BETON
4
LIFE

Reinforced-concrete structures

Concrete cover

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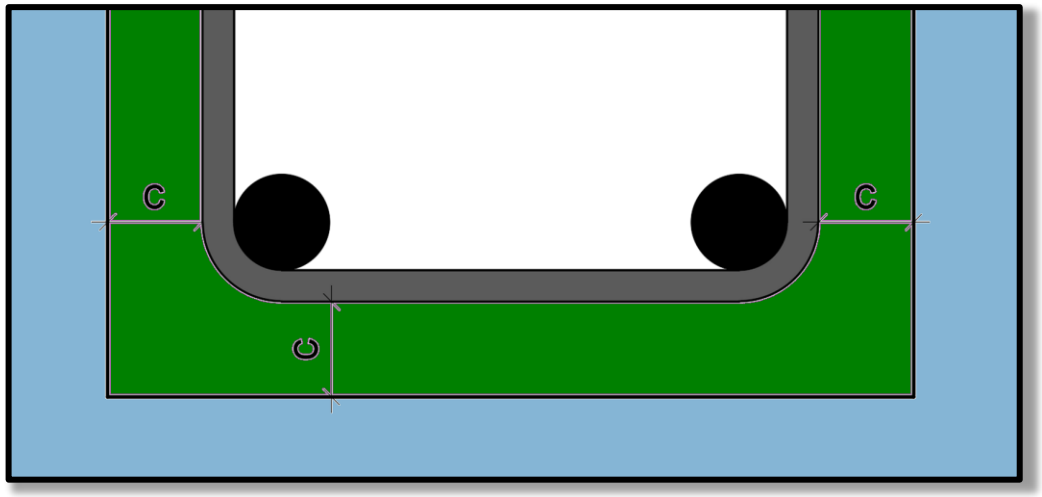
Poslední aktualizace: 24.09.2024 17:25

Concrete cover

Every reinforcement bar in a structural member **must always be separated from the external environment** by a sufficiently thick layer of concrete to ensure sufficient:

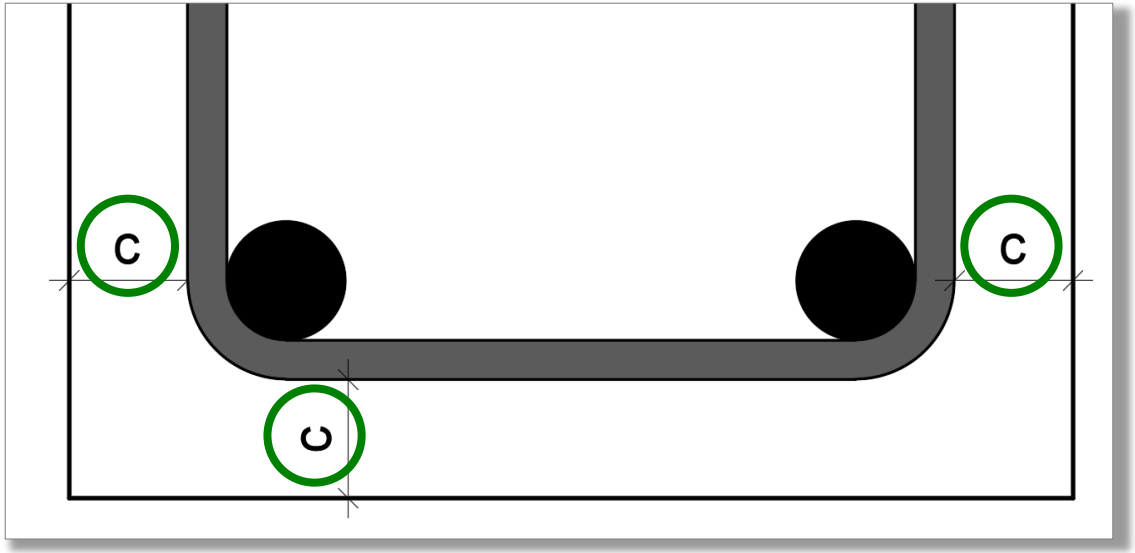
- **bonding** between the concrete and the reinforcement,
- **protection** of reinforcement from external effects (fire and corrosion).



Concrete cover

The thickness of the concrete cover c **must always be greater than the nominal*** **cover layer**

$$c \geq c_{nom}.$$



* In this context “nominal” can be understood as “required”.

Nominal concrete cover c_{nom}

The nominal cover layer is determined using the formula

$$c_{nom} = c_{min} + \Delta c_{dev},$$

where c_{min} is the minimum cover,

Δc_{dev} is the allowance for the design deviation.

Minimum cover c_{min}

The minimum cover is related to ensuring **safe transmission of bond forces** and **protection of the reinforcement against the external environment**. The minimum cover is determined using the equation

$$c_{min} = \max(c_{min,b}, c_{min,dur}, 10\ \text{mm}),$$

where $c_{min,b}$ is minimum cover due to bond requirement (which is equal to the diameter of the reinforcement bars*),

$c_{min,dur}$ is minimum cover due to environmental conditions.

* If the rebar diameter is not yet known when calculating the cover, a suitable estimate is $\varnothing_s = 10$ mm for slabs and $\varnothing_s = 18$ mm to 25 mm for beams.

Cover due to environmental conditions $c_{min,dur}$

When determining the value of $c_{min,dur}$, we proceed in two steps.

1) Determine the **structure class** according to Table 4.3.
2) Determine the **cover due to environmental conditions** according to Table 4.4.

Cover due to environmental conditions $c_{min,dur}$

When determining the class of the structure, we **start from the default class S4** and **adjust it according to the type of the structural member** using Table 4.3.

Structural class								
Criterion	Exposure class related to environmental conditions							
	X0	XC1	XC2	XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3
Working life 80 years	increase class by 1							
Working life 100 years	increase class by 2							
Concrete class	decrease class by 1 if concrete class is at least:							
	C20/25	C25/30	C30/37	C35/45	C40/50	C40/50	C40/50	C45/55
Member with slab geometry	decrease class by 1							
Special quality control of concrete	decrease class by 1							

Cover due to environmental conditions $c_{min,dur}$

Example: Slab with working life 50 years and concrete class C40/50 exposed to environmental conditions XC3.

1) Default class:

   S4

2) Working life 80 years?

   NO ⟶ class remains S4

3) Working life 100 years?

   NO ⟶ class remains S4

4) Is concrete higher than C35/45?

   YES ⟶ reduce class to S3

5) Is it a slab?

   YES ⟶ reduce class to S2

6) Is there a special quality control ensured?

   I do not know ⟶ class remains S2.

Final class: **S2**

Structural class								
Criterion	Exposure class related to environmental conditions							
	X0	XC1	XC2	XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3
Working life 80 years	increase class by 1							
Working life 100 years	increase class by 2							
Concrete class	decrease class by 1 if concrete class is at least:							
	C20/25	C25/30	C30/37	C35/45	C40/50	C40/50	C40/50	C45/55
Member with slab geometry	decrease class by 1							
Special quality control of concrete	decrease class by 1							

Cover due to environmental conditions $c_{min,dur}$

The thickness of the $c_{min,dur}$ cover is determined **based** on the **structure class** and the **environmental conditions**.

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	Exposure Class according to Table 4.1						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

You can check your calculation using this interactive tool.

Cover due to environmental conditions $c_{min,dur}$

Example: Slab with structure class S2 exposed to environmental conditions XC3.

$\longrightarrow c_{min,dur} = \mathbf{15\ mm}.$

Environmental Requirement for $c_{min,dur}$ (mm)							
Structural Class	**Exposure Class according to Table 4.1**						
	X0	XC1	XC2 / XC3	XC4	XD1 / XS1	XD2 / XS2	XD3 / XS3
S1	10	10	10	15	20	25	30
S2	10	10	15	20	25	30	35
S3	10	10	20	25	30	35	40
S4	10	15	25	30	35	40	45
S5	15	20	30	35	40	45	50
S6	20	25	35	40	45	50	55

Allowance for deviation Δc_{dev}

We must add a “reserve” part of the cover Δc_{dev} to the minimum cover c_{min} *.

For **monolithic structures** $\Delta c_{dev} \in \langle 5\ \mathrm{mm}, 10\ \mathrm{mm} \rangle$, usually $\Delta c_{dev} = \mathbf{10\ mm}$.

For **prefabricated structures** $\Delta c_{dev} \in \langle 0\ \mathrm{mm}, 5\ \mathrm{mm} \rangle$, usually $\Delta c_{dev} = \mathbf{5\ mm}$.

* We must create a certain reserve in the cover, because errors can occur on the construction site or during production.

Nominal concrete cover c_{nom}

The final nominal concrete cover is

$$c_{nom} = c_{min} + \Delta c_{dev},$$

where c_{min} is the minimum cover,

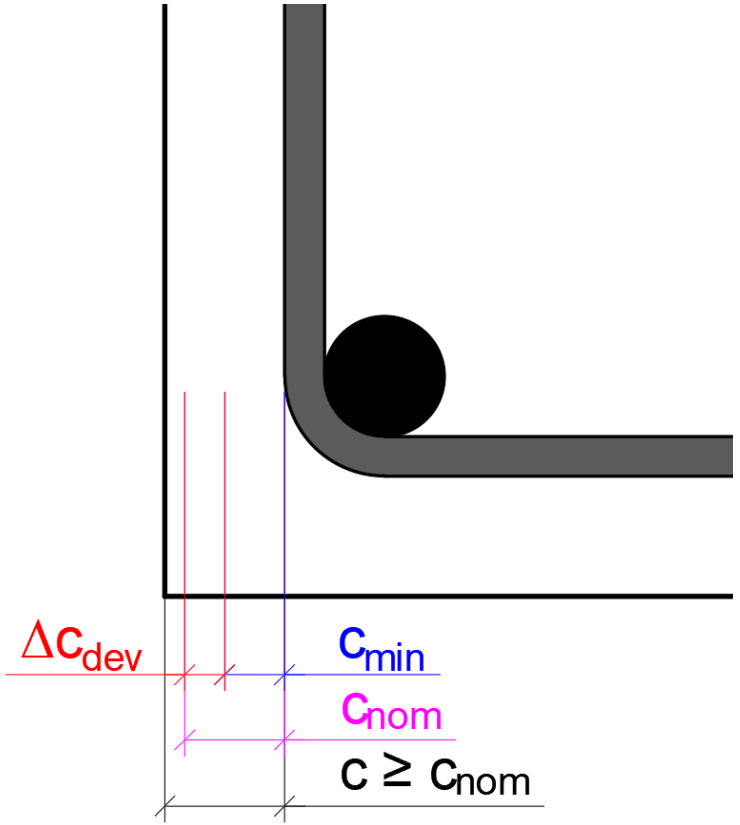
Δc_{dev} is the allowance for the design deviation.

Designed concrete cover c

The **actual thickness** of the concrete cover c **must be designed to satisfy the condition**

$$c \geq c_{nom},$$

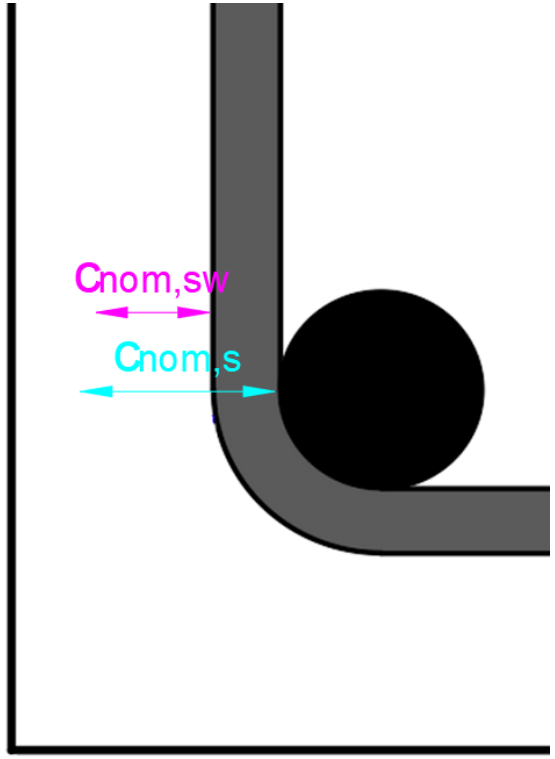
and the thickness of the concrete cover **should be a multiple of 5 mm**.



Advanced

Various rebar diameters

If there are **rebars of various diameters or positions** in the element*, the **nominal concrete cover should be calculated separately** for each rebar.

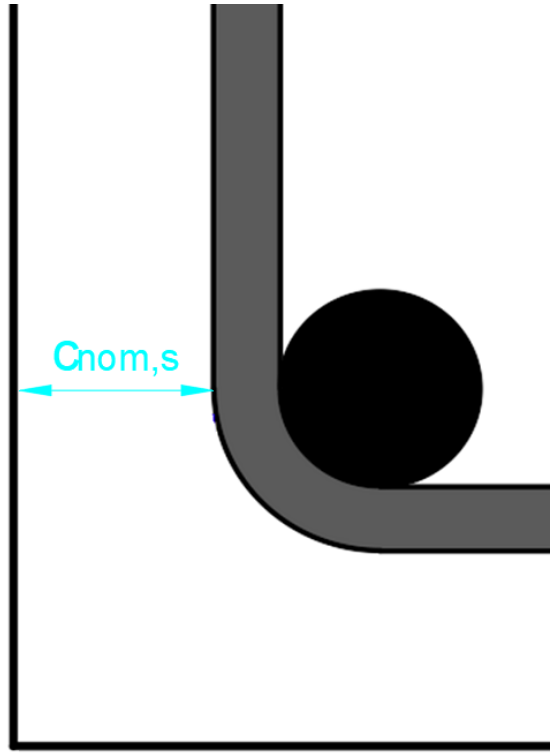


* e.g., stirrups and longitudinal reinforcement in a beam

Advanced

Various rebar diameters

However, we can simplify the calculation* and calculate the nominal cover only for the **largest diameter** of the reinforcement and measure it **from the reinforcement closest to the surface**.



* Please note: This is a fast and conservative approach, but it is not economical!

Advanced

Exact calculation procedure

This presentation serves as an **introduction to the topic** of the calculation of the concrete cover, and therefore **some information are omitted from it**.

For example, according to the standard, the minimum cover is determined as

$$c_{min} = \max(c_{min,b}, c_{min,dur} + \boldsymbol{\Delta c_{dur,\gamma}} - \boldsymbol{\Delta c_{dur,st}} - \boldsymbol{\Delta c_{dur,add}}, 10\ \mathrm{mm}),$$

where the coefficients $\boldsymbol{\Delta c_{dur,i}}$ are usually considered as 0 and have, therefore, been omitted from the presentation.

When calculating the concrete cover in a real project, always perform the calculation exactly according to the procedure described in the EN 1992-1-1 standard!

Thank you for your attention