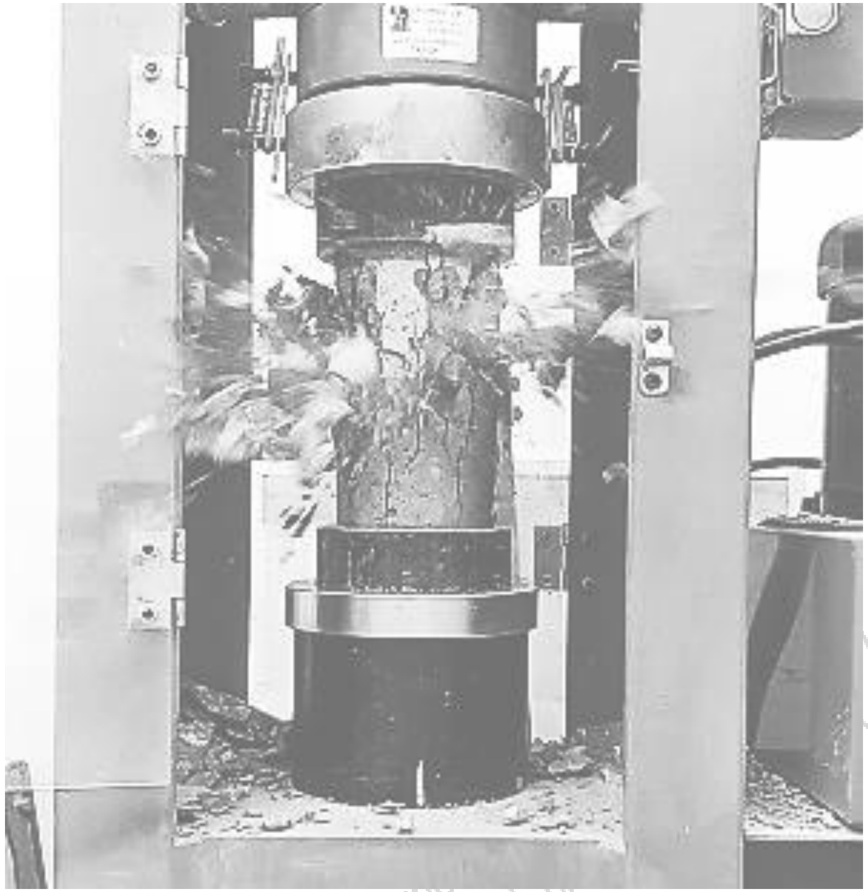

Reinforced Concrete (RC) Structures

Topic 4.

Strength properties of structural concrete

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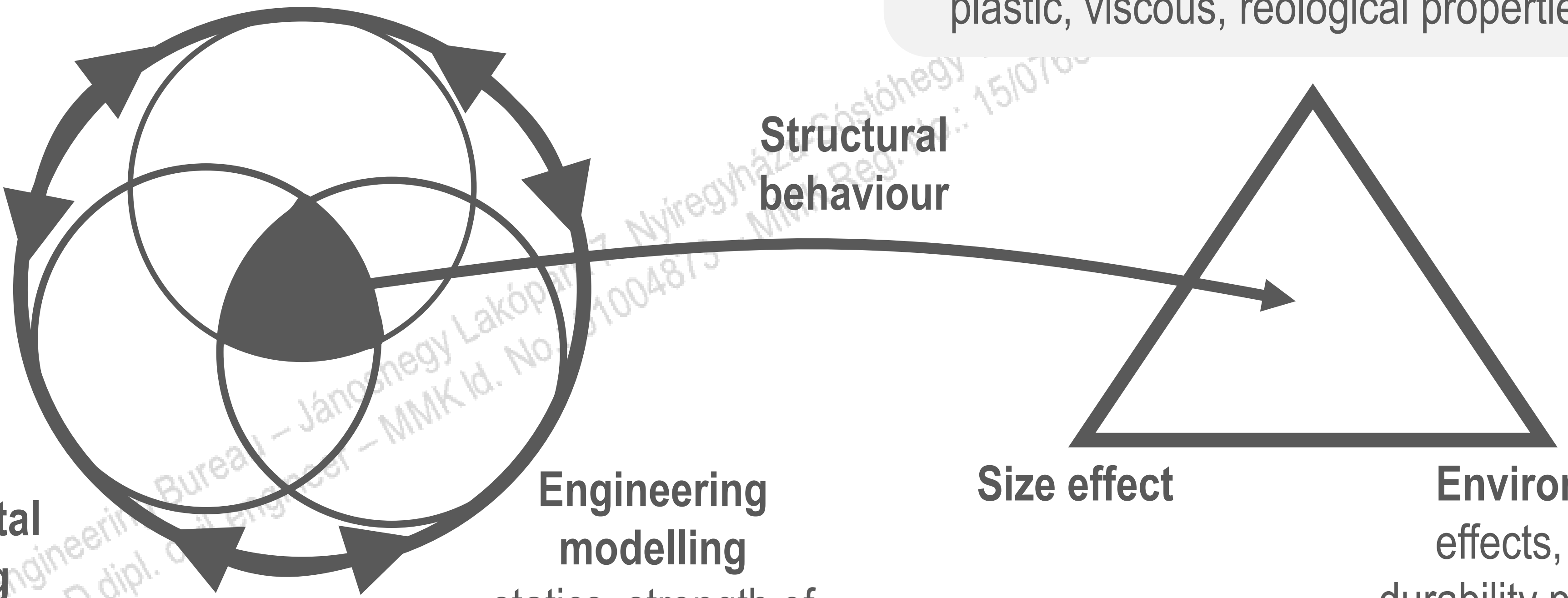
Modeling of structural behaviour of RC members

Numerical modelling
linear, non linear, plastic, 1st order theory, 2nd order theory, etc.

Material properties
homogen, inhomogen, izotropic, anizotropic
elastic linear, non linear elastic,
plastic, viscous, reological properties, etc.



Experimental modelling
full-scale,
non full-scale, etc.

Engineering modelling
statics, strength of materials, elasticity, plasticity, dynamics, etc.

Size effect

Environment
effects, loads,
durability properties,
etc.

Compressive strength of concrete – MSZ EN 1992-1-1:2010

The **compressive strength of concrete** is denoted by **concrete strength classes** which relate to the **characteristic (5%) cylinder strength**, f_{ck} or the **cube strength** $f_{ck,cube}$, in accordance with **EN 206-1 (MSZ 4798:2016/2M:2018)**.

[MSZ EN 1992-1-1:2010 - 3.1.2 Section – (1)P Paragraph – page 27.]

The **strength classes** in this code are based on the **characteristic cylinder strength** f_{ck} determined at **28 days** with a maximum value of C_{max}. (The recommended value for C_{max} is **C90/105**)

[MSZ EN 1992-1-1:2010 - 3.1.2 Section – (2)P Paragraph – page 27.]

$$\mathbf{C30/37 \rightarrow C}\ f_{ck} / f_{ck,cube}$$

f_{ck} is the specified characteristic compressive strength value measured on **Ø150 × 300 mm cylinder specimens** at **28 days**, made in a **formwork** and **stored under water** until the compressive test [N/mm^2]

$f_{ck,cube}$ is the specified characteristic compressive strength value measured on **150 × 150 × 150 mm cube specimens** at **28 days**, made in a **formwork** and **stored under water** until the compressive test [N/mm^2]

Compressive strength of concrete – EN 206-1 / MSZ 4798:2016/2M:2018

For classifying concrete on the basis of compressive strength, **Table 12** (**page 38.**) of **MSZ 4798: 2016/2M:2018** shall be applied to **conventional and heavy concrete**, and **Table 13** (**page 39.**) shall be applied to **lightweight concrete**. For classification, the characteristic value of the **28-day compressive strength** measured on cylinders with **150 mm diameter** and **300 mm height** according to **MSZ 4798: 2016**, **Section 8.2.1** noted by $f_{ck,cyl}$, or the characteristic value of **28-day compressive strength** measured on cubes with **150 mm edge length** according to **MSZ 4798: 2016**, **Section 8.2.1**,noted by $f_{ck,cube}$ according to **MSZ EN 12390-3** may be used.

[MSZ 4798:2016 - 4.3.1 Section – 1 Paragraph – page 37.]

$$\mathbf{C30/37 \rightarrow C}\ f_{ck,cyl} / f_{ck,cube}$$

f_{ck} is the specified characteristic compressive strength value measured on **Ø150 × 300 mm cylinder specimens** at **28 days**, made in a **formwork** and **stored under water** until the compressive test [N/mm^2]

$f_{ck,cube}$ is the specified characteristic compressive strength value measured on **150 × 150 × 150 mm cube specimens** at **28 days**, made in a **formwork** and **stored under water** until the compressive test [N/mm^2]

Compressive strength of concrete – EN 206-1 / MSZ 4798:2016/2M:2018

The **compressive strength class** is usually determined at **28 days** (e.g **road construction concrete**) or at **56 days** (e.g **bulk concrete**) or up to **90 days** (e.g **very slow-setting concrete**) on **standard specimens**, made in **formwork** and tested according to **MSZ 4798:2016 Section 5.5.1.2.** The **characteristic value of the comressive strength** of concrete also refer to **28 days**, **42 days**, **56 days** or at most **90 days**.

[MSZ 4798:2016 - 4.3.1 Section – (1) Paragraph – 2. NOTE – page 38.]

$$\mathbf{C30/37_{42\ days}} \longrightarrow \mathbf{C}\ f_{ck,cyl,42\ days}\ /\ f_{ck,cube,42\ days}$$

$f_{ck,cyl,42\ days}$ is the specified characteristic compressive strength value measured on **Ø150 × 300 mm cylinder specimens** at **42 days**, made in a **formwork** and **stored under water** until the compressive test [N/mm^2]

$f_{ck,cube,42\ days}$ is the specified characteristic compressive strength value measured on **150 × 150 × 150 mm cube specimens** at **28 days**, made in a **formwork** and **stored under water** until the compressive test [N/mm^2]

Compressive strength of concrete – EN 206-1 / MSZ 4798:2016/2M:2018

If the **compressive strength class determined other than 28 days is used** to characterize the compressive strength of concrete, this circumstance **must be recorded in the contract** for the construction of the structure, in the **concrete technology instruction** and in the **concrete delivery note**.
The structural element may only be subjected to stress after the compressive strength of the concrete has reached the specified compressive strength.

The compressive strength of concrete older than 28 days must not be inferred retrospectively from 28 days or its conformity must not be verified.

In justified cases (e.g public holidays) the compressive strength test may be carried out **not more than 2 days before the age of 28, 42, 56 or 90 days of the concrete or not more than 3 days afterwards**.

[MSZ 4798:2016 - 4.3.1 Section – (2) Paragraph – page 38.]

Compressive strength of concrete – EN 206-1 / MSZ 4798:2016/2M:2018

According to **MSZ 4798:2016** standard concrete (normal density) test **cubes may be stored mixed**. See **Section 5.5.1.2 of MSZ 4798: 2016** for a detailed description and the method of conversion.

[MSZ 4798:2016 - 4.3.1 Section –(3) Paragraph – page 38.]

The experiential (**measured**) **individual compressive strength** ($f_{ci,cube,test,H}$) of a **150 mm edge test cube stored mixed after formworking** shall be converted to the **individual compressive strength** ($f_{ci,cube,test}$) of a **150 mm edge cube stored under water after formworking** in the following relation.

$$f_{ci,cube,test} = 0{,}92 \cdot f_{ci,cube,test,H}$$ ➡ If the compressive strength class is ≤ C50/60

$$f_{ci,cube,test} = 0{,}95 \cdot f_{ci,cube,test,H}$$ ➡ If the compressive strength calss is ≥ C55/67

At least three test specimens must be prepared for one compressive strength test. The mean value of these three results gives a test result.

[MSZ 4798:2016 - 5.5.1.2 Section – (2) Paragraph – page 55.]

Compressive strength classes for normal concretes – MSZ EN 1992-1-1:2010

The characteristic strength for f_{ck} and the corresponding necessary mechanical properties for design, are given in **MSZ EN 1992-1-1:2010 Table 3.1 (page 29.)**

[MSZ EN 1992-1-1:2010 - 3.1.2 Section – (3) Paragraph – page 27.]

Compressive strength classes for normal strength, normal density concretes: C12/15…C50/60

[N/mm²]	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
f_{ck}	12	16	20	25	30	35	40	45	50
$f_{ck,cube}$	15	20	25	30	37	45	50	55	60
f_{cm}	20	24	28	33	38	43	48	53	58

and …C55/67…C90/105

[N/mm²]	C55/67	C60/75	C70/85	C80/95	C90/105
f_{ck}	55	60	70	80	90
$f_{ck,cube}$	67	75	85	95	105
f_{cm}	63	68	78	88	98

[according to MSZ EN 1992-1-1:2010 – Table 3.1 – page 29.]

$$f_{cm} = f_{ck} + 8$$

Compressive strength classes for lightweight concretes – MSZ EN 1992-1-1:2010

In general, where strength values originating from **MSZ EN 1992-1-1:2010 Table 3.1** are used in Expressions, those values have to be replaced by the corresponding values for **lightweight concrete**, given in **MSZ EN 1992-1-1:2010 – Section 11.1.1 – Table 11.3.1 – page 174.**:

Compressive strength classes for normal strength, lightweight concretes: LC12/13…C50/55

[N/mm²]	LC12/13	LC16/18	LC20/22	LC25/28	LC30/33	LC35/38	LC40/44	LC45/50	LC50/55
f_{lck}	12	16	20	25	30	35	40	45	50
$f_{lck,cube}$	13	18	22	28	33	38	44	50	55
f_{lcm}	17	22	28	33	38	43	48	53	58

and …LC55/60…LC80/88

[N/mm²]	LC55/60	LC60/66	LC70/77	LC80/88
f_{lck}	55	60	70	80
$f_{lck,cube}$	60	66	77	88
f_{lcm}	63	68	78	88

[according to MSZ EN 1992-1-1:2010 – Table 11.3.1 – page 174.]

if ➡ $f_{lck} \geq 20\,\mathrm{N/mm^2}$

than ➡ $f_{lcm} = f_{lck} + 8$

…and for normal and heavy concretes – EN 206-1 / MSZ 4798:2016/2M:2018

Compressive strength classes for normal and heavy concretes: C8/10…C50/60										
[N/mm^2]	C8/10	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
* $f_{ck,cyl}$	8	12	16	20	25	30	35	40	45	50
** $f_{ck,cube}$	10	15	20	25	30	37	45	50	55	60

and …C55/67…C100/115						
[N/mm^2]	C55/67	C60/75	C70/85	C80/95	C90/105	C100/115
* $f_{ck,cyl}$	55	60	70	80	90	100
** $f_{ck,cube}$	67	75	85	95	105	115

[according to MSZ 4798:2016 – Table 12. – page 38.]

* $f_{ck,cyl}$ is the defined characteristic value of the compressive strength for Ø150 × 300 mm cylinder specimens stored under water until the compressive strength test. [Minimum characteristic value of cylinder strength]

** $f_{ck,cube}$ is the defined characteristic value of the compressive strength for cube specimens with an edge length of 150 mm stored under water until the compressive strength test. [Minimum characteristic value of cube strength]

These concrete compressive strength classes can not be found in MSZ EN 1992-1-1:2010 (shaded cells: C8/10 and C100/115)

…and for lightweight concretes – EN 206-1 / MSZ 4798:2016/2M:2018

Compressive strength classes for normal strength, lightweight concretes: LC8/9…LC50/55										
[N/mm²]	LC8/9	LC12/13	LC16/18	LC20/22	LC25/28	LC30/33	LC35/38	LC40/44	LC45/50	LC50/55
* $f_{lck,cyl}$	8	12	16	20	25	30	35	40	45	50
** $f_{lck,cube}$	9	13	18	22	28	33	38	44	50	55

and …LC55/60…LC80/88				
[N/mm²]	LC55/60	LC60/66	LC70/77	LC80/88
* $f_{lck,cyl}$	55	60	70	80
** $f_{lck,cube}$	60	66	77	88

[according to MSZ 4798:2016 – Table 13. – Page 39.]

* $f_{lck,cyl}$ is the defined characteristic value of the compressive strength for Ø150 × 300 mm cylinder specimens stored under water until the compressive strength test. [Minimum characteristic value of cylinder strength]

** $f_{lck,cube}$ is the defined characteristic value of the compressive strength for cube specimens with an edge length of 150 mm stored under water until the compressive strength test. [Minimum characteristic value of cube strength]

(Grey shading:) *These concrete compressive strength classes can not be found in MSZ EN 1992-1-1:2010*

Compressive strength of concrete at an age of *t* days – MSZ EN 1992-1-1:2010

The compressive strength of concrete at an age *t* depends on the **type of cement**, **temperature** and **curing conditions**. For a mean temperature of **20 ^{0}C** and during in accordance with **EN12390** the compressive strength of concrete at various ages $f_{cm(t)}$ may be **estimated** from **Expression (3.1) and (3.2) of MSZ EN 1992-1-1:2010 (3.1)**:

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

and

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

⬆

relationship according to Arrhenius

[MSZ EN 1992-1-1:2010 – 3.1.2 Section – (6) Paragraph – page 27.]

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

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

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

t ➡ is the age of the concrete in days

s ➡ 0,20 for CEM 42,5 R, CEM 52,5 N, CEM 52,5 R **(Class R)**

0,25 for CEM 32,5 R, CEM 42,5 N **(Class N)**

0,38 for CEM 32,5 N **(Class S)**

Compressive strength of concrete at an age of *t* days – MSZ EN 1992-1-1:2010

It may be required to specify he concrete compressive strength, $f_{ck}(t)$, at time ***t*** for a number of stages (e.g demoulding, transfer of prestress), where

$$f_{ck}(t) = f_{cm}(t) - 8$$ ➡ if 3 < ***t*** < 28 days

$$f_{ck}(t) = f_{ck}$$ ➡ if ***t*** ≥ 28 days

More precise values should be based on tests especially for ***t* ≤ 3 days**.

[MSZ EN 1992-1-1:2010 – 3.1.2 Section – (5) Paragraph – page 27.]

Where the concrete does not conform with the specification for compressive strength at **28 days** the use of **Expression (3.1) and (3.2)** of **MSZ EN 1992-1-1:2010 is not appropriate**.
This **clause should not be used** retrospectively **to justify a non conforming reference strength** by a **later increase of the strength**.

[MSZ EN 1992-1-1:2010 – 3.1.2 Fejezet – (6) Bekezdés – 28. oldal]

Example for estimation of compressive strength of concrete

Example 1.: Estimate the expected compressive strength and strength class of a concrete of strength class **C30/37** (**f_{ck} = 30 N/mm²**, **f_{cm} = 38 N/mm²**) at ***t* = 12 days** if the type of cement used is **CEM I 42.5 R** (**Class R**) (***s* = 0,20**)!

$$\beta_{cc}(12\,\text{days}) = e^{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]} = e^{0{,}20\left[1-\left(\frac{28}{12}\right)^{1/2}\right]} = 0{,}86$$

$$f_{cm}(12\,\text{days}) = \beta_{cc}(12\,\text{days})\cdot f_{cm} = 0{,}86\cdot 38 = 32{,}7\,\text{N/mm}^2$$

$$f_{ck}(12\,\text{days}) = f_{cm}(12\,\text{days}) - 8 = 32{,}7 - 8 = 24{,}7\,\text{N/mm}^2$$

➡ Based on the estimated compressive strength of concrete, concrete can be classified into **strength class C20/25 at the age of 12 days**!

Example for estimation of compressive strength of concrete

Example 2.: Estimate the expected compressive strength and strength class of a concrete of strength class **C20/25** (**f_{ck} = 20 N/mm²**, **f_{cm} = 28 N/mm²**) at **t = 365 days** if the type of cement used **CEM III 32,5 N** (**Class S**) (**s = 0,38**)!

$$\beta_{cc}(365\,\text{days}) = e^{s\left[1-\left(\frac{28}{t}\right)^{1/2}\right]} = e^{0,38\left[1-\left(\frac{28}{365}\right)^{1/2}\right]} = 1{,}32$$

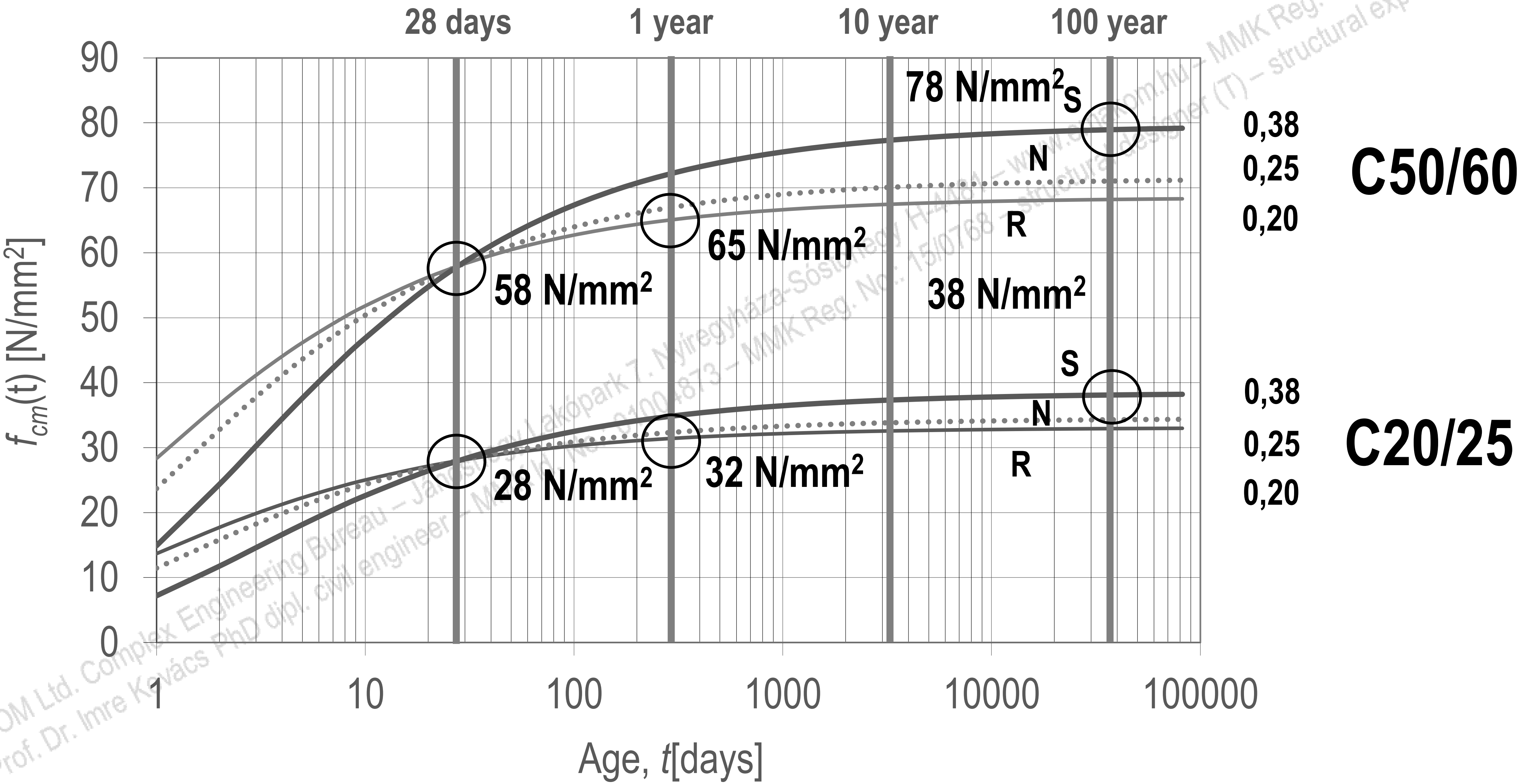
$$f_{cm}(365\,\text{days}) = \beta_{cc}(365\,\text{days})\cdot f_{cm} = 1{,}32\cdot 28 = 37{,}0\,\text{N/mm}^2$$

$$t = 365\,\text{days} > 28\,\text{days} \quad \Rightarrow \quad f_{ck}(\text{t}) = f_{ck}$$

$$f_{ck}(365\,\text{days}) = f_{ck} = 20\,\text{N/mm}^2$$

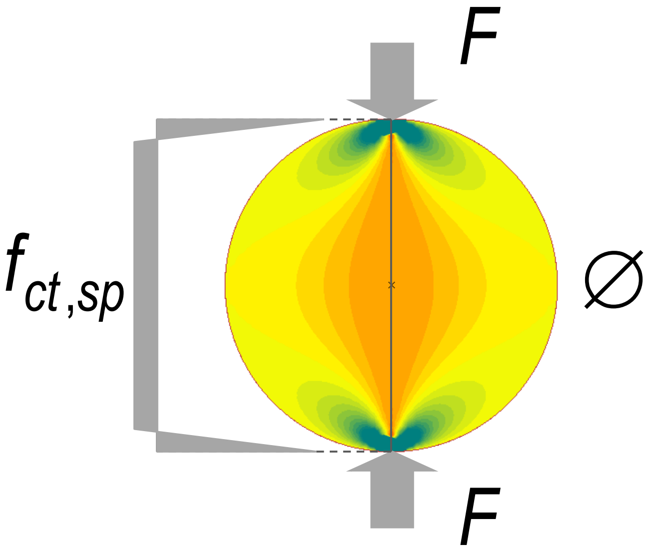
➡ Based on the estimated compressive strength of the concrete at the age of **365 days**, the concrete **is still considered** to have a **strength class of C20/25**!

Compressive strength of concrete as a function of time – MSZ EN 1992-1-1:2010



Tensile strength of concrete – different tensile test procedures

Splitting tensile strength

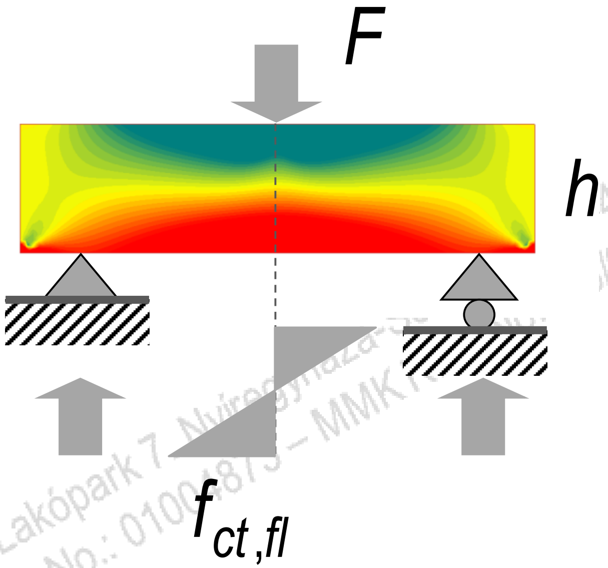


$$f_{ct,sp} = \frac{2 \cdot F}{\pi \cdot \varnothing \cdot L}$$

Ø150×300 mm
cylinder specimens

$$f_{ct} = |0{,}9| \cdot f_{ct,sp}$$

Flexural tensile strength

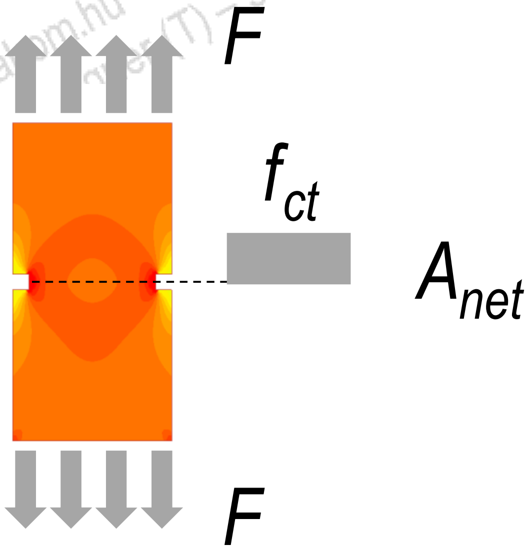


$$f_{ct,fl} = 4{,}5 \cdot \frac{F}{h^2}$$

150×150×600 mm
prism specimens

$$f_{ct} = |0{,}5| \cdot f_{ct,fl}$$

Axial tensile strength



$$f_{ct} = \frac{F}{A_{net}}$$

prism or cylinder specimens
with different sizes

Tensile strength of normal concrete – MSZ EN 1992-1-1:2010

The tensile strength refers to the highest stress reached under concentric tensile loading.

[MSZ EN 1992-1-1:2010 - 3.1.2 Section – (7)P Paragraph – Page 28.]

Tensile strength of normal concretes: C12/15…C50/60

[N/mm^2]	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
f_{ctm}	1,6	1,9	2,2	2,6	2,9	3,2	3,5	3,8	4,1
$f_{ctk,0,05}$	1,1	1,3	1,5	1,8	2,0	2,2	2,5	2,7	2,9
$f_{ctk,0,95}$	2,0	2,5	2,9	3,3	3,8	4,2	4,6	4,9	5,3

and…C55/67…C90/105

[N/mm^2]	C55/67	C60/75	C70/85	C80/95	C90/105
f_{ctm}	4,2	4,4	4,6	4,8	5,0
$f_{ctk,0,05}$	3,0	3,1	3,1	3,4	3,5
$f_{ctk,0,95}$	5,5	5,7	6,0	6,3	6,6

[according to MSZ EN 1992-1-1:2010 – Table 3.1 – page 29.]

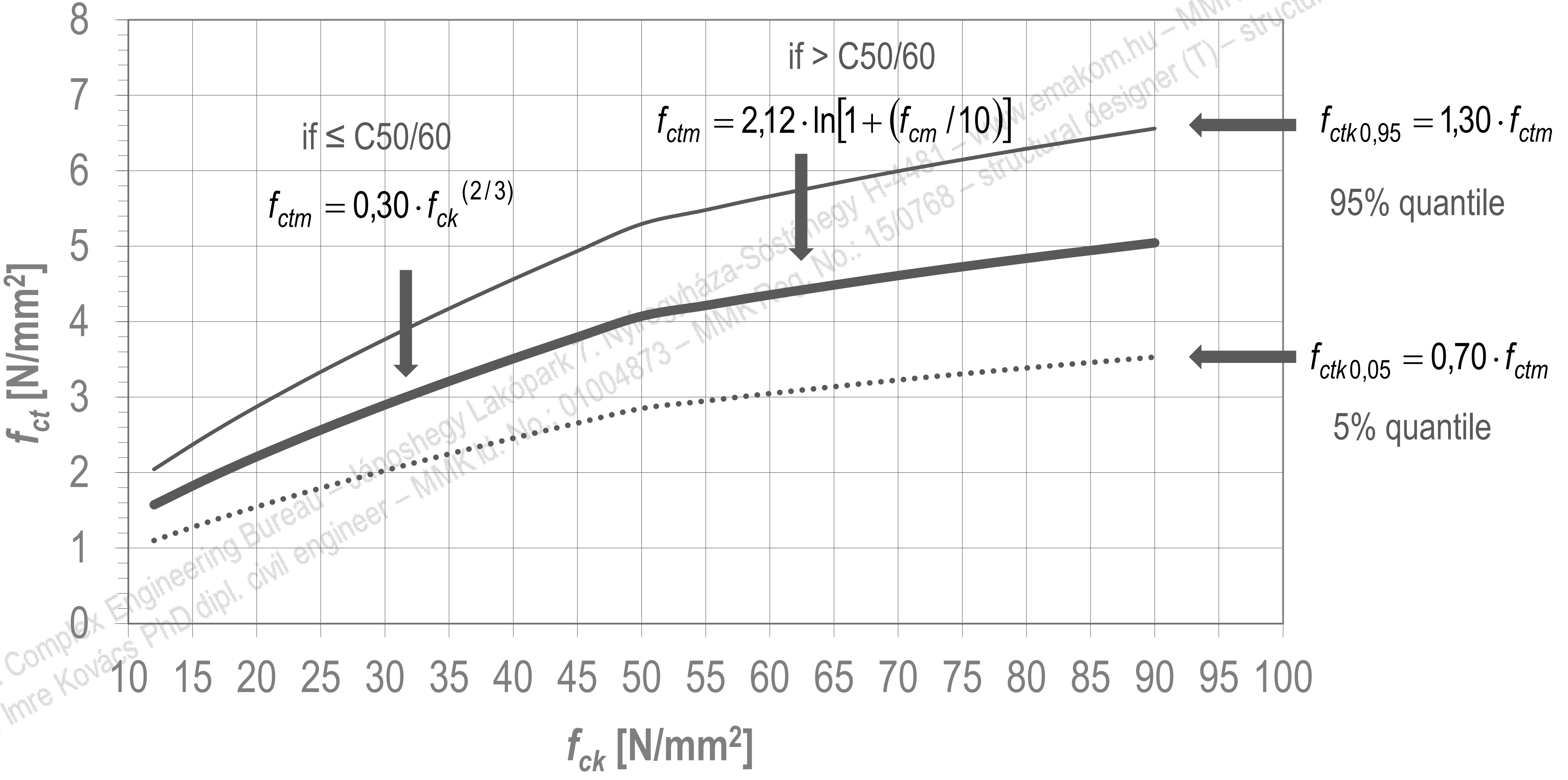
$$f_{ctm} = 0{,}30 \cdot f_{ck}^{(2/3)}$$ ➡ if ≤ C50/60

$$f_{ctm} = 2{,}12 \cdot \ln\left[1 + \left(f_{cm}/10\right)\right]$$ ➡ if > C50/60

$$f_{ctk\,0,05} = 0{,}70 \cdot f_{ctm}$$ ➡ 5% quantile

$$f_{ctk\,0,95} = 1{,}30 \cdot f_{ctm}$$ ➡ 95% quantile

Tensile strength of normal concrete – MSZ EN 1992-1-1:2010



Tensile strength of lightweight concrete – MSZ EN 1992-1-1:2010

The tensile strength of lightweight aggregate concrete may be obtained by multiplying the f_{ct} values given in **MSZ EN 1992-1-1:2010 Table 3.1** (page 29.) by a coefficient:

$$\eta_1 = 0{,}4 + 0{,}6 \cdot \frac{\rho}{2200}$$

where:

ρ is the upper limit of the density for the relevant class in accordance with **MSZ EN 1992-1-1:2010 Table 11.1.** (page 172.)

[MSZ EN 1992-1-1:2010 – 11.3.1 Section – (3) Paragraph – page 172.]

Density classes and corresponding design densities of LWAC according to EN 206-1							
Density class		**1,0**	**1,2**	**1,4**	**1,6**	**1,8**	**2,0**
Density [kg/m³]		**801-1000**	**1001-1200**	**1201-1400**	**1401-1600**	**1601-1800**	**1801-2000**
Density [kg/m³]	**Plain concrete**	**1050**	**1250**	**1450**	**1650**	**1850**	**2050**
	RC	**1150**	**1350**	**1550**	**1750**	**1950**	**2150**

[MSZ EN 1992-1-1:2010 – Table 11.1 – page 172.]

Example for determination of tensile strength of lightweight concrete

Determine the tensile strength values of a lightweight concrete with strength class **LC30/33** and density class ρ**1.4**!
(The tensile strength properties of lightweight concrete are determined from the tensile strength characteristics of normal concrete of strength class C30/37, based on the upper density value of the specified density class.)

$$f_{lctm} = f_{ctm} \cdot \eta_1 = f_{ctm} \cdot \left(0{,}4 + 0{,}6 \cdot \frac{\rho}{2200}\right) = 2{,}9 \cdot \left(0{,}4 + 0{,}6 \cdot \frac{1400}{2200}\right) = 2{,}2\,\text{N/mm}^2$$

$$f_{lctk\,0{,}05} = f_{ctk\,0{,}05} \cdot \eta_1 = f_{ctk\,0{,}05} \cdot \left(0{,}4 + 0{,}6 \cdot \frac{\rho}{2200}\right) = 2{,}0 \cdot \left(0{,}4 + 0{,}6 \cdot \frac{1400}{2200}\right) = 1{,}5\,\text{N/mm}^2$$

$$f_{lctk\,0{,}95} = f_{ctk\,0{,}95} \cdot \eta_1 = f_{ctk\,0{,}95} \cdot \left(0{,}4 + 0{,}6 \cdot \frac{\rho}{2200}\right) = 3{,}8 \cdot \left(0{,}4 + 0{,}6 \cdot \frac{1400}{2200}\right) = 2{,}9\,\text{N/mm}^2$$

Tensile strength of normal concrete as a funcion of time – MSZ EN 1992-1-1:2010

The development of tensile strength with time is strongly influenced by curing and drying conditions as well as by the dimensions of the structural members. As a first approximation it may be assumed that the tensile strength $f_{ctm}(t)$ is equal to:

$$f_{ctm}(t)=\left[\beta_{cc}(t)\right]^{\alpha}\cdot f_{ctm}$$

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

⬆

relationship according to Arrhenius

[according to MSZ EN 1992-1-1:2010 – 3.1.2 Section – (9) Paragraph – page 28.]

- $f_{ctm}(t)$ ➡ is the mean concrete tensile strength at an age of ***t*** days
- $\beta_{cc}(t)$ ➡ is a coefficient which depends on the age of the concrete ***t***
- f_{ctm} ➡ is the mean concrete tensile strength at 28 days
- t ➡ is the age of the concrete in days
- s ➡
  - 0,20 for CEM 42,5 R, CEM 52,5 N, CEM 52,5 R **(Class R)**
  - 0,25 for CEM 32,5 R, CEM 42,5 N **(Class N)**
  - 0,38 for CEM 32,5 N **(Class S)**
- α ➡
  - 1 if t < 28 days
  - 2/3 if t ≥ 28 days

Mean flexural tensile strength of RC members – MSZ EN 1992-1-1:2010

The mean flexural tensile strength of reinforced concrete members depends on the mean axial tensile strength and the depth of the cross-section. The following relationship may be used:

$$f_{ctm,fl} = \max \begin{Bmatrix} \left(1{,}6 - \dfrac{h}{1000}\right) \cdot f_{ctm} \\ f_{ctm} \end{Bmatrix}$$

h ➡ is the total member depth in mm

f_{ctm} ➡ is the mean axial tensile strength following from **MSZ EN 1992-1-1:2010 Table 3.1** (page 29.)

[MSZ EN 1992-1-1:2010 - 3.1.8 Section – (1) Paragraph – page 36.]

When the total member depth is greater than **600 mm**, f_{ctm} can be considered as $f_{ctm,fl}$! The above relation given in **MSZ 1992-1-1:2010 Eq. (3.23)** also applies for the characteristic tensile strength values:

$$f_{ctk,fl} = \max \begin{Bmatrix} \left(1{,}6 - \dfrac{h}{1000}\right) \cdot f_{ctk} \\ f_{ctk} \end{Bmatrix} \quad f_{ctk0,05,fl} = \max \begin{Bmatrix} \left(1{,}6 - \dfrac{h}{1000}\right) \cdot f_{ctk0,05} \\ f_{ctk0,05} \end{Bmatrix} \quad f_{ctk0,95,fl} = \max \begin{Bmatrix} \left(1{,}6 - \dfrac{h}{1000}\right) \cdot f_{ctk0,95} \\ f_{ctk0,95} \end{Bmatrix}$$

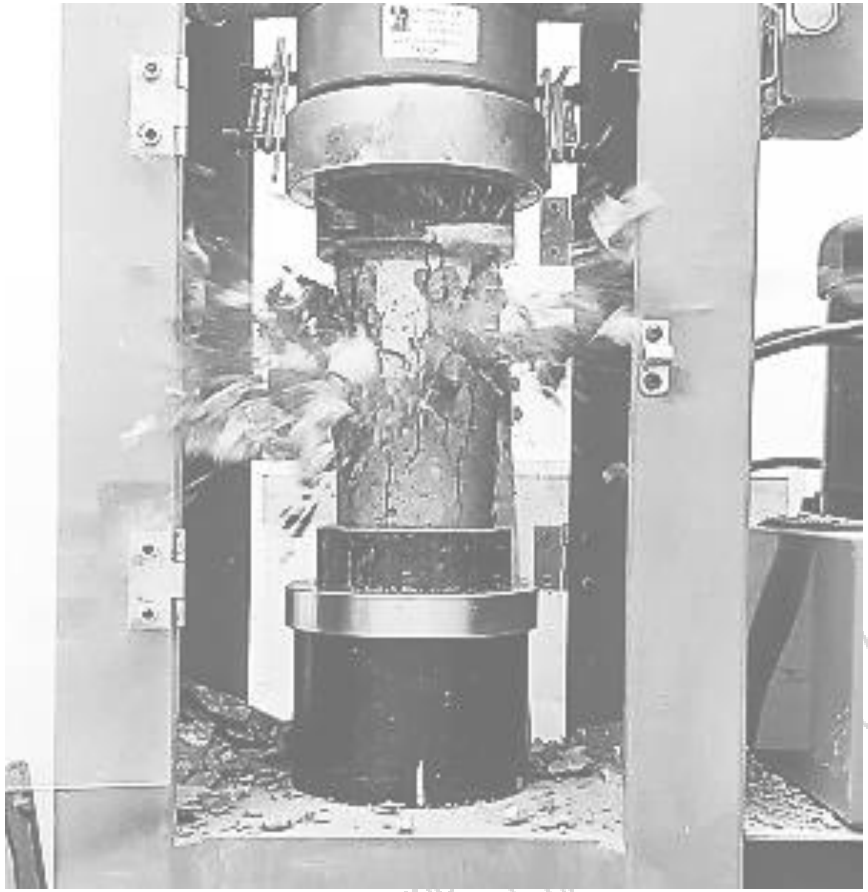
Examples for determination of flexural tensile strength of RC members

Example 1.: Determine the mean value of the flexural tensile strength of a prefabricated reinforced concrete beam with strength class **C40/50** (f_{ctm} = 3,5 N/mm^2) and height ***h* = 1200 mm**!

$$f_{ctm,fl} = \max\begin{Bmatrix}\left(1{,}6-\dfrac{h}{1000}\right)\cdot f_{ctm} \\ f_{ctm}\end{Bmatrix} = \max\begin{Bmatrix}\left(1{,}6-\dfrac{1200}{1000}\right)\cdot 3{,}5 = 1{,}4\,\text{N/mm}^2 \\ 3{,}5\,\text{N/mm}^2\end{Bmatrix} = 3{,}5\,\text{N/mm}^2$$

Example 2.: Determine the mean value of the flexural tensile strength of a reinforced concrete flat slab with strength class **C20/25** (f_{ctm} = 2,2 N/mm^2) and height ***h* = 200 mm**!

$$f_{ctm,fl} = \max\begin{Bmatrix}\left(1{,}6-\dfrac{h}{1000}\right)\cdot f_{ctm} \\ f_{ctm}\end{Bmatrix} = \max\begin{Bmatrix}\left(1{,}6-\dfrac{200}{1000}\right)\cdot 2{,}2 = 3{,}1\,\text{N/mm}^2 \\ 2{,}2\,\text{N/mm}^2\end{Bmatrix} = 3{,}1\,\text{N/mm}^2$$



Reinforced Concrete (RC) Structures

Topic 4.

Strength properties of structural concrete

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Thank you for your kind attention!

