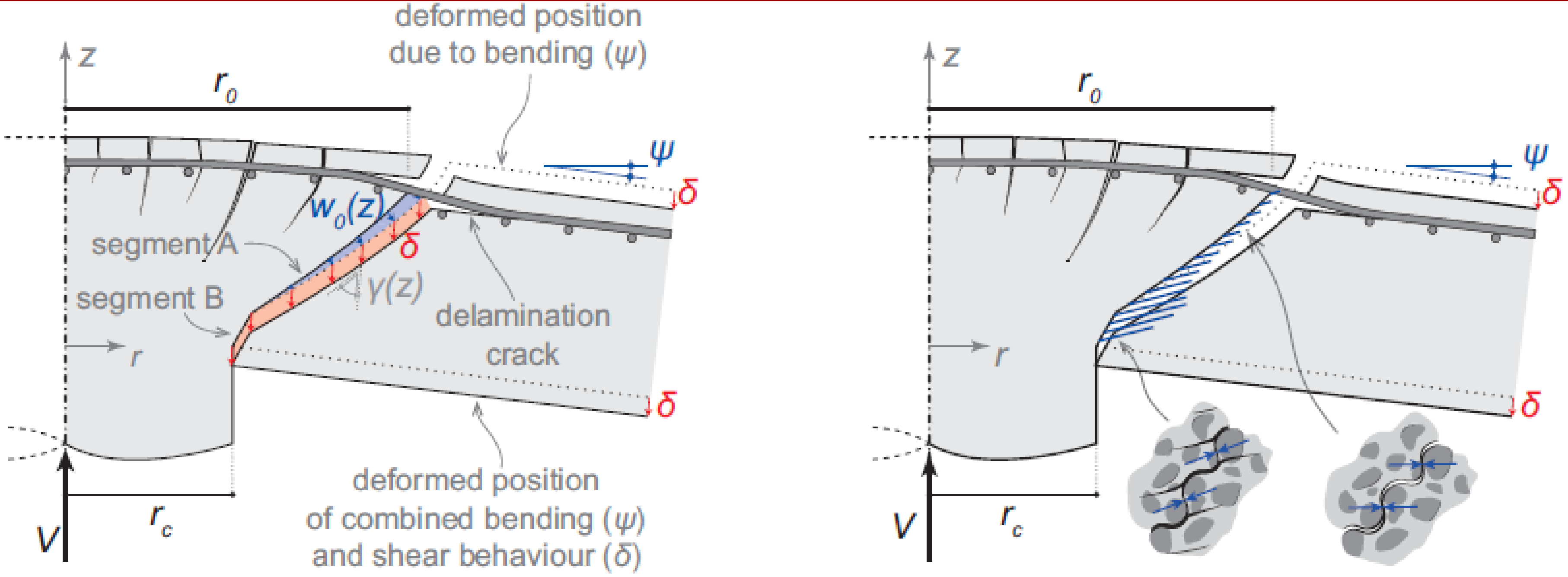


***Figure C8.2:** Theoretical principles of the mechanical model of Critical Shear Crack Theory: (a) kinematics of the critical shear crack at failure and resulting (b) internal stresses (adapted from [C8.4]).*

Future EN-1992-1-1. ULS, shear, torsion, punching and general plane stress problems

Verification of shear and punching in slabs will be based on The Critical Shear Crack Theory

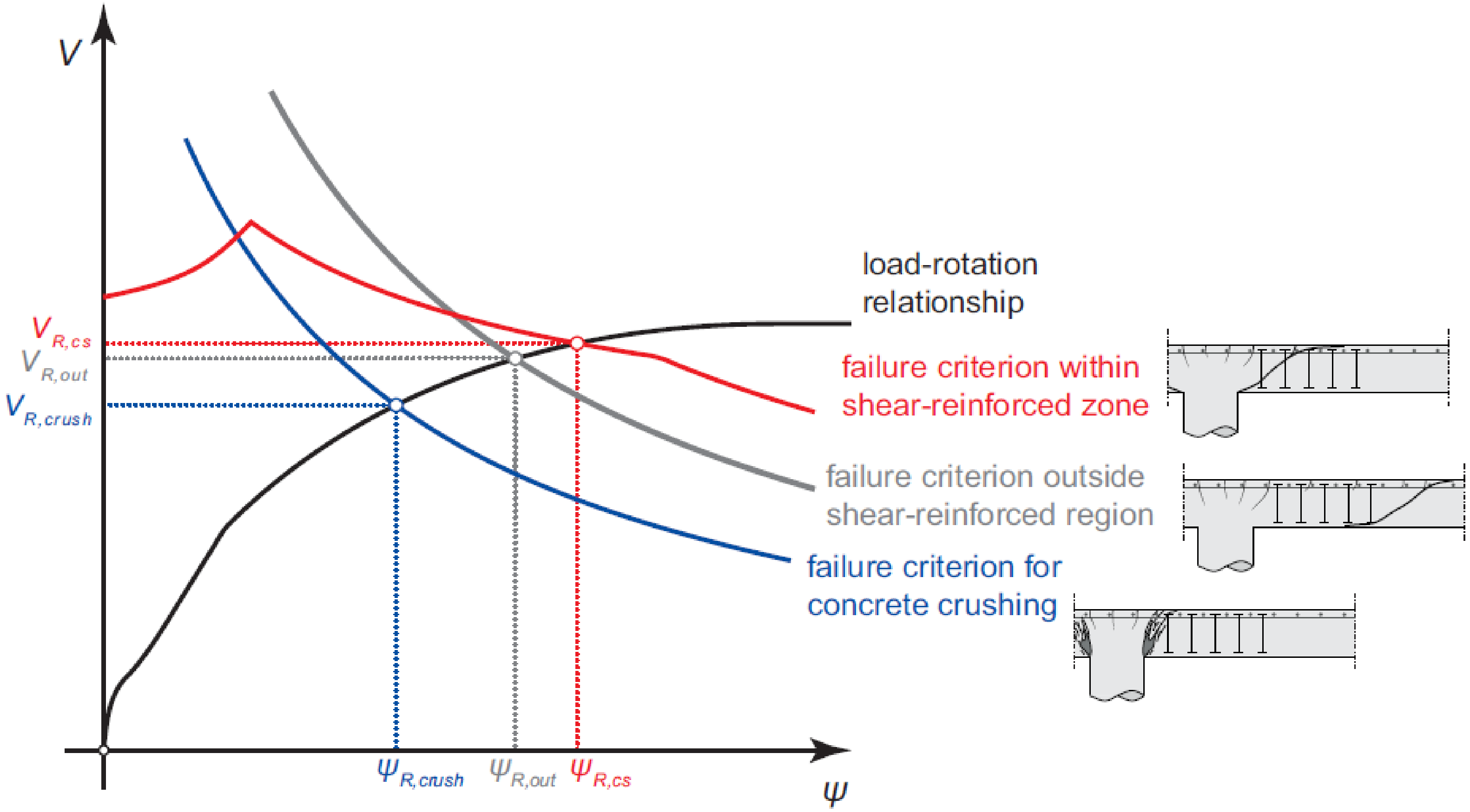
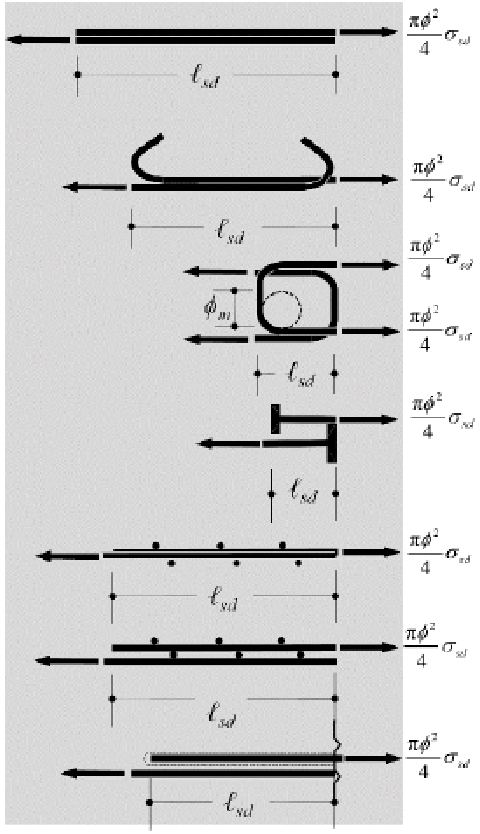
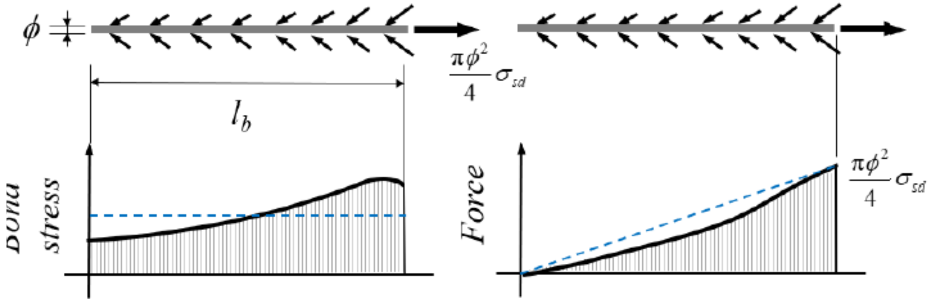


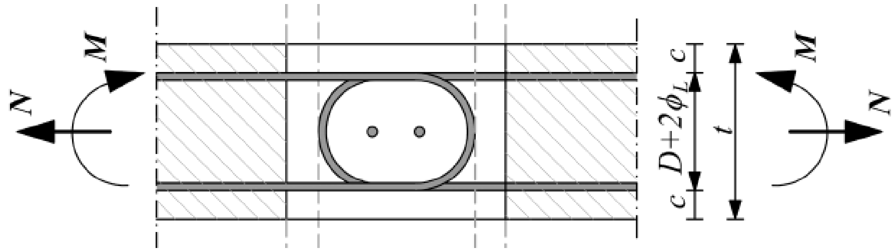
Figure C8.7: *Failure criteria associated to the different failure modes (Eqs. (C8.3) to (C8.5)) and intersection with load-rotation relationship (failure modes adapted from [C8.5])*

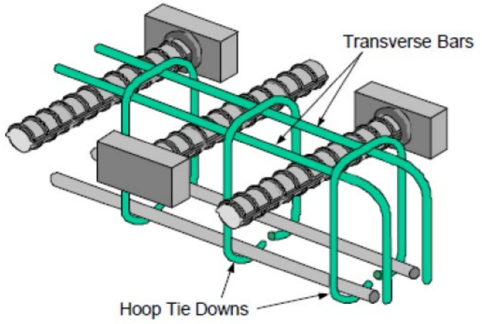
Future EN-1992-1-1. ULS, Anchorage & laps

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

Type of lap splice		Design lap length l_{sd}: Tension laps	Design lap length l_{sd}: Compression laps
 ((preliminary figure!!!!)	straight bars	$l_{sd} = l_{bd} \geq 15\phi$ where l_{bd} is calculated according to 11.4.2, see also 11.5.3	$l_{sd} = l_{bd} \geq 15\phi$ where l_{bd} is calculated according to 11.4.2, see also 11.5.3
	bends and hooks (tension only)	$l_{sd} = l_{bd} \geq 15\phi$ where l_{bd} is calculated according to 11.4.3, see also 11.5.3	–
	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	l_{sd} is calculated according to 11.5.5
	intermeshed fabric	$l_{sd} = l_{bd} \geq \max\{15\phi;\ 250\text{ mm}\}$ where l_{bd} is calculated according to 11.4.5	$l_{sd} = l_{bd} \geq \max\{15\phi;\ 250\text{ mm}\}$ where l_{bd} is calculated according to 11.4.5
	layered fabric	$l_{sd} = l_{bd} + 2\phi \geq \max\{15\phi;\ 250\text{ mm}\}$ where l_{bd} is calculated according to 11.4.5	$l_{sd} = l_{bd} + 2\phi \geq \max\{15\phi;\ 250\text{ mm}\}$ where l_{bd} is calculated according to 11.4.5
	bonded post-installed reinforcement	$l_{sd,pi} = l_{bd,pi} \geq \max\{15\phi;\ 250\text{ mm}\}$ where $l_{bd,pi}$ is calculated according to 11.4.8	$l_{sd,pi} = l_{bd,pi} \geq \max\{15\phi;\ 250\text{ mm}\}$ where $l_{bd,pi}$ is calculated according to 11.4.8







Future EN-1992-1-1. Minimum reinforcement

12.2 Minimum reinforcement rules

(1) In members designed as parts of reinforced concrete structures, minimum reinforcement $A_{s,min}$ shall be provided to:

a) ensure distributed cracking and to handle forces from restrained deformations where not considered explicitly in the design ((2) and (4));

b) ensure sufficient deformation capacity to contribute to structural robustness by allowing alternative load paths ((2) and (4));

c) avoid failures due to unpredicted cracking (3);

d) ensure applicability of design models in Clauses 8 and 9 and Annex G;

e) ensure constructability

NOTE 1 Additional provisions for crack control at SLS are given in 9.2.2.

NOTE 2 The area of minimum reinforcement $A_{s,min}$ can include prestressed and ordinary reinforcement when bonded to the concrete.

Future EN-1992-1-1. Detailing of members and particular rules

Table 12.4(NDP) — Detailing requirements for reinforcement in walls and deep beams

	Description	Symbol	Requirement
1	Minimum amount of vertical reinforcement (each surface): — where the member carries in-plane normal and shear stresses and designed/verified by use of 8.5 or Annex G. — where the member is only loaded by vertical in-plane compression and out of plane bending	$A_{s,min,v}$	 $0{,}25A_c \cdot \frac{f_{ctm}}{f_{yk}}$ $0{,}001A_c$
2	Minimum amount of horizontal reinforcement (each face): — where the member carries in-plane normal and shear stresses and designed/verified by use of 8.5 or Annex G. — where the member is only loaded by vertical in-plane compression and out of plane bending.	$A_{s,min,h}$	 $0{,}25A_c \cdot \frac{f_{ctm}}{f_{yk}}$ $0{,}25A_{s,v}$
3	Maximum spacing of vertical reinforcement		min{3h[a]; 400 mm}
4	Maximum spacing of horizontal reinforcement		400 mm
5	Maximum spacing of orthogonal-to-the-surface reinforcement where $A_{s,v}$ exceeds $0{,}02A_c$ and is utilised in compression (end region is taken as $\geq 4h$ [a])		see 12.6.

[a] h – thickness of wall

Future EN-1992-1-1. Minimum reinforcement for robustness

Deem to work

(2) The area of minimum reinforcement $A_{s,min}$ shall provide nominal section strength which is at least equal to the effect causing cracking:

a) In members subjected to bending without or with axial force and any form of cross section, minimum reinforcement shall be provided so that:

$$M_{R,min}(N_{Ed}) \geq M_{cr}(N_{Ed}) \quad (12.1)$$

Performance based

(3) Where $M_{Ed} < M_{cr}(N_{Ed})$, the member is designed as statically determinate and where no distribution of cracking is required, a sudden collapse after cracking may also be avoided with a minimum reinforcement designed for following resistance:

$$M_{Rd,min}(N_{Ed}) = k_{dc} \cdot M_{Ed} \quad (12.3)$$

where $M_{Rd,min}$ is the design bending strength of the section in the presence of the simultaneous axial force N_{Ed}, M_{Ed} is the ULS bending force and k_{dc} is a coefficient which depends on the ductility class of the reinforcement:

— $k_{dc} = 1{,}3$ for ductility class A,

— $k_{dc} = 1{,}1$ for ductility class B,

— $k_{dc} = 1{,}0$ for ductility class C.

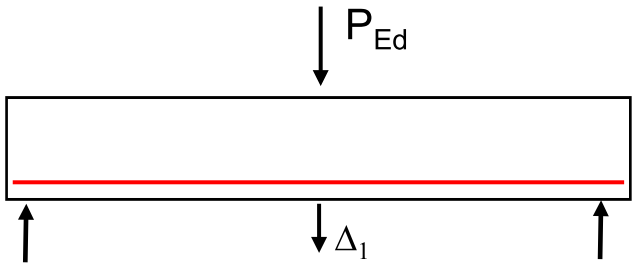
The area of reinforcement calculated need not be taken as greater than determined from Formula (12.1).

NOTE 3 Use of Formula (12.3) can result in wide cracks in SLS.

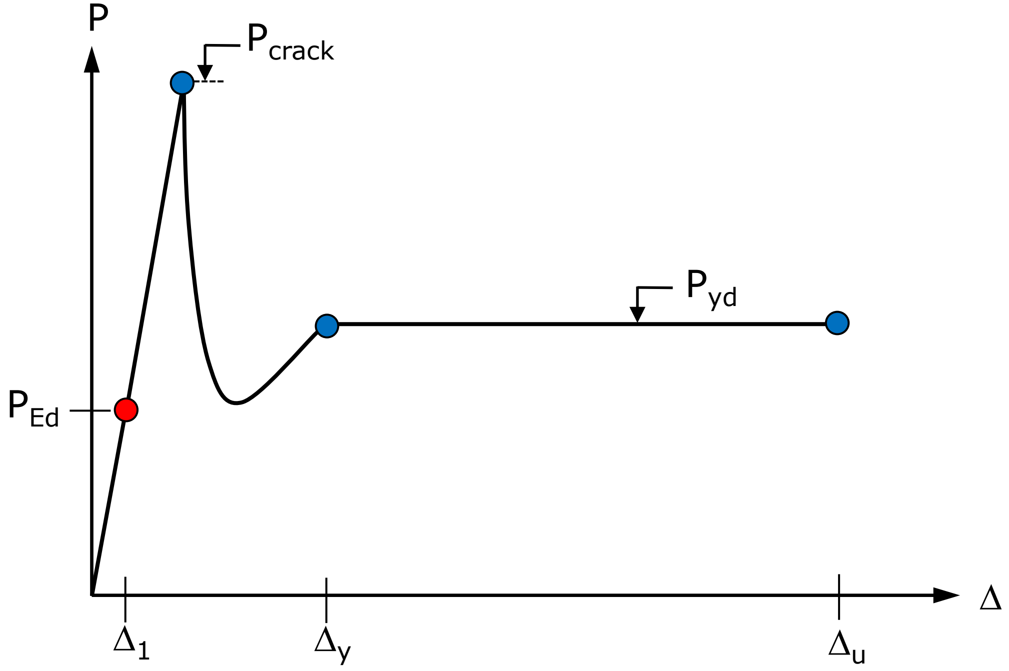
Future EN-1992-1-1. Minimum reinforcement for robustness

Performance based approach for minimum reinforcement for robustness:

$\mathbf{P_{Ed} < P_{yd} < P_{cr}}$



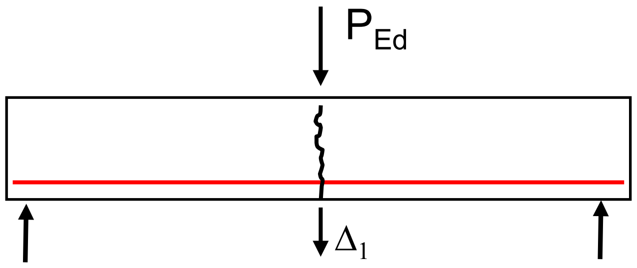
ULS-verification of beam ($P_{Ed} < P_{yd}$) is based on the assumption of reinforced, cracked member. But the beam actually carries P_{Ed} as unreinforced/uncracked member.



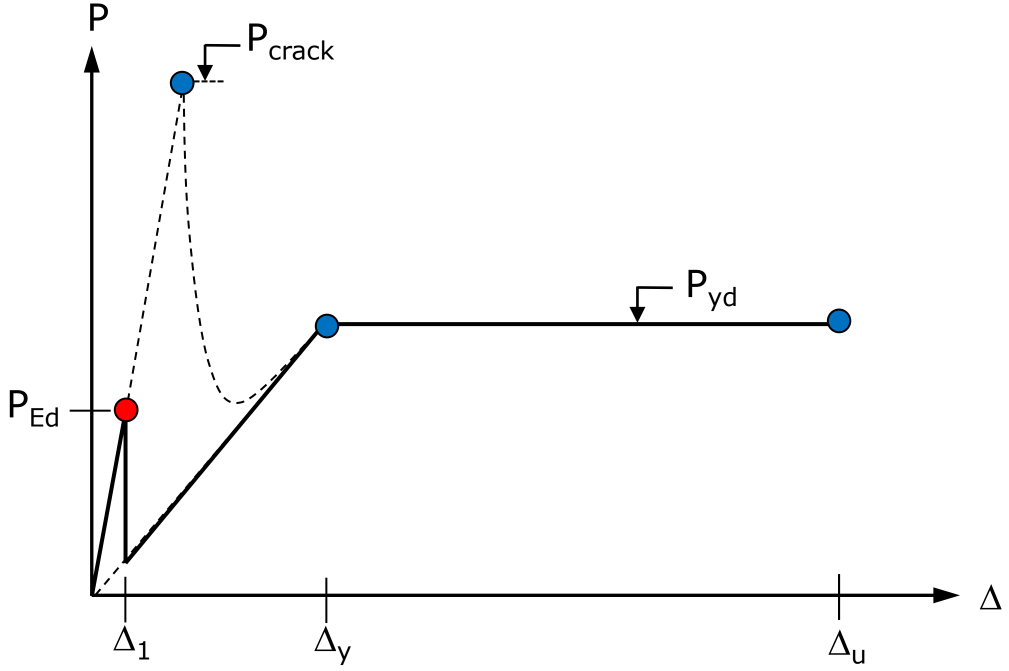
Future EN-1992-1-1. Minimum reinforcement for robustness

Performance based approach for minimum reinforcement for robustness:

$P_{Ed} < P_{yd} < P_{cr}$



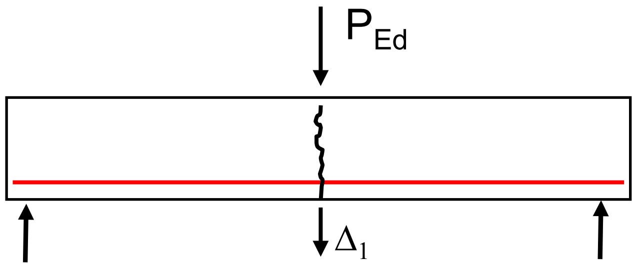
Sudden local loss of tensile strength at mid span section (e.g. cracking due to restrained temperature action) while the member still carries P_{Ed}



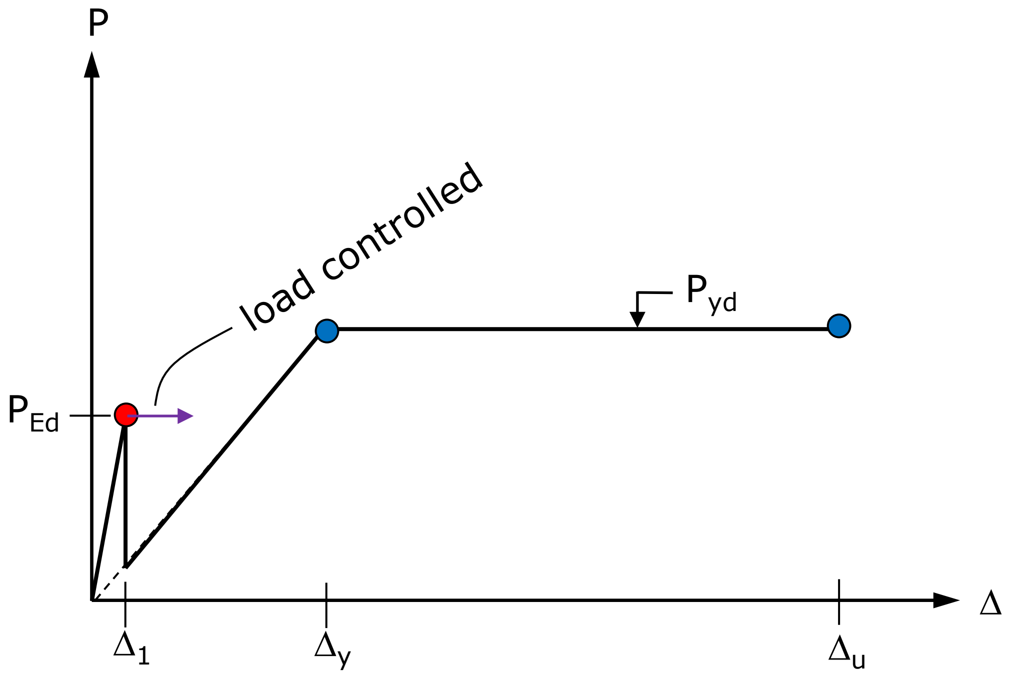
Future EN-1992-1-1. Minimum reinforcement for robustness

Performance based approach for minimum reinforcement for robustness:

$\mathbf{P_{Ed} < P_{yd} < P_{cr}}$



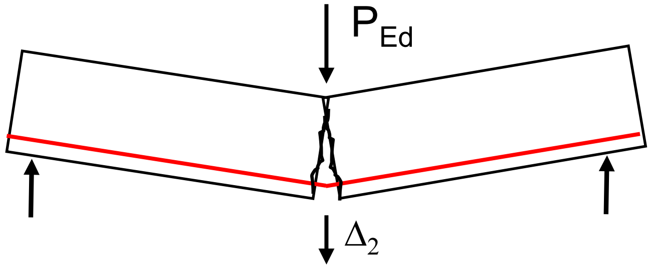
Loss of static equilibrium → Dynamic increase of displacement



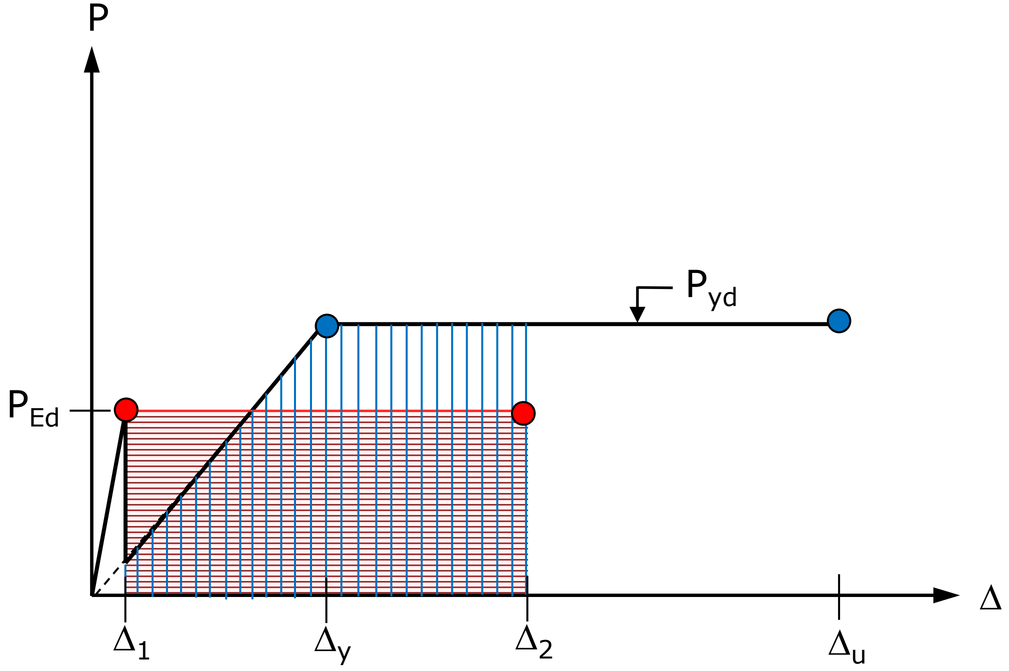
Future EN-1992-1-1. Minimum reinforcement for robustness

Performance based approach for minimum reinforcement for robustness:

$\mathbf{P_{Ed} < P_{yd} < P_{cr}}$



Blue area = Internal work
(dissipated energy)



Schedule & Deadlines for EN-1992-1-1 & -1-2

- CEN Enquiry: September 2021 – December 2021
- CEN Final Vote: November 2022
- Availability: March 2023
- Translation and development of national annexes: From 2023
- Withdrawal of 1st generation of Eurocodes : 2028

DTU