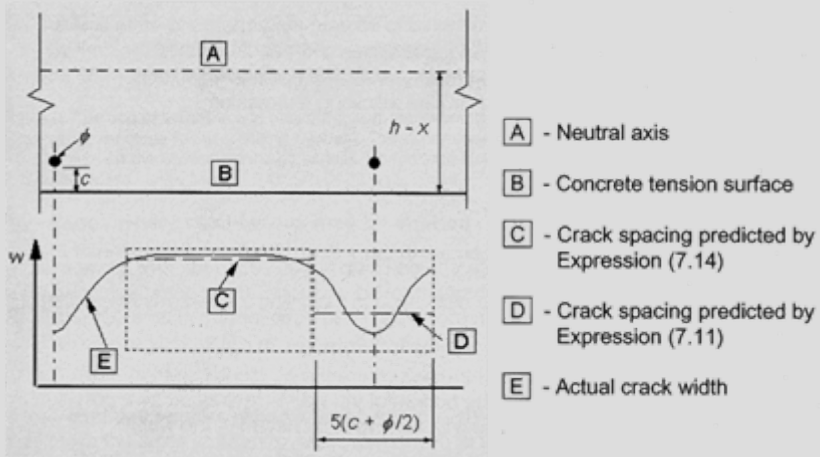
Eurocode 2 - HC-design

Focus on the requirements in the serviceability limit states; in particular cracking



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General

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SECTION 7 SERVICEABILITY LIMIT STATES (SLS)

7.1 General

(1)P This section covers the common serviceability limit states. These are:

- stress limitation (see 7.2) ✓
- crack control (see 7.3) ✓
- deflection control (see 7.4) ✓

Other limit states (such as vibration) may be of importance in particular structures but are not covered in this Standard.

(2) In the calculation of stresses and deflections, cross-sections should be assumed to be uncracked provided that the flexural tensile stress does not exceed $f_{ct,eff}$. The value of $f_{ct,eff}$ may be taken as f_{ctm} or $f_{ctm,fl}$ provided that the calculation for minimum tension reinforcement is also based on the same value. For the purposes of calculating crack widths and tension stiffening f_{ctm} should be used.

?

Crack control - general

7.3 Crack control

7.3.1 General considerations

(1)P Cracking shall be limited to an extent that will not impair the proper functioning or durability of the structure or cause its appearance to be unacceptable.

(6) For members with only unbonded tendons, the requirements for reinforced concrete elements apply. For members with a combination of bonded and unbonded tendons requirements for prestressed concrete members with bonded tendons apply.

Crack control - general

(5) A limiting calculated crack width, w_{max}, taking into account the proposed function and nature of the structure and the costs of limiting cracking, should be established.

Note: The value of w_{max} for use in a Country may be found in its National Annex. The recommended values for relevant exposure classes are given in Table 7.1N.

related to note → recommended value.

Table 7.1N Recommended values of w_{max} (mm)

Exposure Class	Reinforced members and prestressed members with unbonded tendons	Prestressed members with bonded tendons
	Quasi-permanent load combination	Frequent load combination
X0, XC1	0,4[1]	0,2
XC2, XC3, XC4	0,3	0,2[2]
XD1, XD2, XS1, XS2, XS3		Decompression

Note 1: For X0, XC1 exposure classes, crack width has no influence on durability and this limit is set to guarantee acceptable appearance. In the absence of appearance conditions this limit may be relaxed.

Note 2: For these exposure classes, in addition, decompression should be checked under the quasi-permanent combination of loads.

Crack control - general

(9) Crack widths may be calculated according to 7.3.4. A simplified alternative is to limit the bar size or spacing according to 7.3.3.

No topic(s) about minimum reinforcement in the general considerations of crack control! ?

Crack control – min. reinforcement

7.3.2 Minimum reinforcement areas

(1)P If crack control is required, a minimum amount of bonded reinforcement is required to control cracking in areas where tension is expected. The amount may be estimated from equilibrium between the tensile force in concrete just before cracking and the tensile force in reinforcement at yielding or at a lower stress if necessary to limit the crack width.

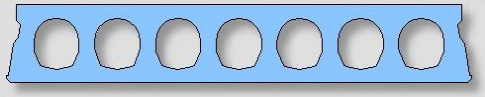
→ Crack control is required → determine the min. reinforcement ✓

(4) In prestressed members no minimum reinforcement is required in sections where, under the characteristic combination of loads and the characteristic value of prestress, the concrete is compressed or the absolute value of the tensile stress in the concrete is below $\sigma_{ct,p}$.

Note: The value of $\sigma_{ct,p}$ for use in a Country may be found in its National Annex. The recommended value is $f_{ct,eff}$ in accordance with 7.3.2 (2).

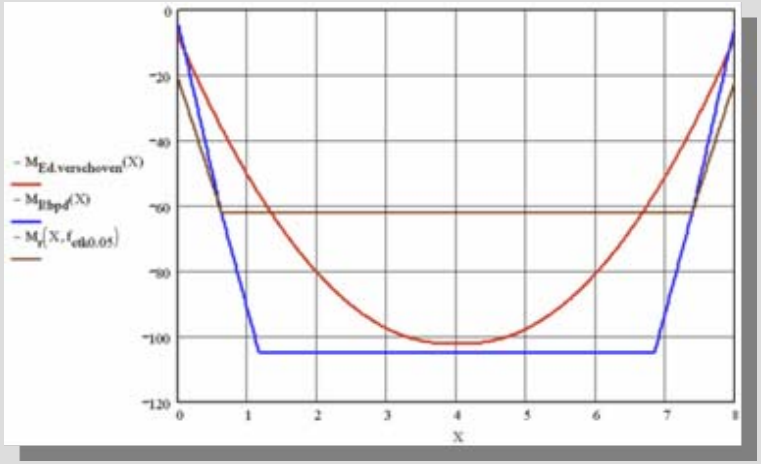
? No minimum reinforcement needed and no crack control needed?

Crack control – min. reinforcement

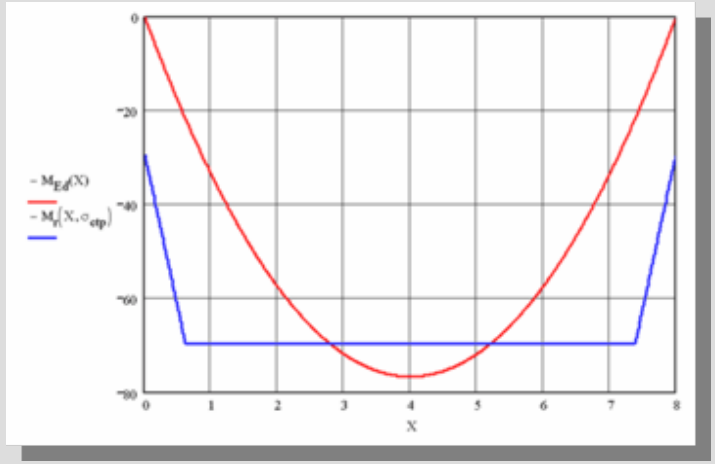


HC 200 mm
8 strands ∅9,3 mm a=32 mm 1100 MPa

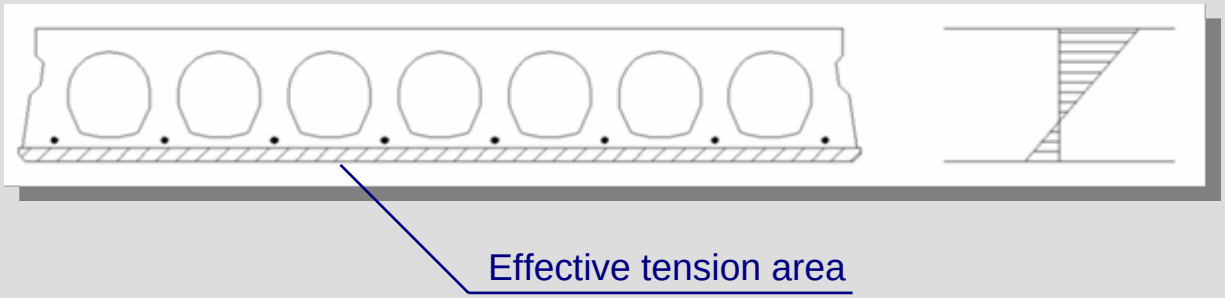
ULS:



SLS:



Crack control – min. reinforcement



Depth of the effective tension area = the lesser of:

2,5 . (h – d)

(h – x) / 3

or

h/2 = 19 mm

No strands in the effective tension area!

Requirements not satisfied!

Crack control – min. reinforcement

(3) Bonded tendons in the tension zone may be assumed to contribute to crack control within a distance ≤ 150 mm from the centre of the tendon. This may be taken into account by adding the term $\xi_1 A_p' \Delta\sigma_p$ to the left hand side of Expression (7.1),

where

A_p' is the area of pre or post-tensioned tendons within $A_{c,eff}$.

$A_{c,eff}$ is the effective area of concrete in tension surrounding the reinforcement or prestressing tendons of depth, $h_{c,ef}$, where $h_{c,ef}$ is the lesser of 2,5(h-d), (h-x)/3 or h/2 (see Figure 7.1).

ξ_1 is the adjusted ratio of bond strength taking into account the different diameters of prestressing and reinforcing steel:

$$= \sqrt{\xi \cdot \frac{\phi_s}{\phi_p}} \qquad (7.5)$$

ξ ratio of bond strength of prestressing and reinforcing steel, according to Table 6.2 in 6.8.2.

ϕ_s largest bar diameter of reinforcing steel

ϕ_p equivalent diameter of tendon according to 6.8.2

If only prestressing steel is used to control cracking, $\xi_1 = \sqrt{\xi}$.

$\Delta\sigma_p$ Stress variation in prestressing tendons from the state of zero strain of the concrete at the same level

Crack control – min. reinforcement

Nevertheless assume that the strands are in the effective tension area:

$\Delta\sigma_p$ = 10 N/mm^2 Due to small relative strain of the concrete

$$A_{p,min} = \frac{k_c \cdot k \cdot f_{ct,eff} \cdot A_{ct}}{\sqrt{\xi}\Delta\sigma_p}$$

$A_{p,min}$ = 21600 !!??

? Interpretation of the calculation of the minimum reinforcement is UNCLEAR!

Calculation of crack widths

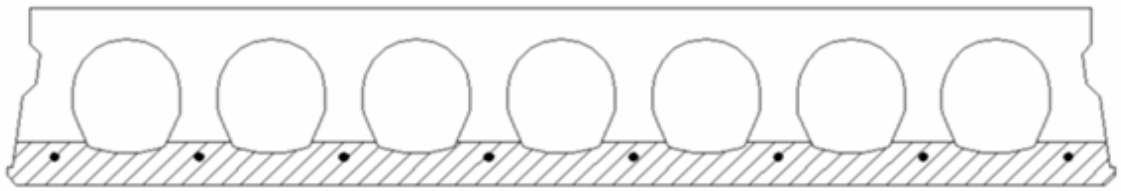
7.3.3 Control of cracking without direct calculation

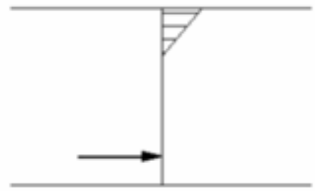
or

7.3.4 Calculation of crackwidths

? Only calculation when tensile stress exceeds $\sigma_{ct,p}$?

Cracked situation:





$\Delta\sigma_p$ = 117 N/mm^2

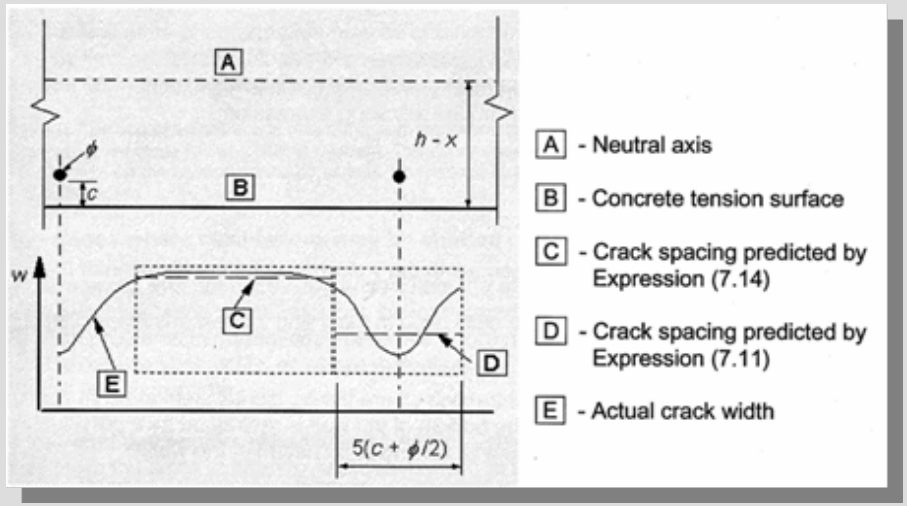
Calculation of crack widths

Strain variation:
$\varepsilon_{sm} - \varepsilon_{cm} = 0{,}00037$

Calculated crack spacing($S_{r,max}$):

Expression 7.11: 484 mm
Expression 7.14: 190 mm

?



Crack width:

$wk = S_{r,max}(\varepsilon_{sm} - \varepsilon_{cm}) = 0{,}18$ mm (< 0,20)

Calculation of crack widths

Other calculation examples:

HC 200 mm	10 strands	∅9,3	wk = 0,18
HC 200 mm	6 strands	∅12,5	wk = 0,05
HC 200 mm	8 strands	∅12,5	wk = 0,09
HC 400 mm	8 strands	∅12,5	wk = 0,41 !!
HC 400 mm	10 strands	∅12,5	wk = 0,26

? What if strands are above the effictive tension area?

Note: in Dutch NDP: multiply value of w_{max} (7.1N) with: $\frac{c_{applied}}{c_{nominal}} \leq 2$

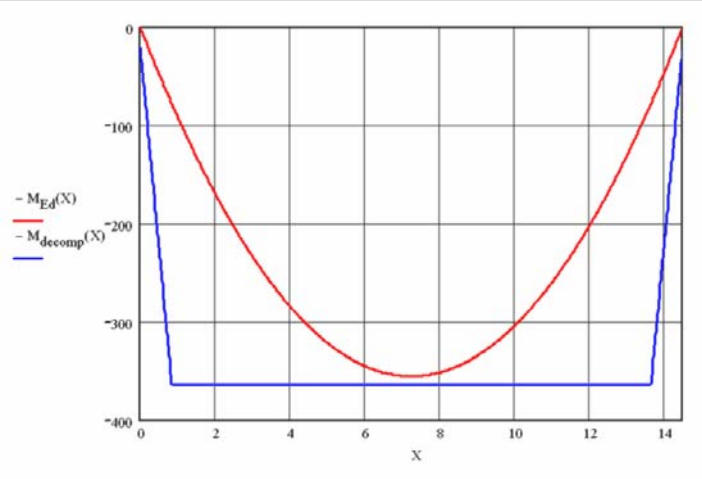
Crack control – decompression

Exposureclass XC3

HC 400 mm

14 strands ∅12,5 mm a=52 mm 1100 MPa

SLS: Decompression



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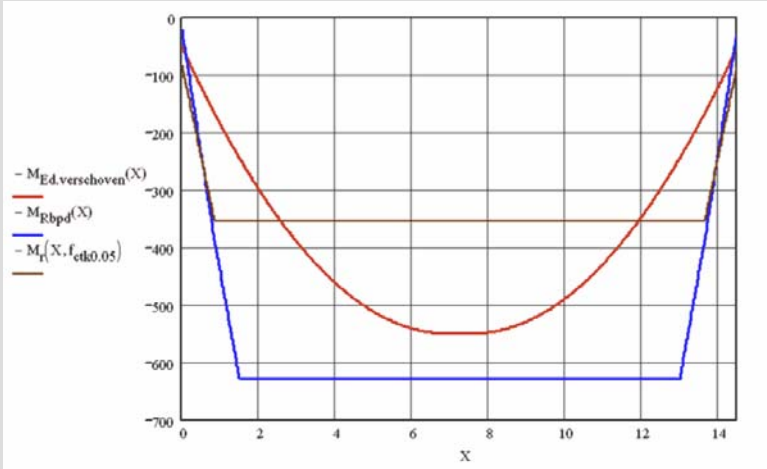

Depends on loadingcase and HC configuration!

Proposal

- Validation by more calulation examples
- Paper with good documented calculation examples published by IPHA