Examples

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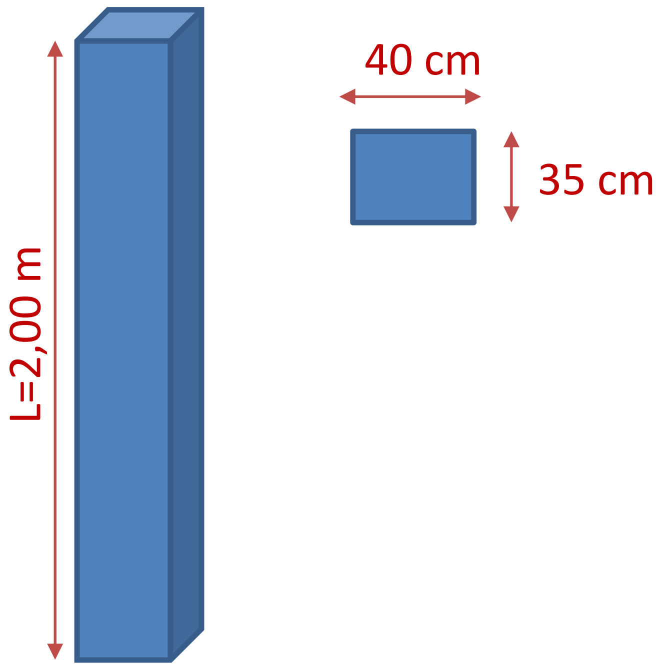
P1. CONCRETE SHRINKAGE

P2. CONCRETE CREEP

P3. CONCRETE CONFINEMENT

Determination of shrinkage / Determinarea contracției

Compute the value of shrinkage for the concrete element



Concrete: **C30/37**

Environmental condition: **Interior RH=40%**

Cement type: **CEM II 42,5N**

Final of the treatment: $\mathbf{t_s = 1}$ **day**

Analysed data:

- **at 7 days after casting**
- **at the end-life (∞)**

Determination of shrinkage / Determinarea contracției

The total shrinkage strain:

$$\boldsymbol{\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}}$$

ε_{cd} - drying shrinkage
ε_{ca} - autogenous shrinkage

The final value of drying shrinkage strain

$$\varepsilon_{cd,\infty} = k_h \cdot \varepsilon_{cd,0}$$

$$h_0 = 2A_c/u$$

Table 3.3 Values for k_h in Expression (3.9)

h_0	k_h
100	1.0
200	0.85
300	0.75
≥ 500	0.70

h_0 - is the notional size (mm) of the cross-section
A_c - is the concrete cross-sectional area ;
u - is the perimeter of that part of the cross section which is exposed to drying

Determination of shrinkage / Determinarea contracției

The final value of drying shrinkage strain

$$\varepsilon_{cd,\infty} = k_h \cdot \varepsilon_{cd,0}$$

$$h_0 = 2A_c/u = \frac{2\cdot400\cdot350}{2\cdot(400+350)} =$$

Table 3.3 Values for k_h in Expression (3.9)

h_0	k_h
100	1.0
200	0.85
300	0.75
≥ 500	0.70

$$k_h = 0,88$$

Determination of shrinkage / Determinarea contracției

The final value of drying shrinkage strain

$$\varepsilon_{cd,\infty} = k_h \cdot \varepsilon_{cd,0}$$

$$h_0 = 2A_c/u = \frac{2 \cdot 400 \cdot 350}{2 \cdot (400+350)} = 186{,}7mm$$

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Table 3.2 Nominal unrestrained drying shrinkage values $\varepsilon_{cd,0}$ (in $^0/_{00}$) for concrete with cement CEM Class N

$f_{ck}/f_{ck,cube}$ (MPa)	Relative Humidity (in $^0/_0$)					
	20	40	60	80	90	100
20/25	0.62	0.58	0.49	0.30	0.17	0.00
40/50	0.48	0.46	0.38	0.24	0.13	0.00
60/75	0.38	0.36	0.30	0.19	0.10	0.00
80/95	0.30	0.28	0.24	0.15	0.08	0.00
90/105	0.27	0.25	0.21	0.13	0.07	0.00

Determination of shrinkage / Determinarea contracției

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Determination of shrinkage / Determinarea contracției

The final value of drying shrinkage strain

$$\varepsilon_{cd,\infty} = k_h \cdot \varepsilon_{cd,0} = 0{,}88 \cdot 0{,}52 = \mathbf{0{,}458}‰$$

$$h_0 = 2A_c/u = \frac{2\cdot 400\cdot 350}{2\cdot(400+350)} = 186{,}7mm$$

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Final value of the deformation (t=∞) from drying shrinkage:

$$\Delta \boldsymbol{L}_{\boldsymbol{cd},\infty} = \varepsilon_{cd,\infty} \cdot L =$$

Determination of shrinkage / Determinarea contracției

The final value of drying shrinkage strain

$$\varepsilon_{cd,\infty} = k_h \cdot \varepsilon_{cd,0} = 0{,}88 \cdot 0{,}52 = \mathbf{0{,}458‰}$$

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Final value of the deformation (t=∞) from drying shrinkage:

$$\Delta L_{cd,\infty} = \varepsilon_{cd,\infty} \cdot L = 0{,}458‰ \cdot 2000\ mm = \mathbf{0{,}92mm}$$

Determination of shrinkage / Determinarea contracției

The value of drying shrinkage at 7 days :

$$\varepsilon_{cd}(7days) = \beta_{ds}(t, t_s) \cdot k_h \cdot \varepsilon_{cd,0}$$

$$\beta_{ds}(t, t_s) = \frac{(t - t_s)}{(t - t_s) + 0{,}04\sqrt{{h_0}^3}} =$$

t - is the age of the concrete at the moment considered, in days;

t_s - is the age of the concrete (days) at the beginning of drying shrinkage (or swelling). Normally this is at the end of curing;

Determination of shrinkage / Determinarea contracției

The value of drying shrinkage at 7 days :

$$\varepsilon_{cd}(7days) = \beta_{ds}(t, t_s) \cdot k_h \cdot \varepsilon_{cd,0}$$

$$\beta_{ds}(t, t_s) = \frac{(t-t_s)}{(t-t_s)+0{,}04\sqrt{h_0{}^3}} = \frac{(7-1)}{(7-1)+0{,}04\sqrt{186{,}7^3}} = 0{,}056$$

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Determination of shrinkage / Determinarea contracției

The value of drying shrinkage at 7 days :

$$\varepsilon_{cd}(7days) = \beta_{ds}(t,t_s) \cdot k_h \cdot \varepsilon_{cd,0} = 0{,}056 \cdot 0{,}88 \cdot 0{,}52 = \mathbf{0{,}026}\ ‰$$

$$\beta_{ds}(t,t_s) = \frac{(t-t_s)}{(t-t_s)+0{,}04\sqrt{{h_0}^3}} = \frac{(7-1)}{(7-1)+0{,}04\sqrt{186{,}7^3}} = 0{,}056$$

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Determination of shrinkage / Determinarea contracției

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t - is the age of the concrete at the moment considered, in days;

t_s - is the age of the concrete (days) at the beginning of drying shrinkage (or swelling). Normally this is at the end of curing;

The value of deformation from drying shrinkage at 7 days :

$$\Delta \boldsymbol{L}_{\boldsymbol{cd},\mathbf{7}} = \varepsilon_{cd}(7days) \cdot L =$$

Determination of shrinkage / Determinarea contracției

The value of drying shrinkage at 7 days :

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The value of deformation from drying shrinkage at 7 days :

$$\Delta \boldsymbol{L_{cd,7}} = \varepsilon_{cd}(7days) \cdot L = 0{,}026‰ \cdot 2000\ mm = \mathbf{0{,}05mm}$$

Determination of shrinkage / Determinarea contracției

The final value of autogenous shrinkage strain

$$\varepsilon_{ca,\infty} = 2{,}5(f_{ck} - 10) \cdot 10^{-6} =$$

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$$\varepsilon_{ca,\infty} = 2{,}5(f_{ck} - 10) \cdot 10^{-6} = 2{,}5(30 - 10) \cdot 10^{-6} = \mathbf{0,05}‰$$

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Final value of the deformation from autogenous shrinkage:

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Final value of the deformation from autogenous shrinkage:

$$\Delta \boldsymbol{L_{ca,\infty}} = \varepsilon_{ca,\infty} \cdot L = 0{,}05‰ \cdot 2000\,mm = \mathbf{0,10mm}$$

The value of autogenous shrinkage at 7 days :

$$\varepsilon_{ca}(7days) = \beta_{as}(7days) \cdot \varepsilon_{ca,\infty}$$

$$\beta_{as}(7days) = 1 - e^{-0{,}2t^{0{,}5}} =$$

Determination of shrinkage / Determinarea contracției

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$$\varepsilon_{ca}(7days) = \beta_{as}(7days) \cdot \varepsilon_{ca,\infty} =$$

$$\beta_{as}(7days) = 1 - e^{-0{,}2t^{0{,}5}} = 1 - e^{-0{,}2\cdot 7^{0{,}5}} = 0{,}411$$

Determination of shrinkage / Determinarea contracției

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The value of autogenous shrinkage at 7 days :

$$\varepsilon_{ca}(7days) = \beta_{as}(7days) \cdot \varepsilon_{ca,\infty} = 0{,}411 \cdot 0{,}05 = \mathbf{0{,}021}‰$$

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Determination of shrinkage / Determinarea contracției

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Final value of the deformation from autogenous shrinkage:

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The value of autogenous autogenous at 7 days :

$$\varepsilon_{ca}(7days) = \beta_{as}(7days) \cdot \varepsilon_{ca,\infty} = 0{,}411 \cdot 0{,}05 = \mathbf{0{,}021}‰$$

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Determination of shrinkage / Determinarea contracției

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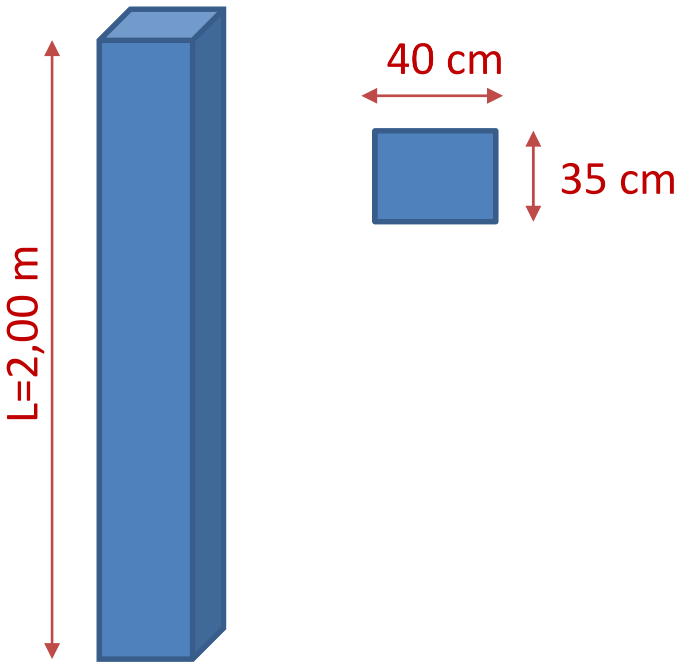
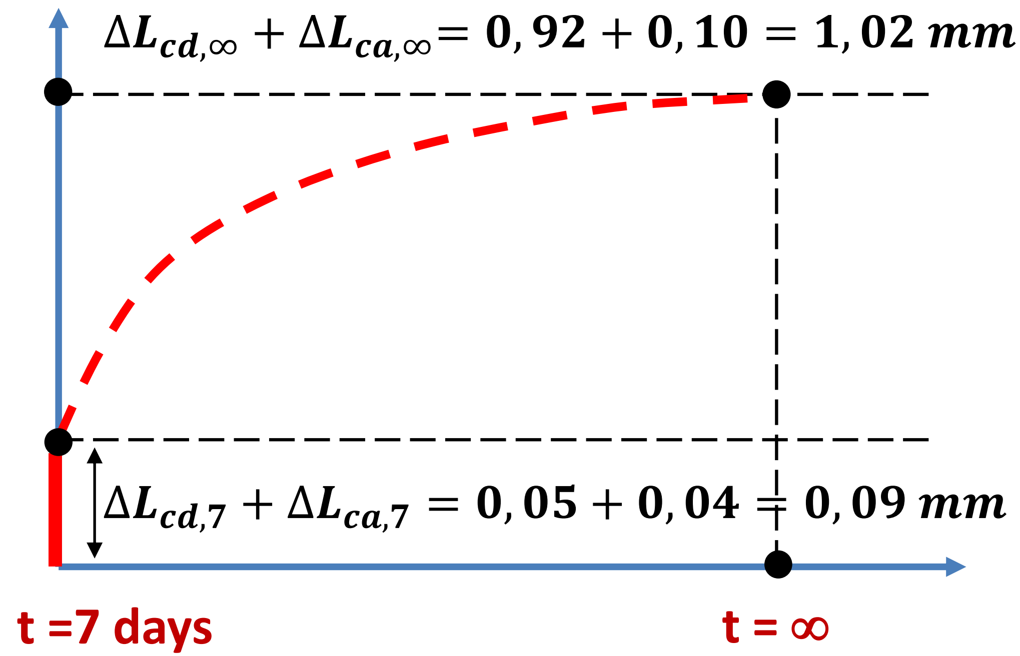
The value of deformation from autogenous shrinkage at 7 days :

$$\Delta \boldsymbol{L}_{\boldsymbol{ca},\mathbf{7}} = \varepsilon_{ca}(7zile) \cdot L = 0{,}021‰ \cdot 2000\, mm = \mathbf{0,04}\boldsymbol{mm}$$

Determination of shrinkage / Determinarea contracției

Deformations from shrinkage of the concrete elemet





Concrete: **C30/37**
Environmental condition: **Interior RH=40%**
Cement type: **CEM II 42,5N**
Final of the treatment: **t_s = 1 zi**

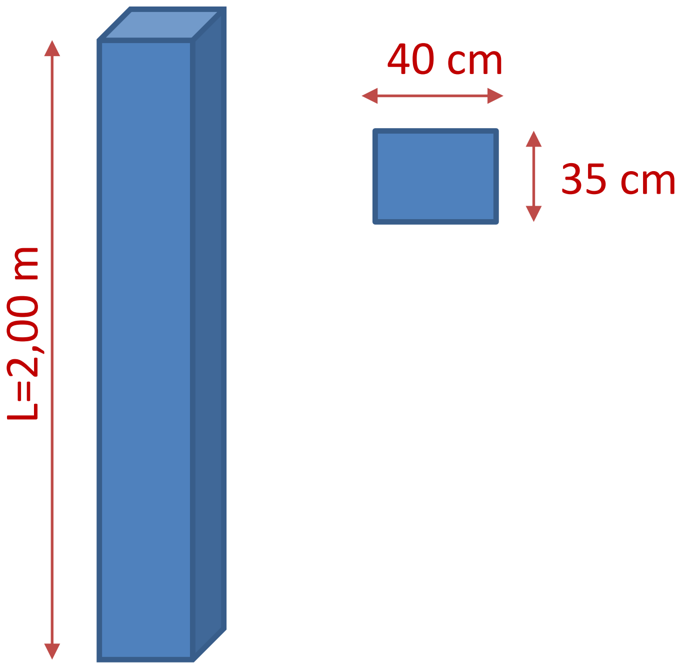
??% from drying shrinkage are consumed in the first 7 days

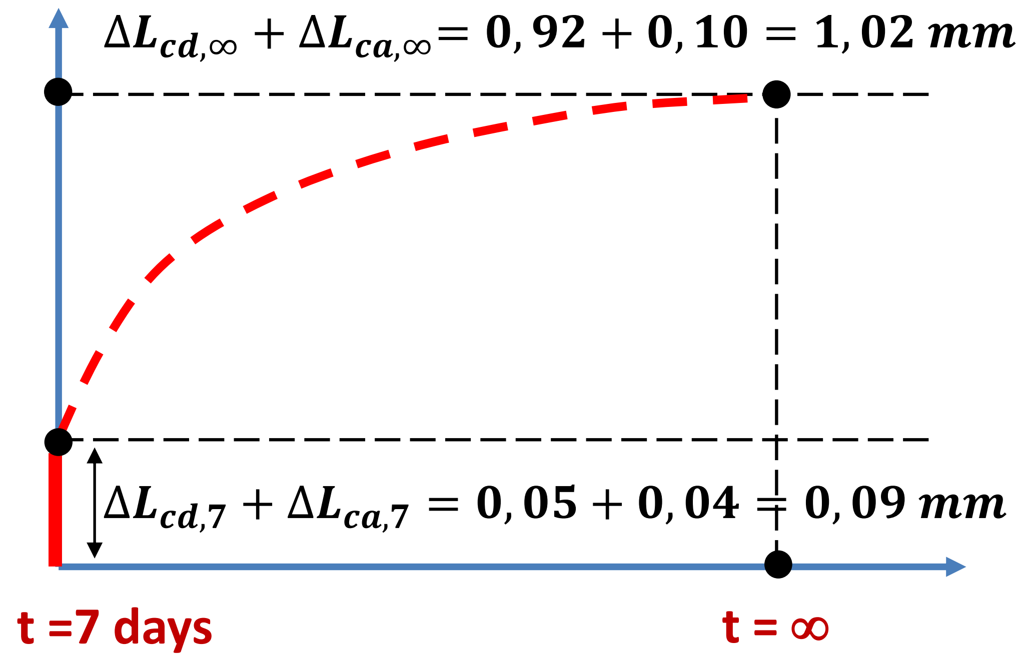
??% from autogenous shrinkage are consumed in the first 7

??% from total shrinkage are consumed in the first 7 days

Determination of shrinkage / Determinarea contracției

Deformations from shrinkage of the concrete elemet





Concrete: **C30/37**
Environmental condition: **Interior RH=40%**
Cement type: **CEM II 42,5N**
Final of the treatment: $\mathbf{t_s = 1}$ **zi**

5% from drying shrinkage are consumed in the first 7 days

40% from autogenous shrinkage are consumed in the first 7

9% from total shrinkage are consumed in the first 7 days

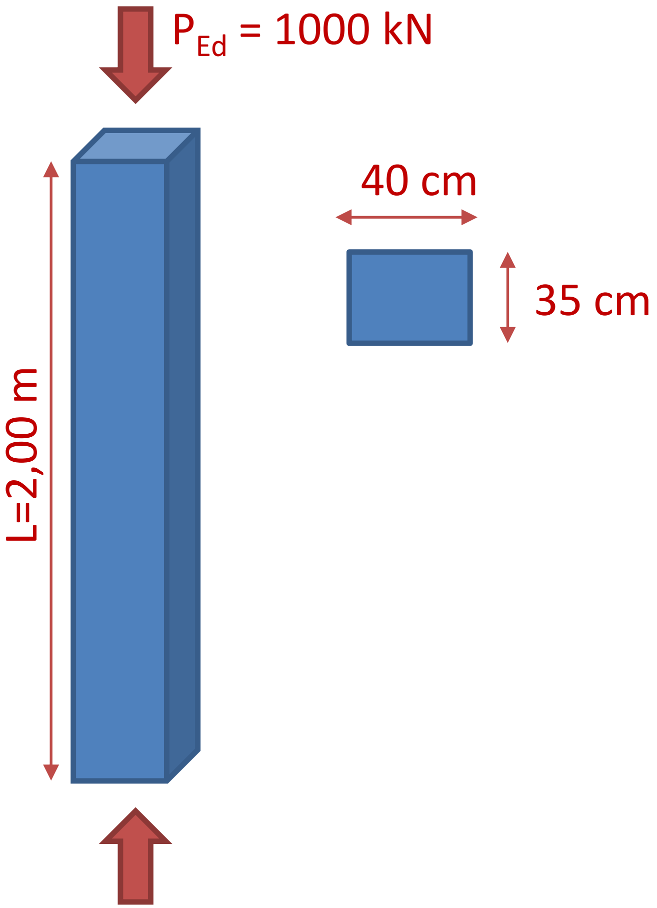
P1. CONCRETE SHRINKAGE

P2. CONCRETE CREEP

P3. CONCRETE CONFINEMENT

Determination of creep / Determinarea curgerii lente

Compute the value of creep for the concrete element



Concrete: **C30/37**

Environmental condition: **Interior RH=50%**

Cement type: **CEM II 52,5R**

First load: **t_0 = 7 days**

Determination of creep / Determinarea curgerii lente

Initial elastic deformation from compression:

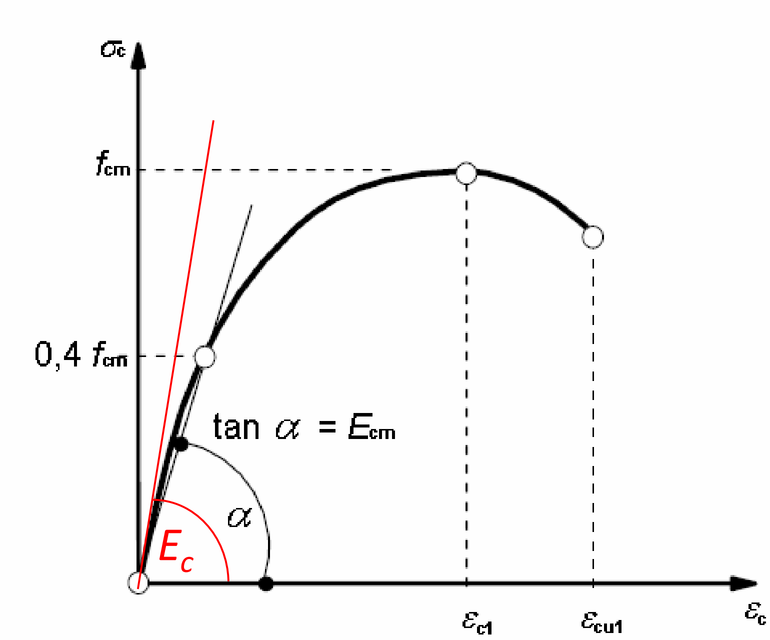
$$\varepsilon_{el} = \frac{\Delta L_{el}}{L} \quad \Rightarrow \quad \Delta L_{el} = \varepsilon_{el} \cdot L = \frac{\sigma_{el}}{E_c} L = \frac{P_{Ed}}{A} \cdot \frac{L}{E_c}$$

where $E_c = 1{,}05 E_{cm}$

At the age of 7 days $\Rightarrow$ $\Delta L_{el}(7\ zile) = \frac{P_{Ed}}{A} \cdot \frac{L}{1{,}05 E_{cm}(7\ zile)}$

E_c - Tangent modulus of elasticity of concrete at 28 days

E_{cm} - Secant modulus of elasticity of concrete



Determination of creep / Determinarea curgerii lente

where

$$E_{cm}(t) = (f_{cm}(t)/f_{cm})^{0.3} \cdot E_{cm}$$

$$f_{cm}(t) = \beta_{cc}(t) f_{cm}$$

$$\beta_{cc}(t) = exp\left\{s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\}$$

$\beta_{cc}(t)$ - is a coefficient which depends on the age of the concrete t

t - is the age of the concrete in days

$f_{cm}(t)$ - is the mean concrete compressive strength at an age of t days

f_{cm} - is the mean compressive strength at 28 days

s - is a coefficient which depends on the type of cement:
= 0,20 for cement of strength Classes CEM 42,5 R, CEM 52,5 N and CEM 52,5 R (Class R)
= 0,25 for cement of strength Classes CEM 32,5 R, CEM 42,5 N (Class N)
= 0,38 for cement of strength Classes CEM 32,5 N (Class S)

Determination of creep / Determinarea curgerii lente

	Strength classes for concrete														Analytical relation / Explanation
f_{ck} (MPa)	12	16	20	25	30	35	40	45	50	55	60	70	80	90	
$f_{ck,cube}$ (MPa)	15	20	25	30	37	45	50	55	60	67	75	85	95	105	
f_{cm} (MPa)	20	24	28	33	38	43	48	53	58	63	68	78	88	98	$f_{cm} = f_{ck}+8$(MPa)
f_{ctm} (MPa)	1,6	1,9	2,2	2,6	2,9	3,2	3,5	3,8	4,1	4,2	4,4	4,6	4,8	5,0	$f_{ctm}=0,30\times f_{ck}^{(2/3)} \leq$C50/60 $f_{ctm}=2,12\cdot\ln(1+(f_{cm}/10))$ > C50/60
$f_{ctk,0,05}$ (MPa)	1,1	1,3	1,5	1,8	2,0	2,2	2,5	2,7	2,9	3,0	3,1	3,2	3,4	3,5	$f_{ctk,0,05} = 0,7\times f_{ctm}$ 5% fractile
$f_{ctk,0,95}$ (MPa)	2,0	2,5	2,9	3,3	3,8	4,2	4,6	4,9	5,3	5,5	5,7	6,0	6,3	6,6	$f_{ctk,0,95} = 1,3\times f_{ctm}$ 95% fractile
E_{cm} (GPa)	27	29	30	31	33	34	35	36	37	38	39	41	42	44	$E_{cm} = 22[(f_{cm})/10]^{0,3}$ (f_{cm} in MPa)
ε_{c1} (‰)	1,8	1,9	2,0	2,1	2,2	2,25	2,3	2,4	2,45	2,5	2,6	2,7	2,8	2,8	see Figure 3.2 $\varepsilon_{c1}(^0/_{00}) = 0,7\, f_{cm}^{0,31} < 2,8$
ε_{cu1} (‰)	3,5									3,2	3,0	2,8	2,8	2,8	see Figure 3.2 for $f_{ck} \geq 50$ Mpa $\varepsilon_{cu1}(^0/_{00})=2,8+27[(98-f_{cm})/100]^4$
ε_{c2} (‰)	2,0									2,2	2,3	2,4	2, 5	2,6	see Figure 3.3 for $f_{ck} \geq 50$ Mpa $\varepsilon_{c2}(^0/_{00})=2,0+0,085(f_{ck}-50)^{0,53}$
ε_{cu2} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.3 for $f_{ck} \geq 50$ Mpa $\varepsilon_{cu2}(^0/_{00})=2,6+35[(90-f_{ck})/100]^4$
n	2,0									1,75	1,6	1,45	1,4	1,4	for $f_{ck} \geq 50$ Mpa $n=1,4+23,4[(90-f_{ck})/100]^4$
ε_{c3} (‰)	1,75									1,8	1,9	2,0	2,2	2,3	see Figure 3.4 for $f_{ck} \geq 50$ Mpa $\varepsilon_{c3}(^0/_{00})=1,75+0,55[(f_{ck}-50)/40]$
ε_{cu3} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.4 for $f_{ck} \geq 50$ Mpa $\varepsilon_{cu3}(^0/_{00})=2,6+35[(90-f_{ck})/100]^4$

Determination of creep / Determinarea curgerii lente

Initial elastic deformation from compression:

$$\beta_{cc}(7\ days) = exp\left\{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]\right\} =$$

$$f_{cm}(7\ days) = \beta_{cc}(7\ days) f_{cm} =$$

$$E_{cm}(7\ days) = (f_{cm}(7\ days)/f_{cm})^{0.3} \cdot E_{cm} =$$

$$\Delta L_{el}(7\ days) = \frac{P_{Ed}}{A} \cdot \frac{L}{1{,}05E_{cm}} =$$

Determination of creep / Determinarea curgerii lente

Initial elastic deformation from compression:

$$\beta_{cc}(7\ days) = exp\left\{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]\right\} = e^{0,20\left[1-\left(\frac{28}{7}\right)^{1/2}\right]} = e^{-0,2} = 0,819$$

$$f_{cm}(7\ days) = \beta_{cc}(7\ days) f_{cm} =$$

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$$\Delta L_{el}(7\ days) = \frac{P_{Ed}}{A} \cdot \frac{L}{1,05 E_{cm}} =$$

Determination of creep / Determinarea curgerii lente

Initial elastic deformation from compression:

$$\beta_{cc}(7\ days) = exp\left\{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]\right\} = e^{0,20\left[1-\left(\frac{28}{7}\right)^{1/2}\right]} = e^{-0,2} = 0,819$$

$$f_{cm}(7\ days) = \beta_{cc}(7\ days)f_{cm} = 0,819 \cdot 38 = 31,1\ N/mm^2$$

$$E_{cm}(7\ days) = (f_{cm}(7\ days)/f_{cm})^{0.3} \cdot E_{cm} =$$

$$\Delta L_{el}(7\ days) = \frac{P_{Ed}}{A} \cdot \frac{L}{1,05E_{cm}} =$$

Determination of creep / Determinarea curgerii lente

Initial elastic deformation from compression:

$$\beta_{cc}(7\ days) = exp\left\{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]\right\} = e^{0,20\left[1-\left(\frac{28}{7}\right)^{1/2}\right]} = e^{-0,2} = 0,819$$

$$f_{cm}(7\ days) = \beta_{cc}(7\ days)f_{cm} = 0,819 \cdot 38 = 31,1\ N/mm^2$$

$$E_{cm}(7\ days) = (f_{cm}(7\ days)/f_{cm})^{0.3} \cdot E_{cm} = \left(\frac{31,1}{38}\right)^{0.3} \cdot 33000 = 31074\ N/mm^2$$

$$\Delta L_{el}(7\ days) = \frac{P_{Ed}}{A} \cdot \frac{L}{1,05E_{cm}} =$$

Determination of creep / Determinarea curgerii lente

Initial elastic deformation from compression:

$$\beta_{cc}(7\ days) = exp\left\{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]\right\} = e^{0,20\left[1-\left(\frac{28}{7}\right)^{1/2}\right]} = e^{-0,2} = 0,819$$

$$f_{cm}(7\ days) = \beta_{cc}(7\ days)f_{cm} = 0,819 \cdot 38 = 31,1\ N/mm^2$$

$$E_{cm}(7\ days) = (f_{cm}(7\ days)/f_{cm})^{0.3} \cdot E_{cm} = \left(\frac{31,1}{38}\right)^{0.3} \cdot 33000 = 31074\ N/mm^2$$

$$\Delta L_{el}(7\ days) = \frac{P_{Ed}}{A} \cdot \frac{L}{1,05E_{cm}} = \frac{1000\cdot 10^3}{400\cdot 350} \cdot \frac{2000}{1,05\cdot 31074} = 0,438\ mm$$

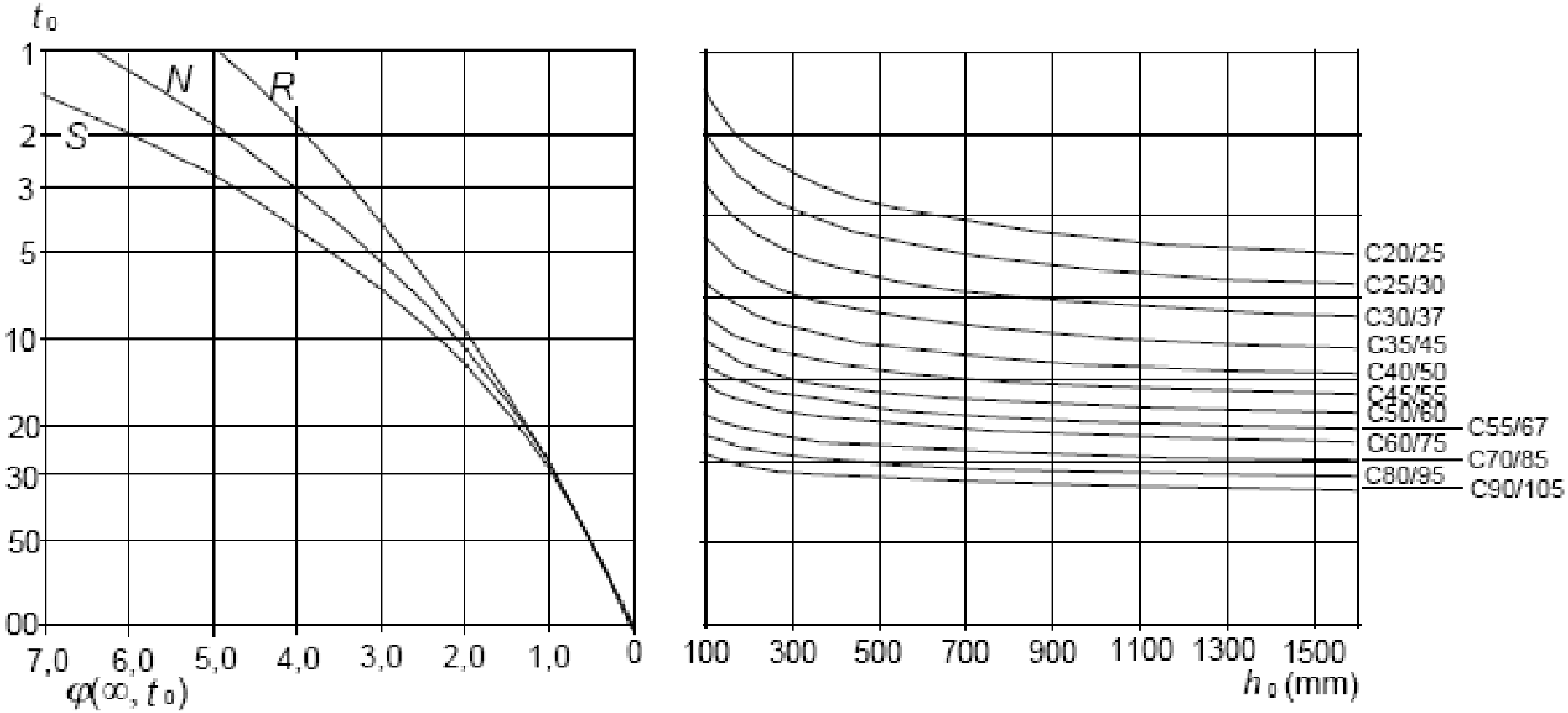
$$\boldsymbol{\Delta L_{el}(7\ days) = 0,438\ mm}$$

Determination of creep / Determinarea curgerii lente

Strain from creep:

$$\varepsilon_{cc}(\infty, t_0) = \varphi(\infty, t_0) \cdot (\sigma_c / E_c) = \varphi(\infty, t_0) \cdot \frac{\sigma_c}{1{,}05 E_{cm}}$$

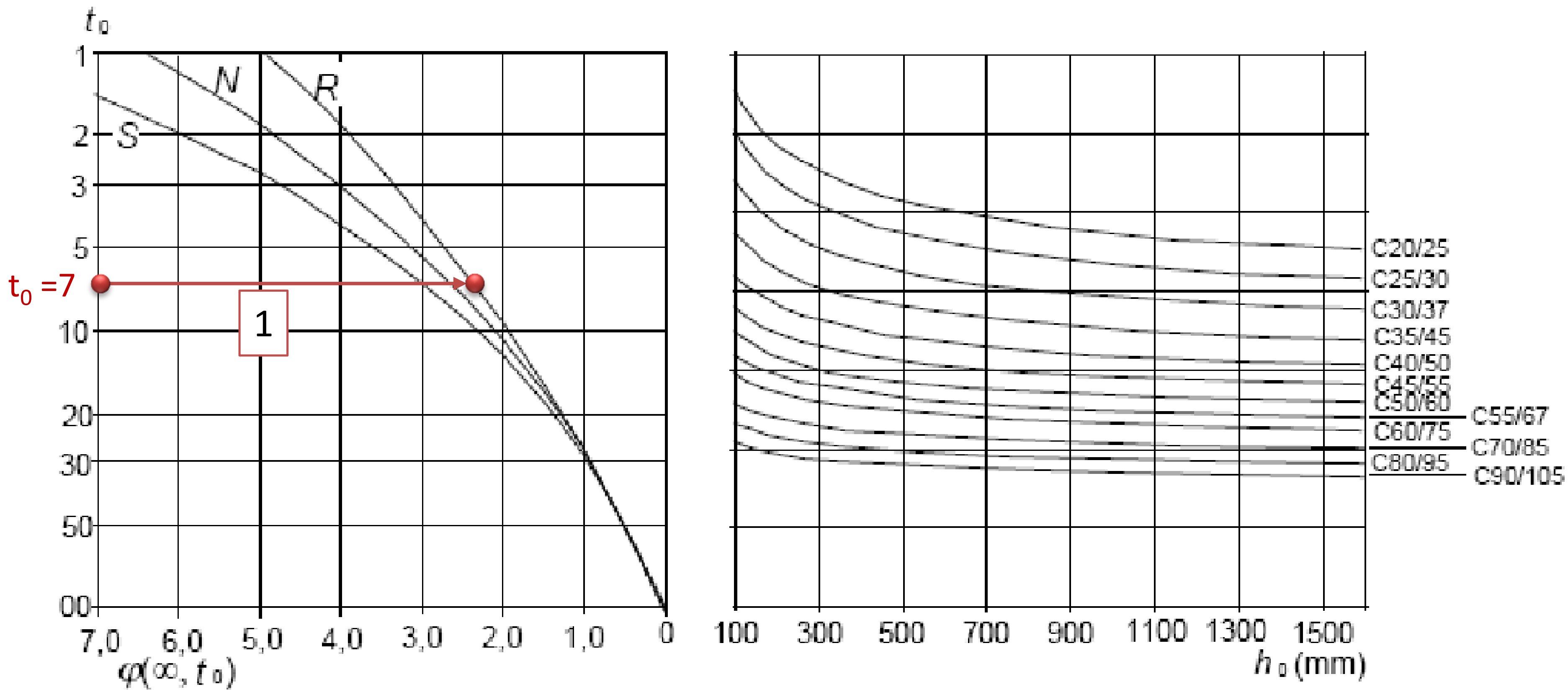
Where $E_c = 1{,}05 E_{cm}$



inside conditions - RH = 50%

Determination of creep / Determinarea curgerii lente

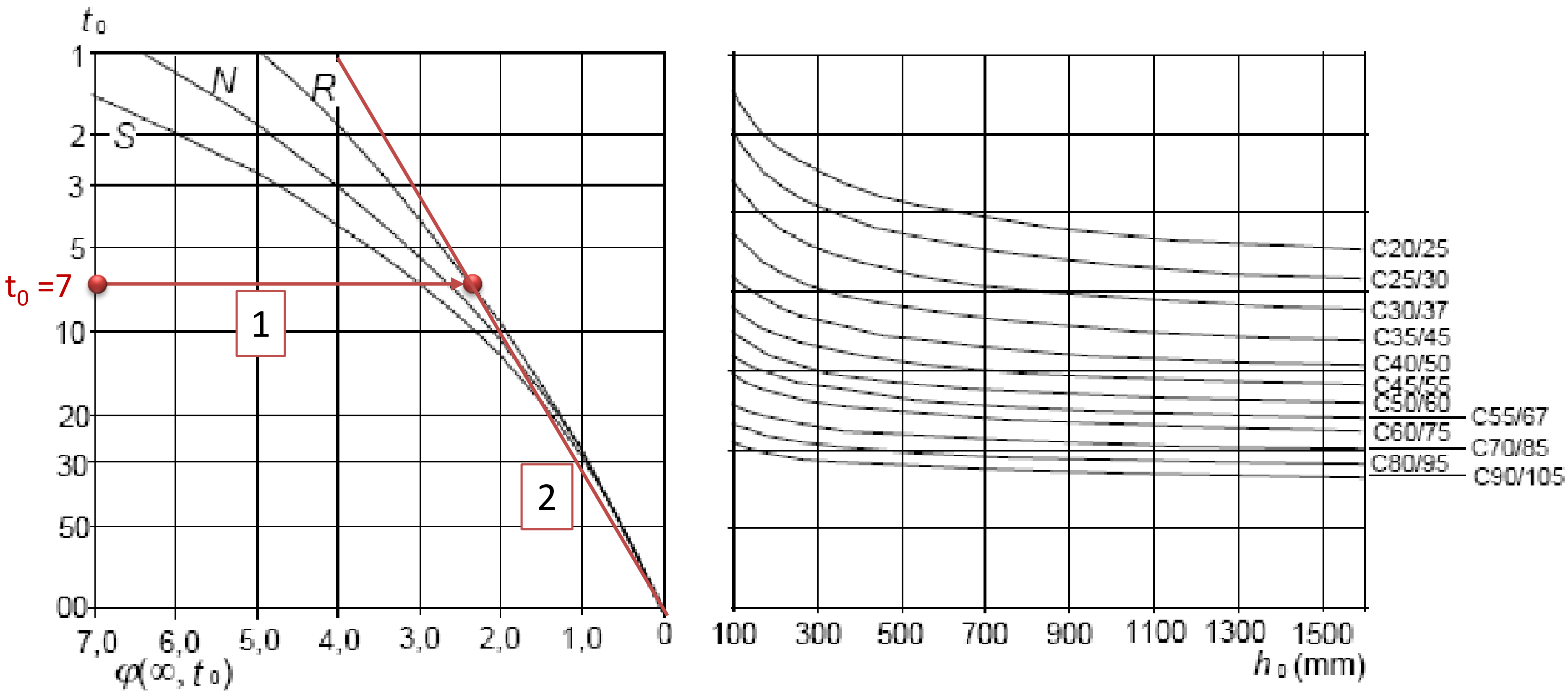
Determination of creep coefficient



inside conditions - RH = 50%

Determination of creep / Determinarea curgerii lente

Determination of creep coefficient

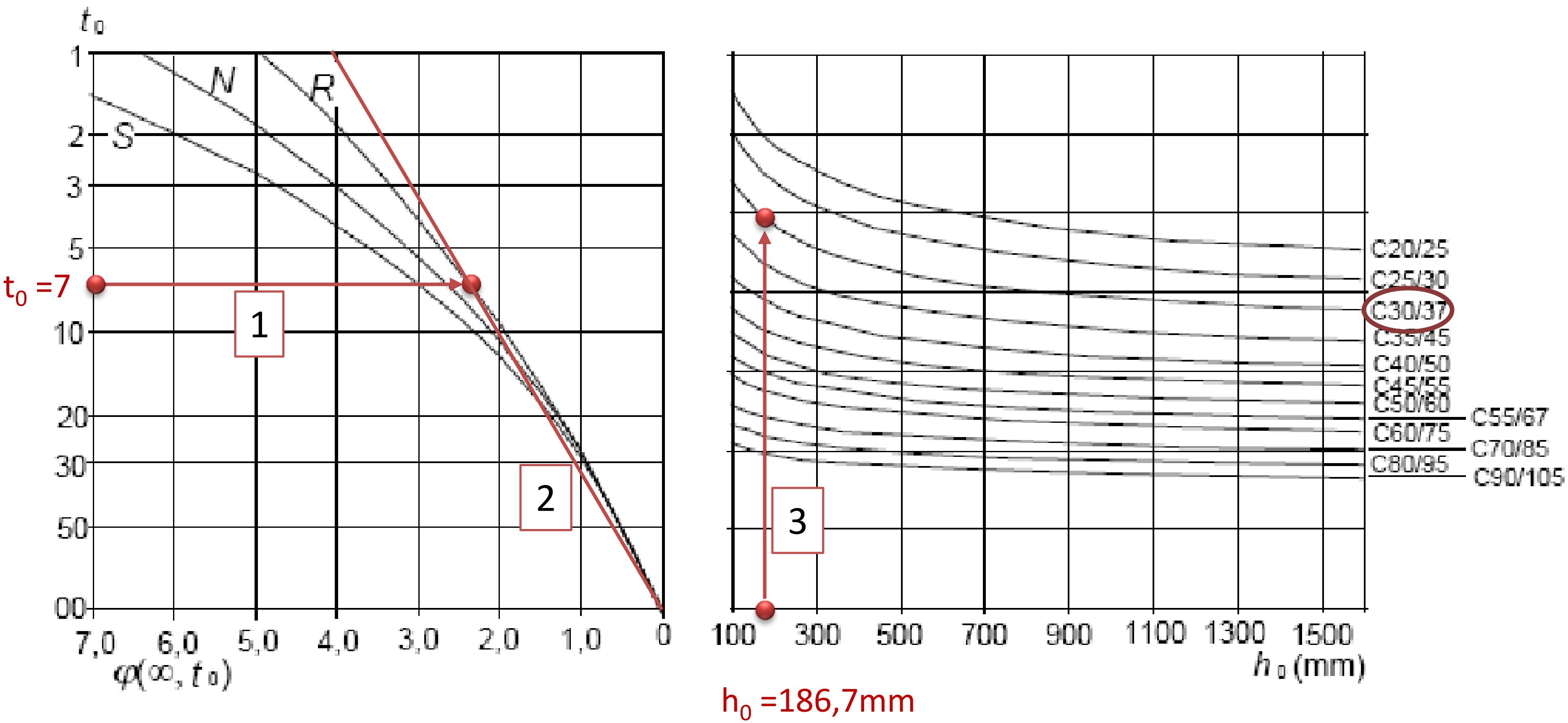


inside conditions - RH = 50%

Determination of creep / Determinarea curgerii lente

Determination of creep coefficient

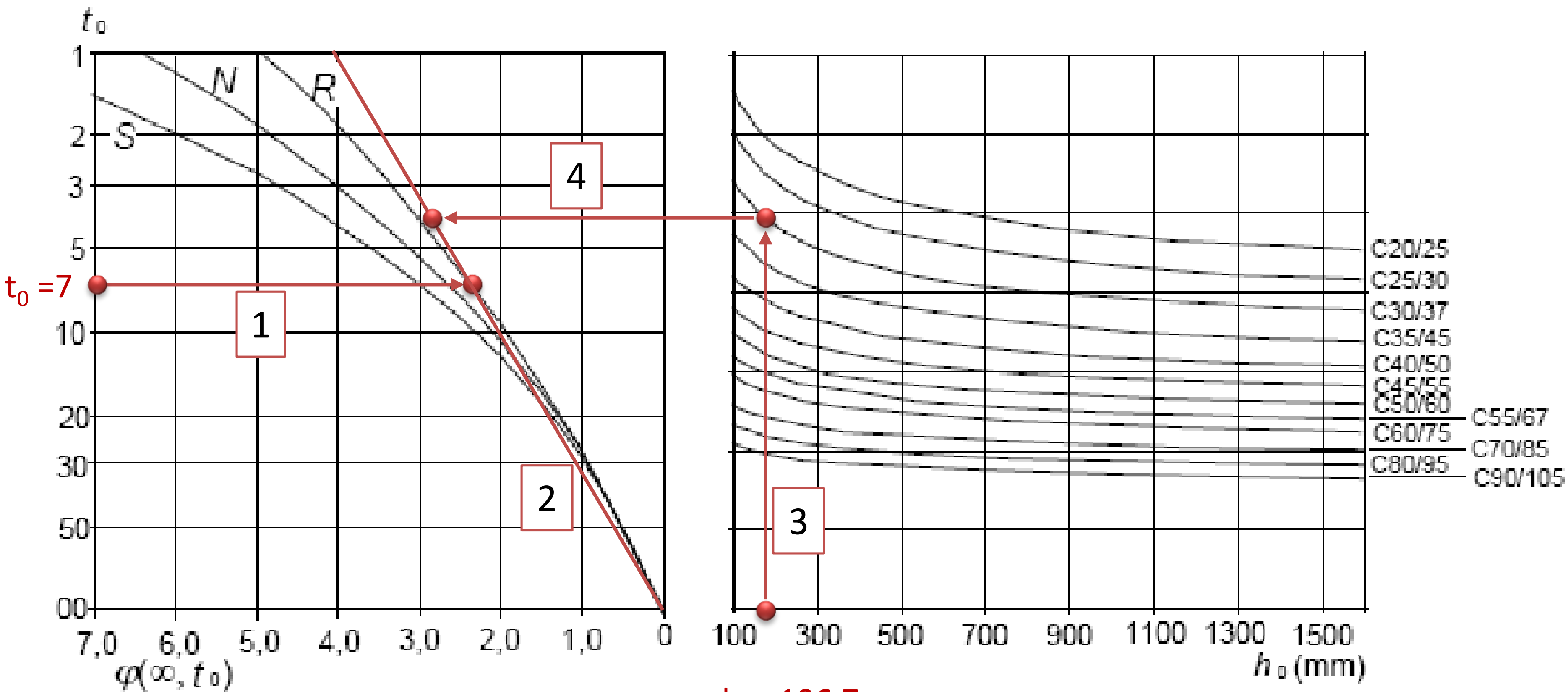
$$h_0 = \frac{2A_c}{u} = \frac{2 \cdot 400 \cdot 350}{2 \cdot (400 + 350)} = 186{,}7\ mm$$



inside conditions - RH = 50%

Determination of creep / Determinarea curgerii lente

Determination of creep coefficient

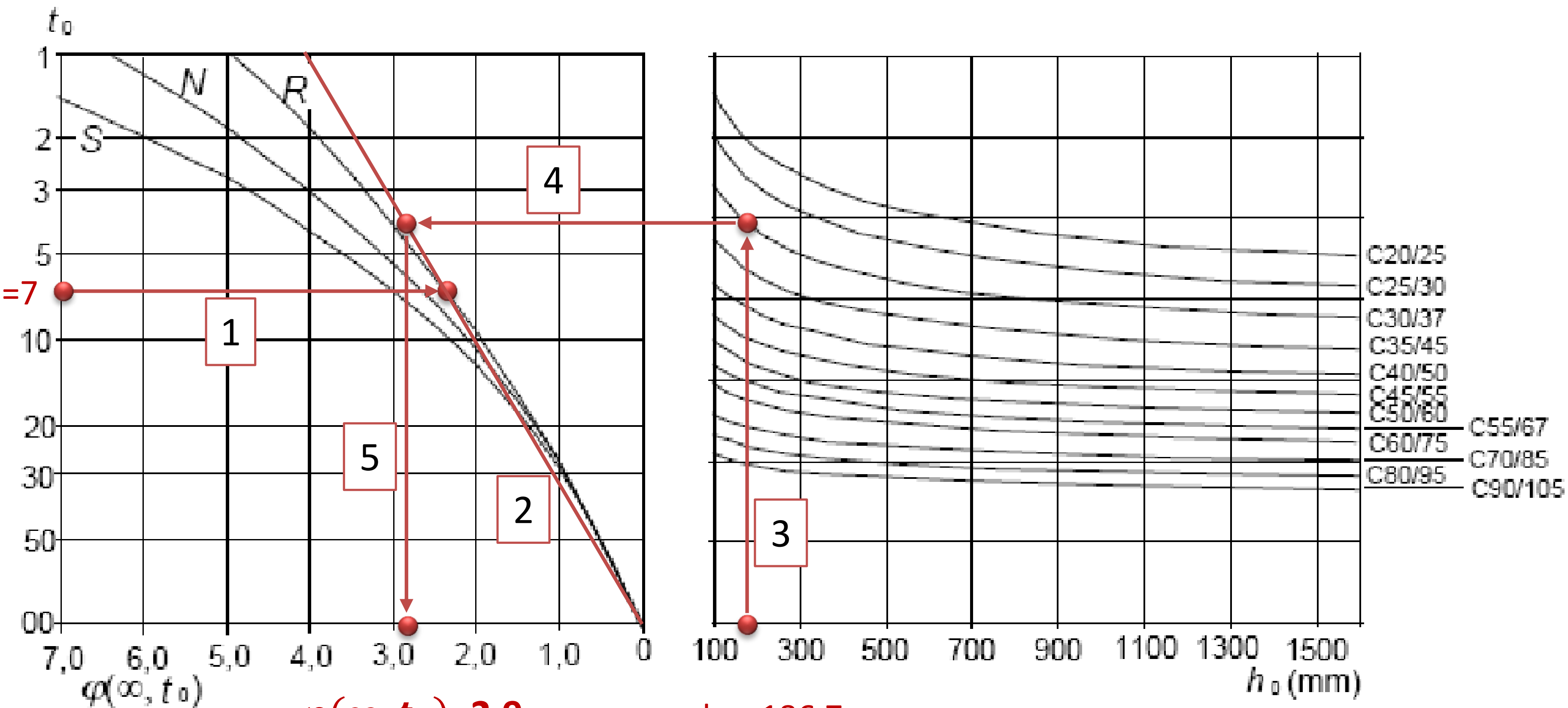


h_0 =186,7mm

inside conditions - RH = 50%

Determination of creep / Determinarea curgerii lente

Determination of creep coefficient



$t_0 = 7$

$\varphi(\infty, t_0) = 2{,}9$

$h_0 = 186{,}7\text{mm}$

inside conditions - RH = 50%

Determination of creep / Determinarea curgerii lente

Value of creep coefficient

$\varphi(\infty, t_0)$=2,9

$\Rightarrow$ Strain from creep

$$\varepsilon_{cc}(\infty, t_0) = \varphi(\infty, t_0) \cdot \frac{\sigma_c}{1{,}05 E_{cm}} =$$

Determination of creep / Determinarea curgerii lente

Value of creep coefficient

$\varphi(\infty, t_0)$=2,9

$\Rightarrow$ **Strain from creep**

$$\varepsilon_{cc}(\infty, t_0) = \varphi(\infty, t_0) \cdot \frac{\sigma_c}{1{,}05 E_{cm}} = 2{,}9 \cdot \frac{1000 \cdot 10^3}{400 \cdot 350} \frac{1}{1{,}05 \cdot 33000} = 0{,}598 \text{ ‰}$$

$\Rightarrow$ **Deformaţia de compresiune din curgere lentă**

$$\Delta L_{cc,\infty} = \varepsilon_{cc}(\infty, t_0) \cdot L =$$

Determination of creep / Determinarea curgerii lente

Value of creep coefficient

$\varphi(\infty, t_0)$=2,9

⇒ Strain from creep

$$\varepsilon_{cc}(\infty, t_0) = \varphi(\infty, t_0) \cdot \frac{\sigma_c}{1{,}05E_{cm}} = 2{,}9 \cdot \frac{1000 \cdot 10^3}{400 \cdot 350} \frac{1}{1{,}05 \cdot 33000} = 0{,}598\ ‰$$

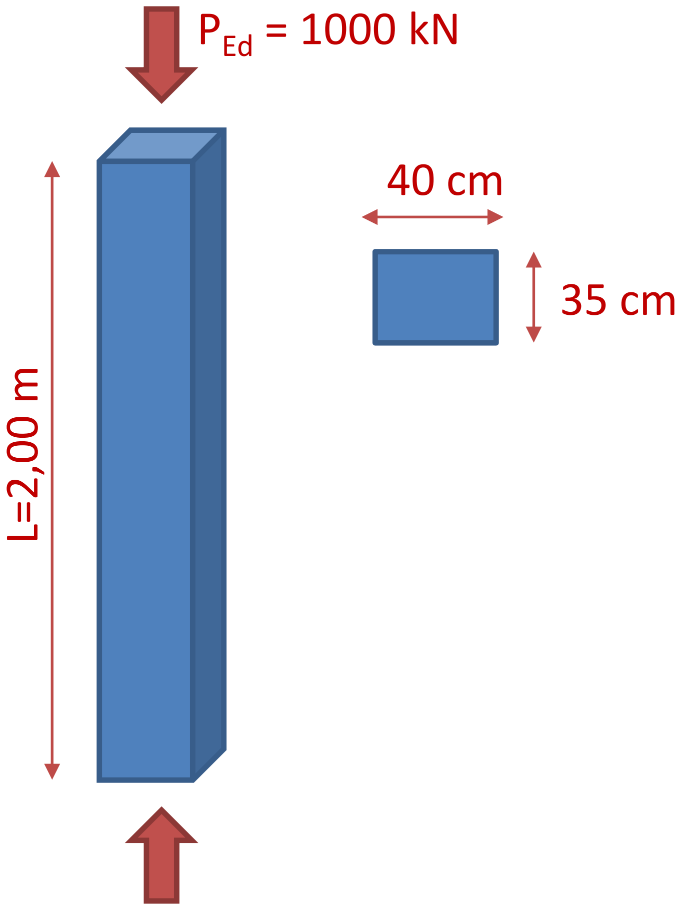
⇒ Deformaţia de compresiune din curgere lentă

$$\Delta L_{cc,\infty} = \varepsilon_{cc}(\infty, t_0) \cdot L = 0{,}598‰ \cdot 2000mm = 1{,}196\ mm$$

$$\boldsymbol{\Delta L_{cc,\infty} = 1{,}196\ mm}$$

Determination of creep / Determinarea curgerii lente

Final deformations from creep for the concrete element

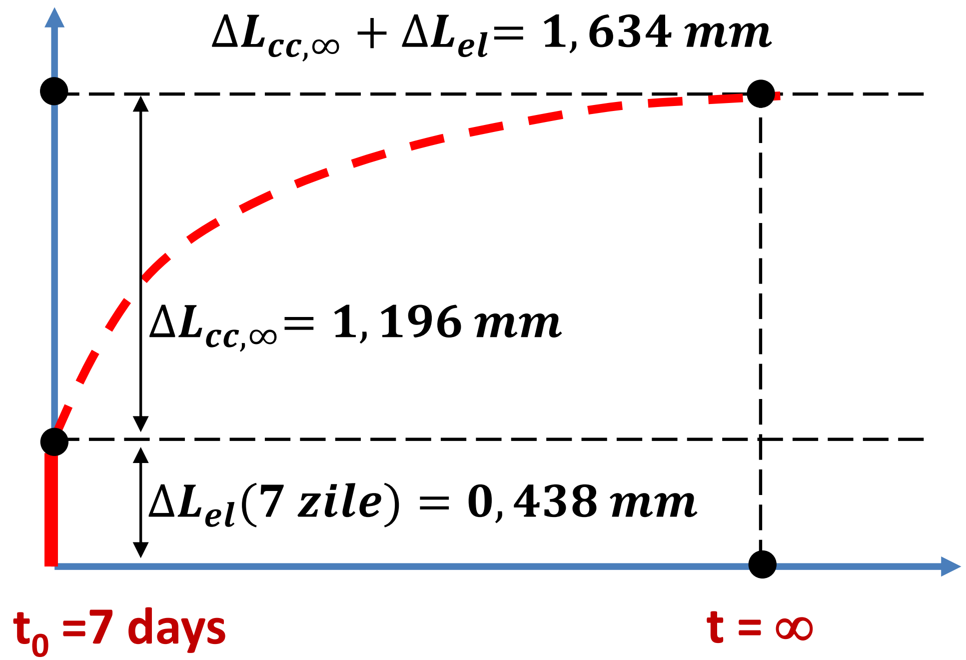


Concrete: **C30/37**

Environmental conditions: **Interior RH=50%**

Cement type: **CEM II 52,5R**

First load: **t_0 = 7 days**



P1. CONCRETE SHRINKAGE

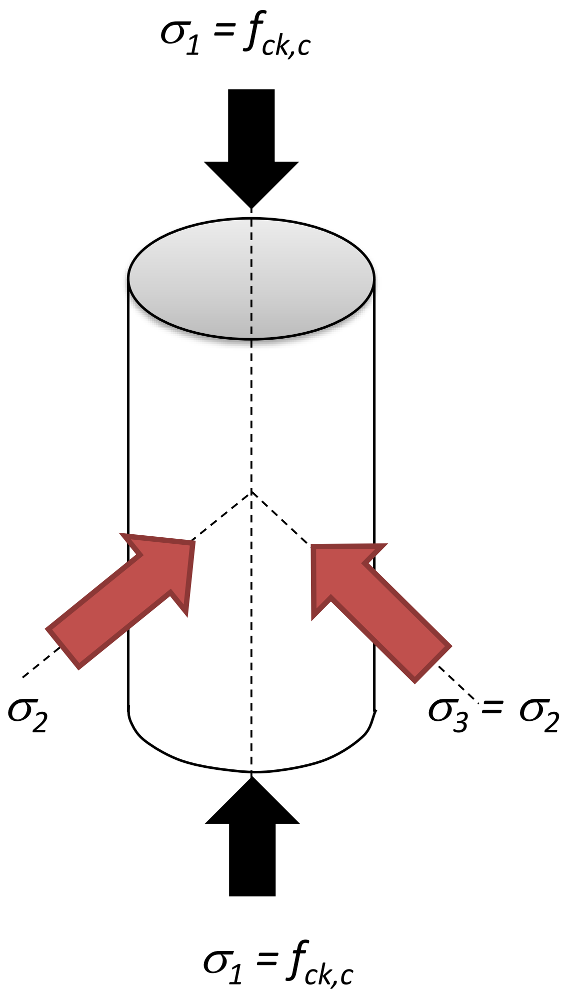
P2. CONCRETE CREEP

P3. CONCRETE CONFINEMENT

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

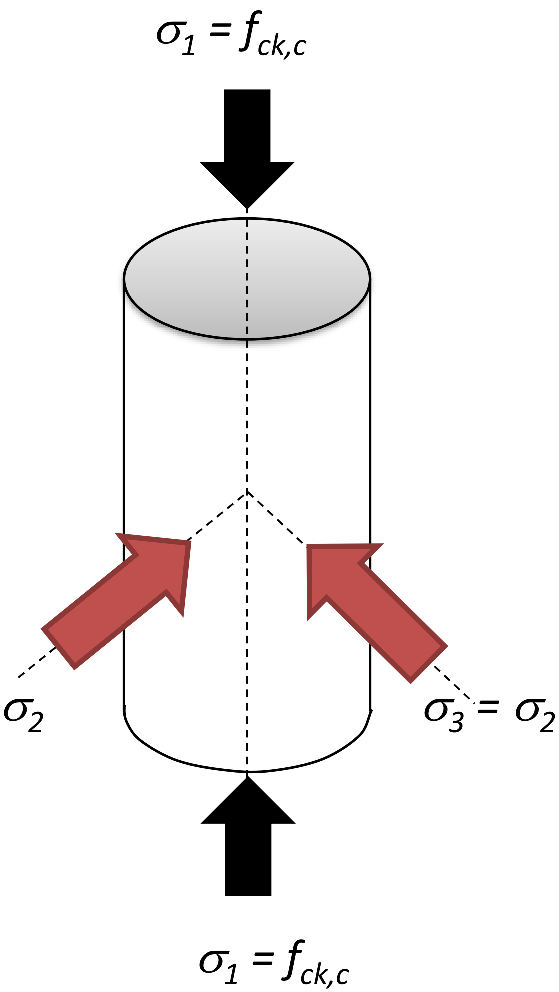
C20/25

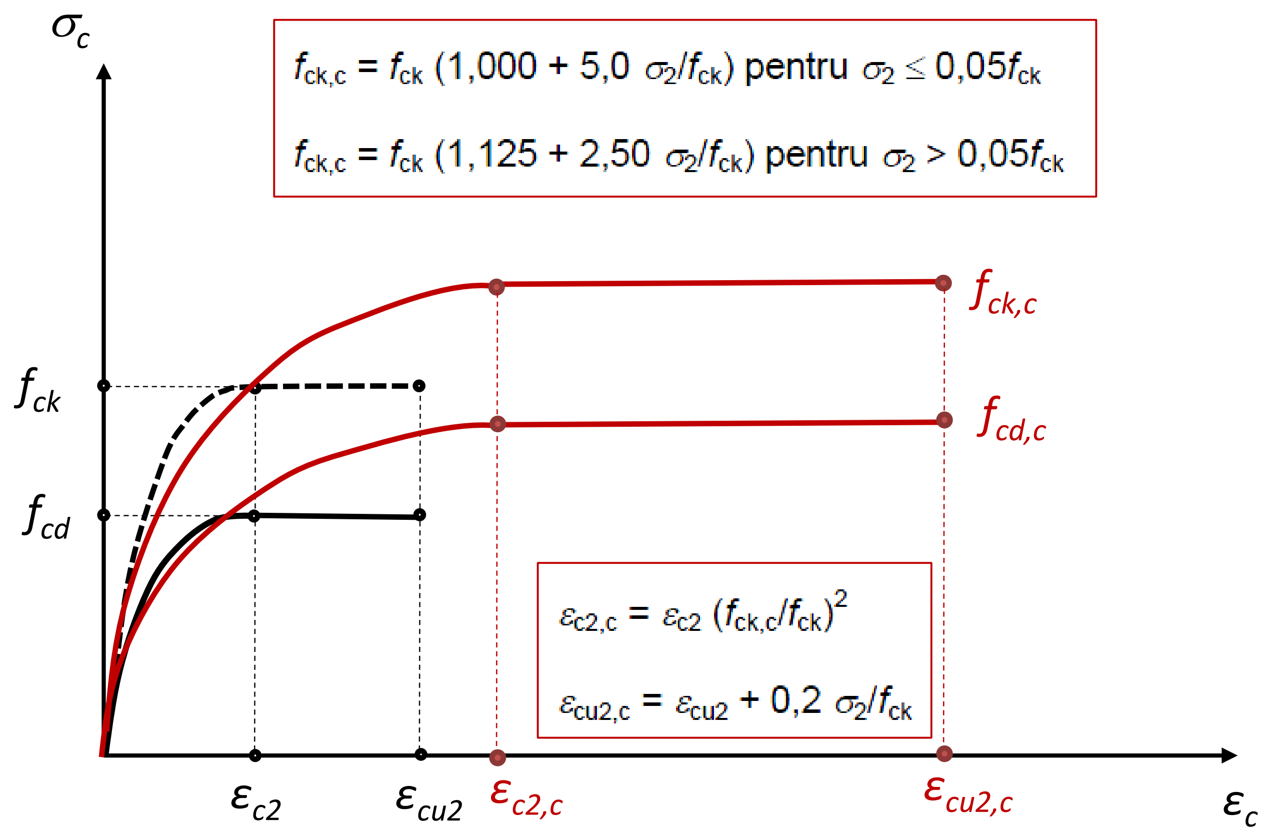


Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25





($\sigma_c - \varepsilon_c$ Parabola-rectangle diagram)

Calculate the diagram of behavior for the confined concrete

C20/25

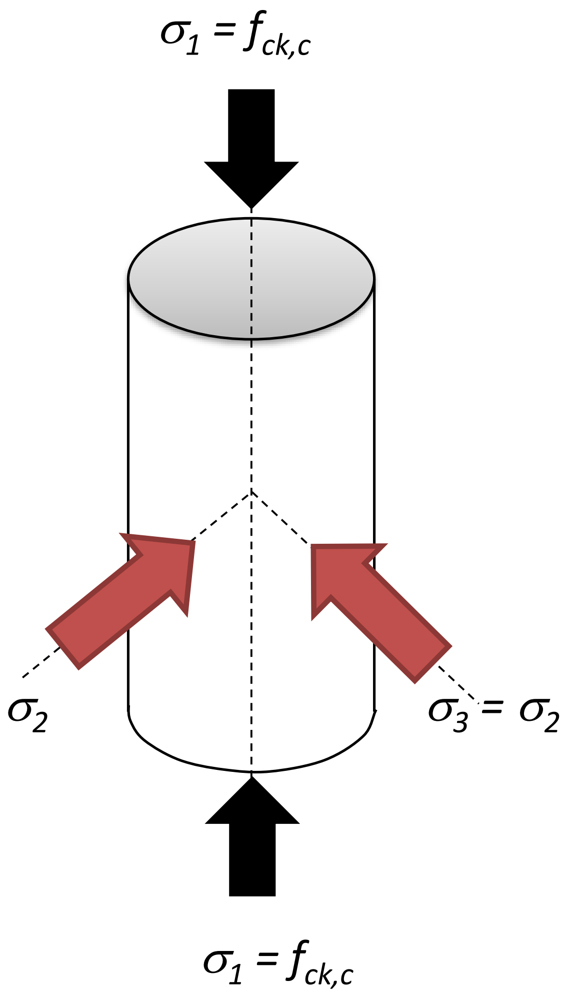
Strength classes for concrete															Analytical relation / Explanation
f_{ck} (MPa)	12	16	20	25	30	35	40	45	50	55	60	70	80	90	
$f_{ck,cube}$ (MPa)	15	20	25	30	37	45	50	55	60	67	75	85	95	105	
f_{cm} (MPa)	20	24	28	33	38	43	48	53	58	63	68	78	88	98	$f_{cm} = f_{ck}+8$(MPa)
f_{ctm} (MPa)	1,6	1,9	2,2	2,6	2,9	3,2	3,5	3,8	4,1	4,2	4,4	4,6	4,8	5,0	$f_{ctm}=0{,}30\times f_{ck}^{(2/3)}$ ≤C50/60 $f_{ctm}=2{,}12\cdot\ln(1+(f_{cm}/10))$ > C50/60
$f_{ctk,0,05}$ (MPa)	1,1	1,3	1,5	1,8	2,0	2,2	2,5	2,7	2,9	3,0	3,1	3,2	3,4	3,5	$f_{ctk,0,05} = 0{,}7\times f_{ctm}$ 5% fractile
$f_{ctk,0,95}$ (MPa)	2,0	2,5	2,9	3,3	3,8	4,2	4,6	4,9	5,3	5,5	5,7	6,0	6,3	6,6	$f_{ctk,0,95} = 1{,}3\times f_{ctm}$ 95% fractile
E_{cm} (GPa)	27	29	30	31	33	34	35	36	37	38	39	41	42	44	$E_{cm} = 22[(f_{cm})/10]^{0,3}$ (f_{cm} in MPa)
ε_{c1} (‰)	1,8	1,9	2,0	2,1	2,2	2,25	2,3	2,4	2,45	2,5	2,6	2,7	2,8	2,8	see Figure 3.2 $\varepsilon_{c1}(^0/_{00}) = 0{,}7 f_{cm}^{0,31} < 2{,}8$
ε_{cu1} (‰)	3,5									3,2	3,0	2,8	2,8	2,8	see Figure 3.2 for $f_{ck} \geq 50$ Mpa $\varepsilon_{cu1}(^0/_{00})=2{,}8+27[(98-f_{cm})/100]^4$
ε_{c2} (‰)	2,0									2,2	2,3	2,4	2, 5	2,6	see Figure 3.3 for $f_{ck} \geq 50$ Mpa $\varepsilon_{c2}(^0/_{00})=2{,}0+0{,}085(f_{ck}-50)^{0,53}$
ε_{cu2} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.3 for $f_{ck} \geq 50$ Mpa $\varepsilon_{cu2}(^0/_{00})=2{,}6+35[(90-f_{ck})/100]^4$
n	2,0									1,75	1,6	1,45	1,4	1,4	for $f_{ck} \geq 50$ Mpa $n=1{,}4+23{,}4[(90-f_{ck})/100]^4$
ε_{c3} (‰)	1,75									1,8	1,9	2,0	2,2	2,3	see Figure 3.4 for $f_{ck} \geq 50$ Mpa $\varepsilon_{c3}(^0/_{00})=1{,}75+0{,}55[(f_{ck}-50)/40]$
ε_{cu3} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.4 for $f_{ck} \geq 50$ Mpa $\varepsilon_{cu3}(^0/_{00})=2{,}6+35[(90-f_{ck})/100]^4$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25

$\boldsymbol{\sigma_2 = 0,02 f_{ck}}$



$f_{ck,c} = f_{ck}\,(1,000 + 5,0\;\sigma_2/f_{ck})$ pentru $\sigma_2 \leq 0,05 f_{ck}$

$f_{ck,c} = f_{ck}\,(1,125 + 2,50\;\sigma_2/f_{ck})$ pentru $\sigma_2 > 0,05 f_{ck}$

$$\sigma_2 = 0{,}02 f_{ck} = 0{,}4\,N/mm^2 < 0{,}05 f_{ck} = 1{,}0 N/mm^2$$

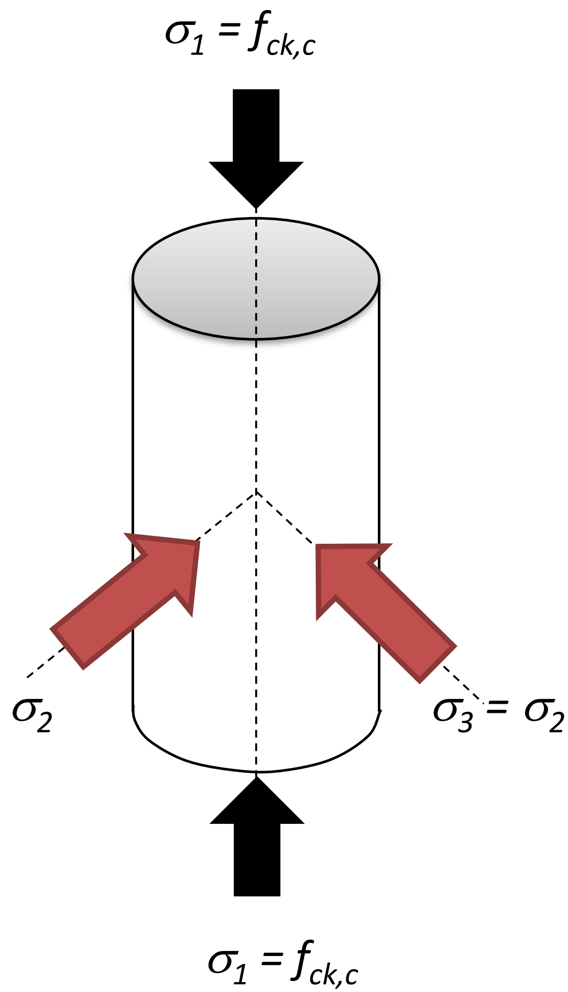
$$f_{ck,c} = f_{ck} \cdot \left(1{,}00 + 5{,}0 \cdot \frac{\sigma_2}{f_{ck}}\right) = 20 \cdot \left(1{,}00 + 5{,}0 \cdot \frac{0{,}4}{20}\right)$$

$$\boldsymbol{f_{ck,c} = 22\,N/mm^2}$$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25



$$\varepsilon_{c2,c} = \varepsilon_{c2}\,(f_{ck,c}/f_{ck})^2$$

$$\varepsilon_{cu2,c} = \varepsilon_{cu2} + 0{,}2\,\sigma_2/f_{ck}$$

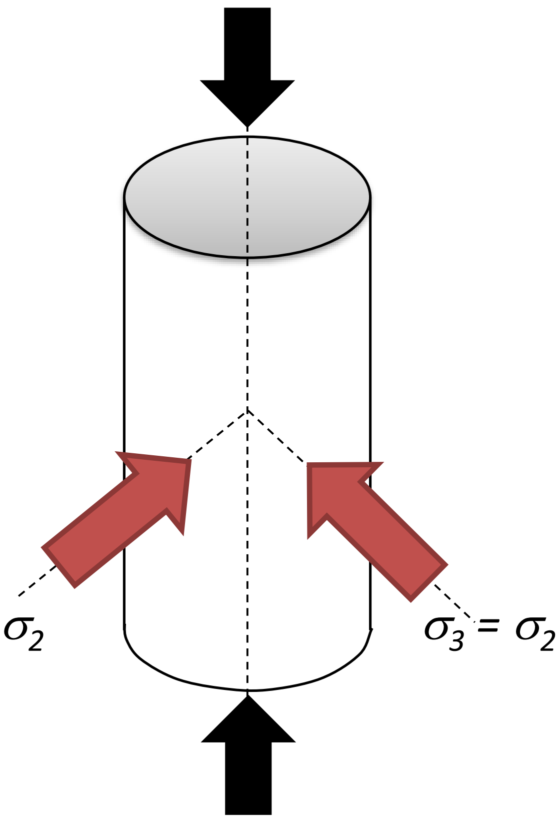
$$\varepsilon_{c2,c} = \varepsilon_{c2}\left(\frac{f_{ck,c}}{f_{ck}}\right)^2 = 2{,}00‰ \cdot \left(\frac{22}{20}\right)^2$$

$$\boldsymbol{\varepsilon_{c2,c} = 2,42‰}$$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25



$$\varepsilon_{c2,c} = \varepsilon_{c2}\,(f_{ck,c}/f_{ck})^2$$

$$\varepsilon_{cu2,c} = \varepsilon_{cu2} + 0{,}2\,\sigma_2/f_{ck}$$

$$\varepsilon_{c2,c} = \varepsilon_{c2}\left(\frac{f_{ck,c}}{f_{ck}}\right)^2 = 2{,}00‰ \cdot \left(\frac{33}{30}\right)^2$$

$$\boldsymbol{\varepsilon_{c2,c} = 2{,}42‰}$$

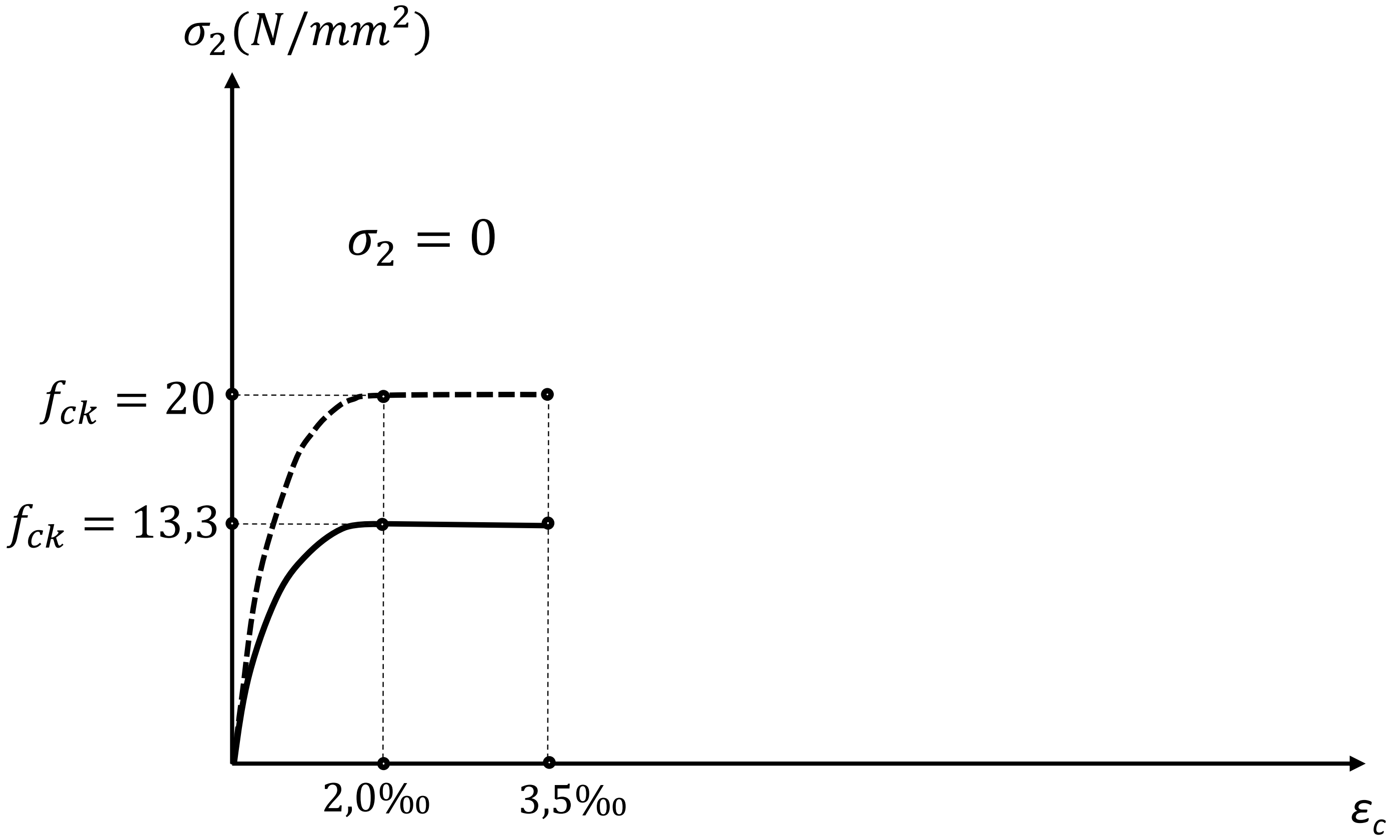
$$\varepsilon_{cu2,c} = \varepsilon_{cu2} + 0{,}2\frac{\sigma_2}{f_{ck}} = 3{,}50‰ + 0{,}2 \cdot \frac{0{,}4}{20}$$

$$\boldsymbol{\varepsilon_{cu2,c} = 7{,}50‰}$$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25

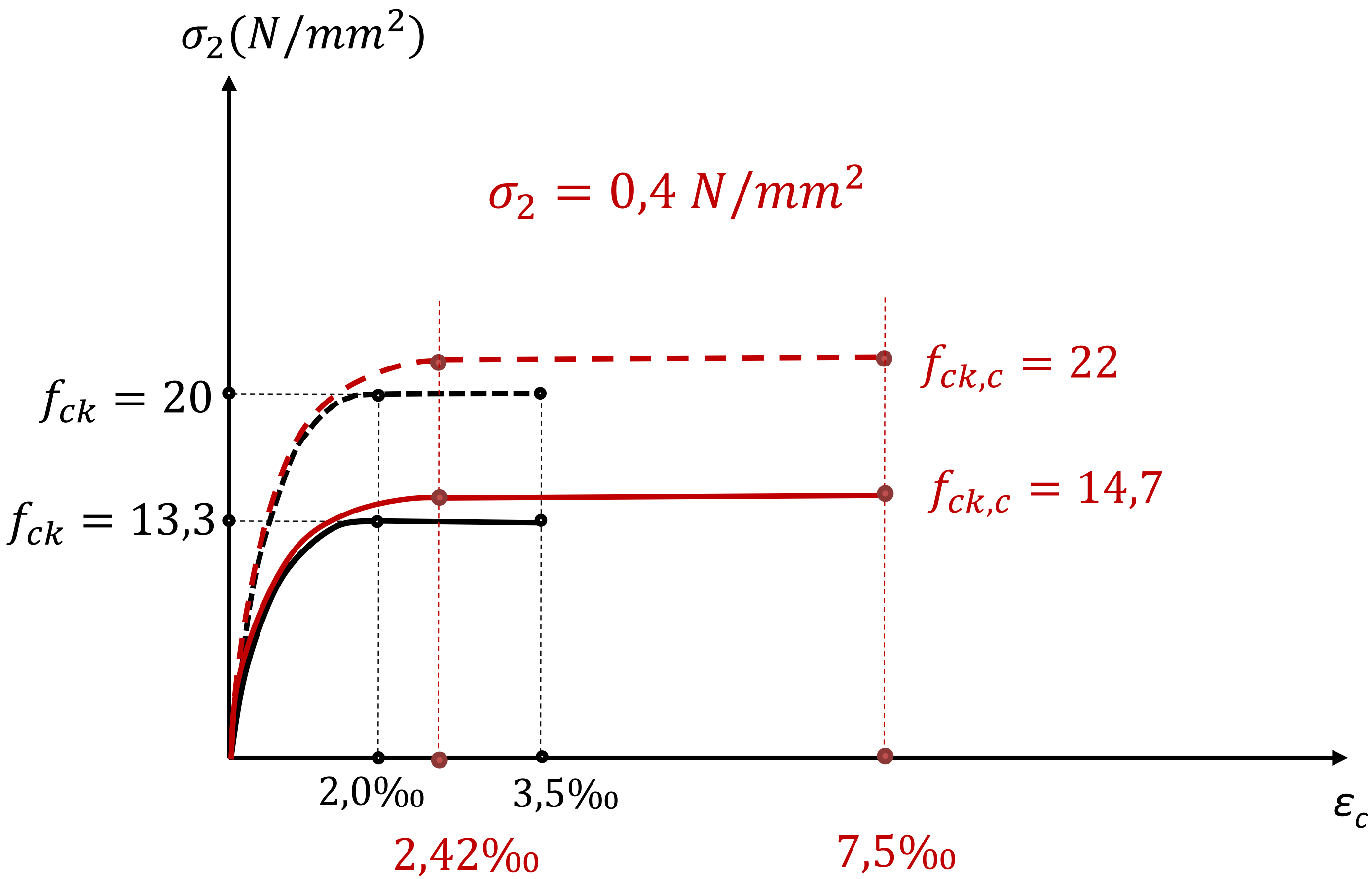


(Diagrama $\sigma_c - \varepsilon_c$ parabolă-dreptunghi)

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25



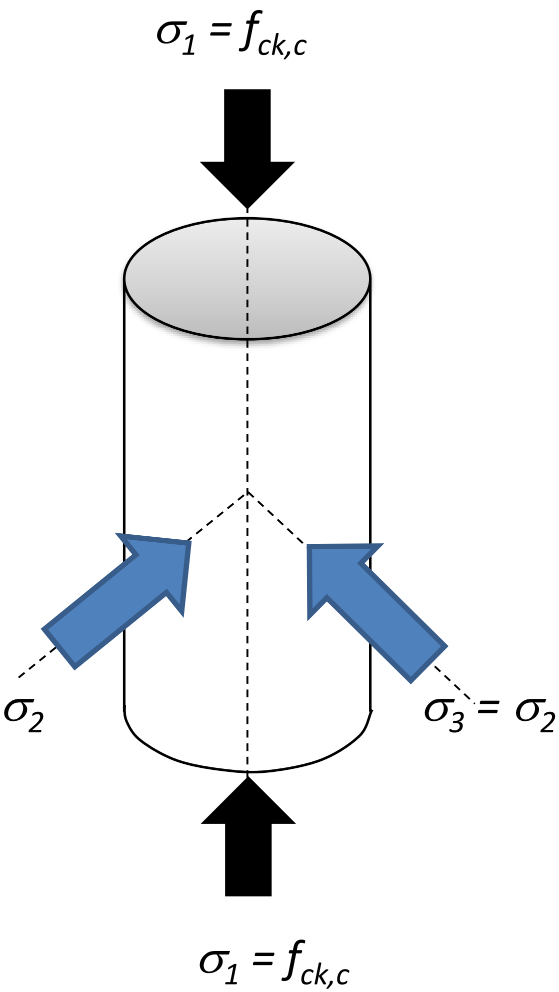
(Diagrama $\sigma_c - \varepsilon_c$ parabolă-dreptunghi)

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25

$\sigma_2 = 0,1 f_{ck}$



$f_{ck,c} = f_{ck}\,(1{,}000 + 5{,}0\ \sigma_2/f_{ck})$ pentru $\sigma_2 \le 0{,}05 f_{ck}$

$f_{ck,c} = f_{ck}\,(1{,}125 + 2{,}50\ \sigma_2/f_{ck})$ pentru $\sigma_2 > 0{,}05 f_{ck}$

$$\sigma_2 = 0{,}1 f_{ck} = 2\,N/mm^2 > 0{,}05 f_{ck} = 1{,}0\,N/mm^2$$

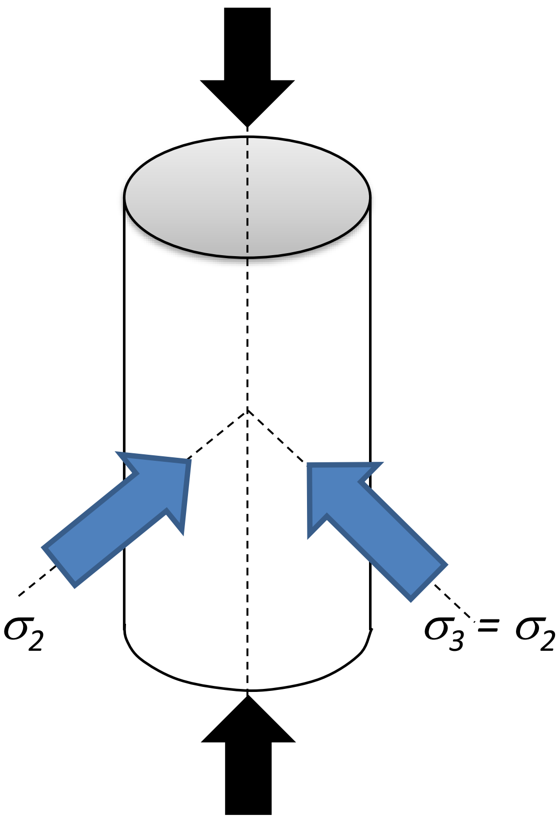
$$f_{ck,c} = f_{ck} \cdot \left(1{,}125 + 2{,}50 \cdot \frac{\sigma_2}{f_{ck}}\right) = 20\left(1{,}125 + 2{,}50\frac{2}{20}\right)$$

$$\boldsymbol{f_{ck,c} = 27,5\,N/mm^2}$$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25



$\varepsilon_{c2,c} = \varepsilon_{c2}\ (f_{ck,c}/f_{ck})^2$

$\varepsilon_{cu2,c} = \varepsilon_{cu2} + 0{,}2\ \sigma_2/f_{ck}$

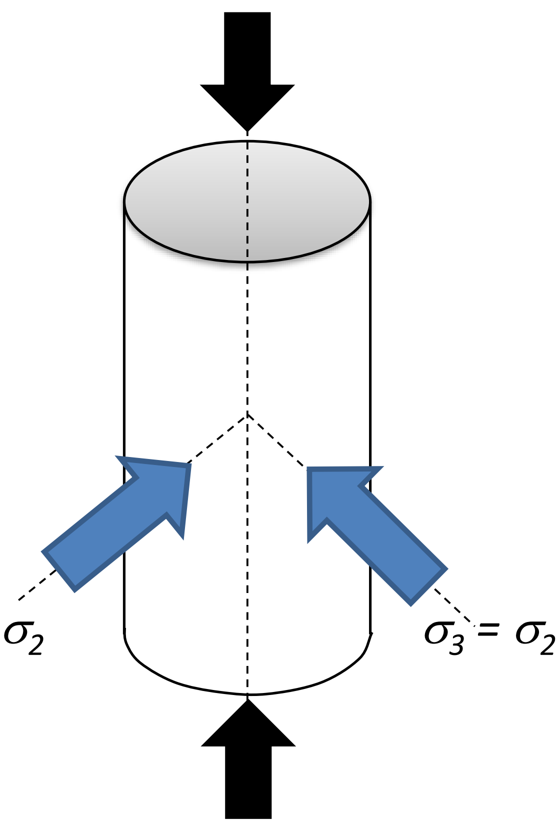
$$\varepsilon_{c2,c} = \varepsilon_{c2}\left(\frac{f_{ck,c}}{f_{ck}}\right)^2 = 2{,}00‰ \cdot \left(\frac{27{,}5}{20}\right)^2$$

$$\boldsymbol{\varepsilon_{c2,c} = 3,78‰}$$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25



$\varepsilon_{c2,c} = \varepsilon_{c2}\,(f_{ck,c}/f_{ck})^2$

$\varepsilon_{cu2,c} = \varepsilon_{cu2} + 0{,}2\,\sigma_2/f_{ck}$

$$\varepsilon_{c2,c} = \varepsilon_{c2}\left(\frac{f_{ck,c}}{f_{ck}}\right)^2 = 2{,}00‰ \cdot \left(\frac{27{,}5}{20}\right)^2$$

$$\boldsymbol{\varepsilon_{c2,c} = 3,78‰}$$

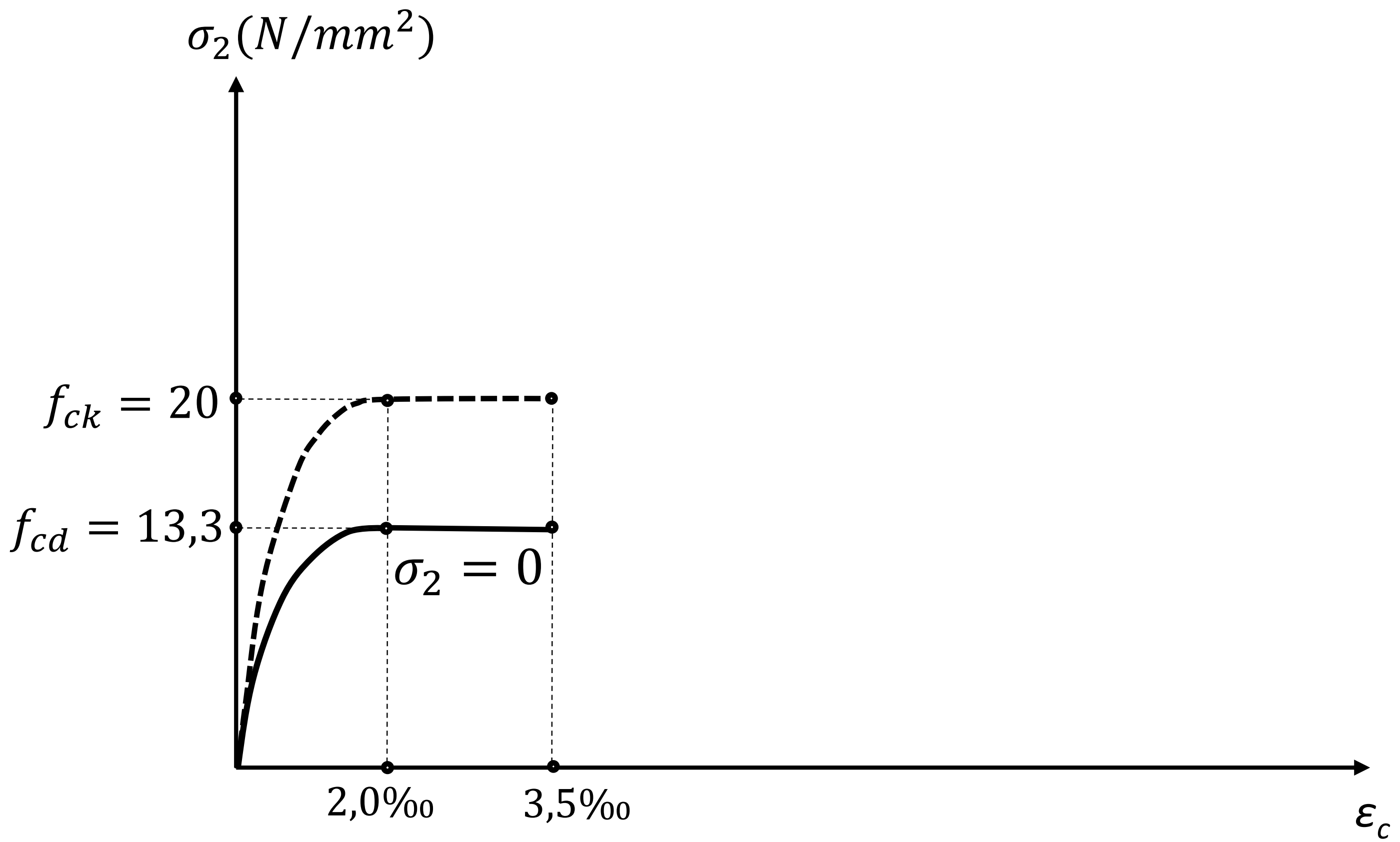
$$\varepsilon_{cu2,c} = \varepsilon_{cu2} + 0{,}2\frac{\sigma_2}{f_{ck}} = 3{,}50‰ + 0{,}2 \cdot \frac{2}{20}$$

$$\boldsymbol{\varepsilon_{cu2,c} = 23,50‰}$$

Design curve of a confined concrete / Curba de comportare pentru beton confinării

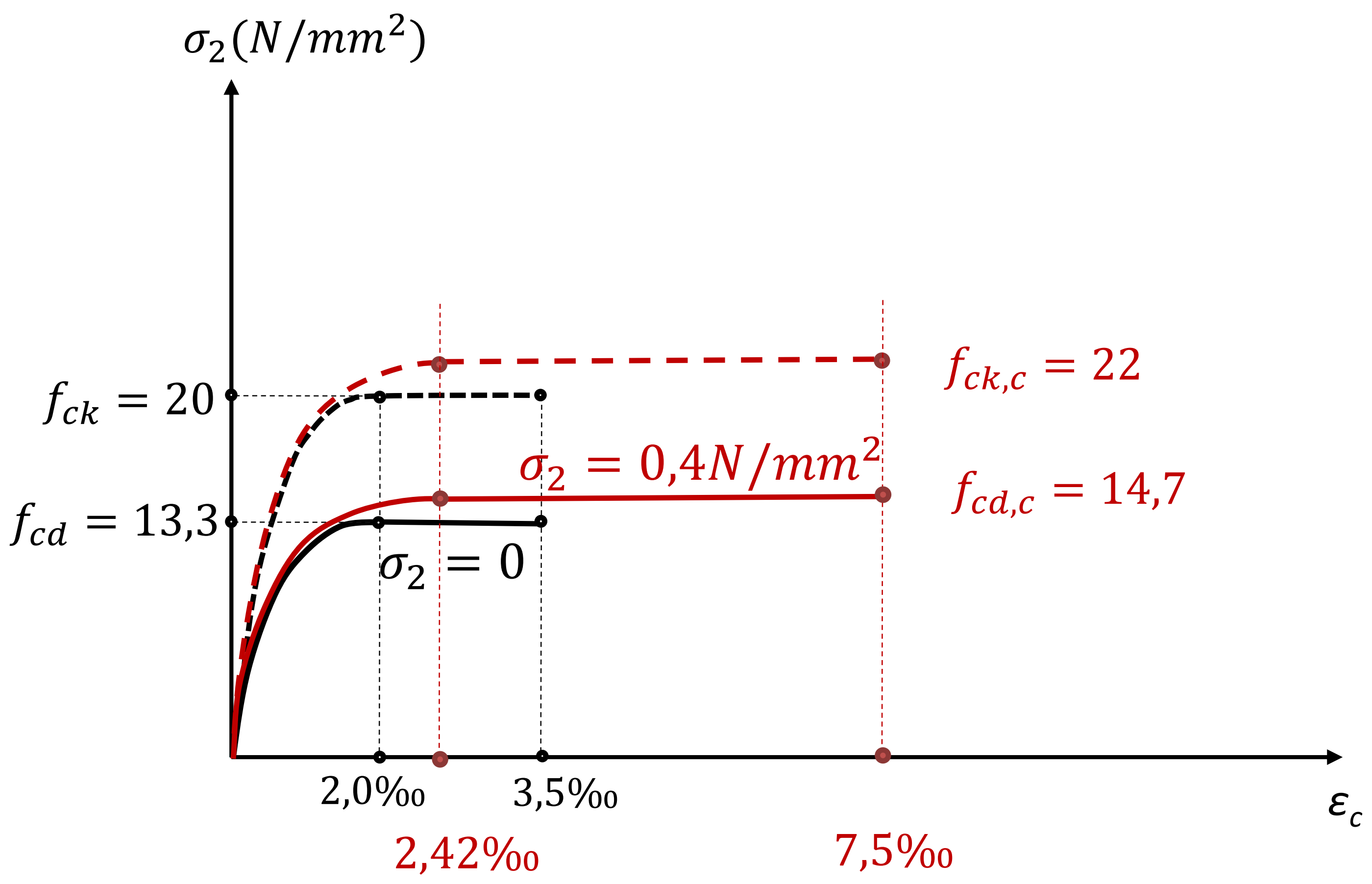
Calculate the diagram of behavior for the confined concrete

C20/25



Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete **C20/25**



Design curve of a confined concrete / Curba de comportare pentru beton confinării

Calculate the diagram of behavior for the confined concrete

C20/25