BETON
4
LIFE

Reinforced-concrete structures

Span-to-depth ratio assessment

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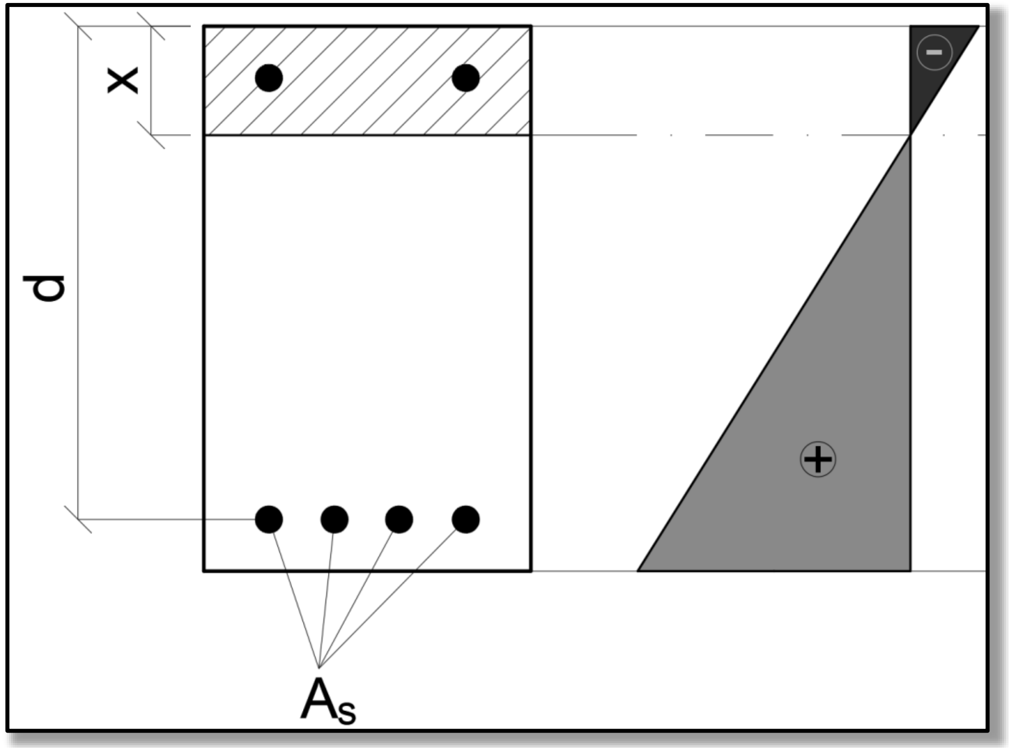
Span-to-depth assessment

The effective depth is one of the **basic cross-section parameters**.

This parameter is **used in various equations**, and its **exact determination is therefore an important step** in the static calculation.

Effective depth

The effective height (d) is the distance **from the most compressed fiber** of the concrete **to the centroid of the tensile reinforcement**.



Serviceability Limit States

Serviceability Limit States

When assessing structures, in addition to the *Ultimate Limit States**, we must also consider the *Serviceability Limit States* – i.e., **check whether the structure is capable of fulfilling its functions during normal operation**.

* i.e., "Will the structure fall?"

Serviceability Limit States

In practice, **we usually check three Serviceability Limit States**:

- **stress** limitation,
- **crack** control,
- **deflection** control.

In **this presentation**, we will focus only on the **deflection control***.

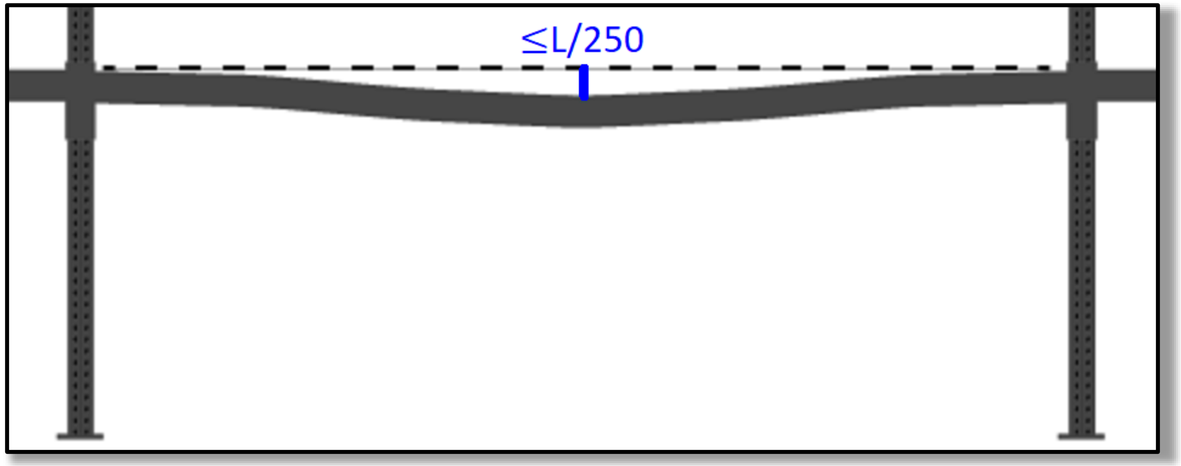
* Other serviceability limit states are also very important, but their assessment is more complicated and will be described in future presentations.

Deflection control

Deflection control

The EC2 standard states that the **deformation** of the member **must not adversely affect** its **functionality** and **appearance**.

Specifically, the standard states that the **appearance and functionality may be compromised** if the calculated **deflection** (under quasi-permanent load) **exceeds 1/250 of the span**.



Deflection control

Therefore, we just **need to calculate the deflection**

$$w = ?$$

and **compare it with the limit value**

$$w_{lim} = \frac{L}{250}.$$

However, it is **very difficult to calculate the deflection**.

Fortunately, the **standard provides a simplified approach** to the deflection control – a ***Span-to-depth ratio assessment***.

Span-to-depth ratio assessment

Span-to-depth ratio assessment

The standard states that if the Span-to-depth ratio of a beam (λ) does not exceed its limiting value (λ_d), i.e.:

$$\boldsymbol{\lambda \leq \lambda_d},$$

it can be assumed that the deflections will not exceed the limit values*.

* And, thus, we don't need to calculate and directly assess the deflection.

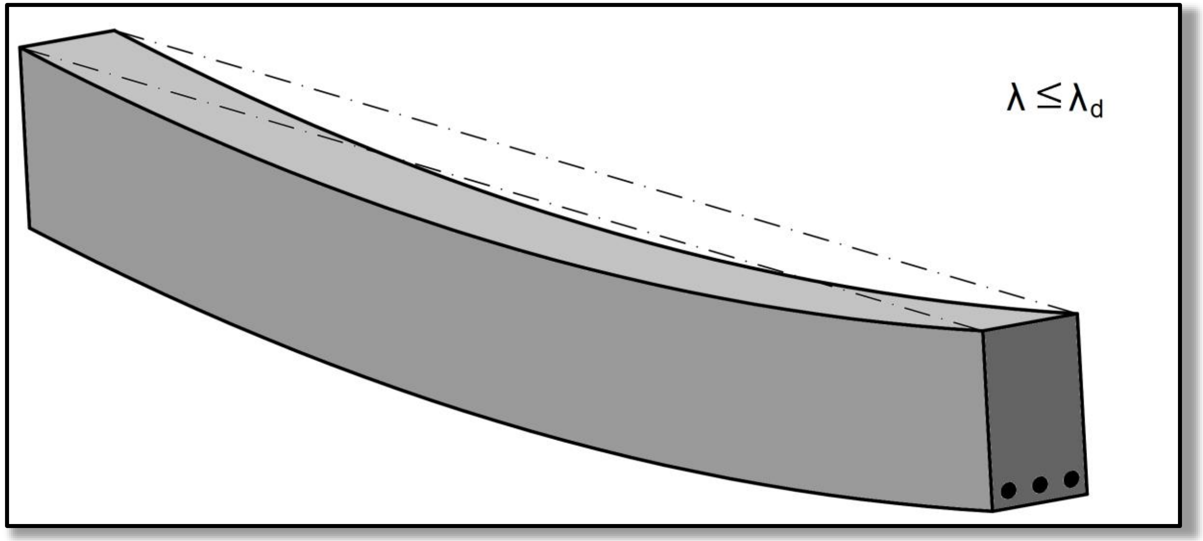
Span-to-depth ratio assessment

Therefore, **we need to verify** the condition

$$\boldsymbol{\lambda \le \lambda_d},$$

where λ is the *Span-to-depth ratio,*

λ_d is the *Limiting span-to-depth ratio*.

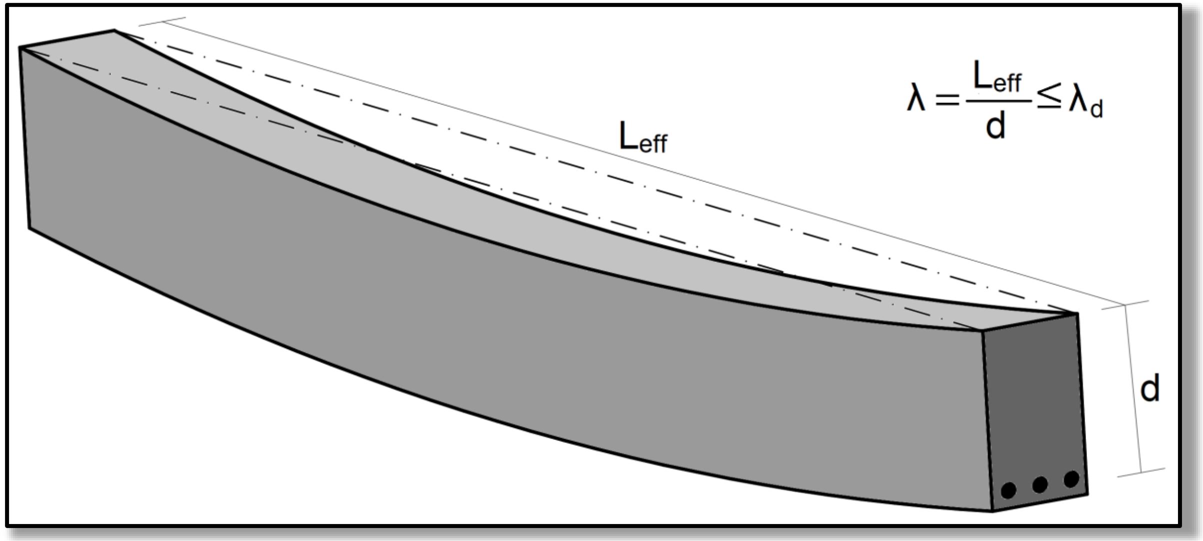


Span-to-depth ratio λ

The **Span-to-depth ratio** of a structural member is calculated using the equation

$$\lambda = \frac{l}{d},$$

where l is the theoretical span (length) of the member*,
d is the effective depth.



Limiting span-to-depth ratio λ_d

The **Limiting span-to-depth ratio** is calculated using the equation

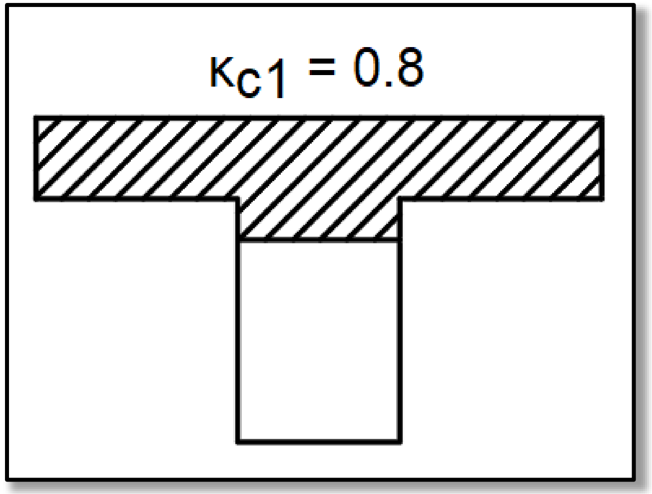
$$\lambda_d = \kappa_{c1}\kappa_{c2}\kappa_{c3}\lambda_{d,tab},$$

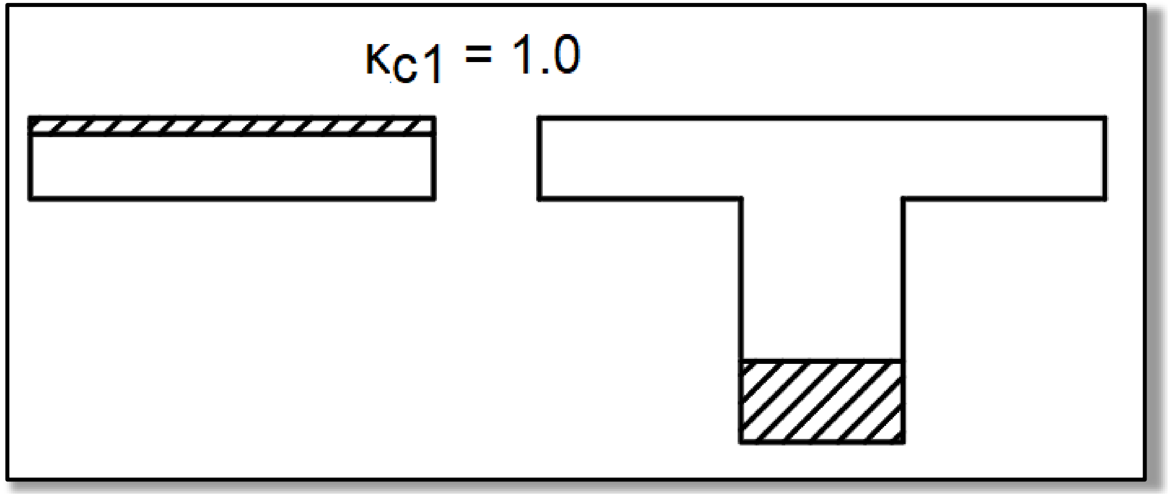
where κ_{c1} is the *cross-section shape* factor,
κ_{c2} is the *span of the element* factor,
κ_{c3} is the *stress* factor,
$\lambda_{d,tab}$ is the tabulated value of the *Basic limiting span-to-depth ratio*.

Cross-section shape factor κ_{c1}

The **Cross-section shape factor** is determined based on the cross-section shape:

- $\kappa_{c1} = \mathbf{0.8}$ for a **T-section** – e.g., a beam in the mid-span,
- $\kappa_{c1} = \mathbf{1.0}$ pro **rectangle** – e.g., a slab or a beam above support*.



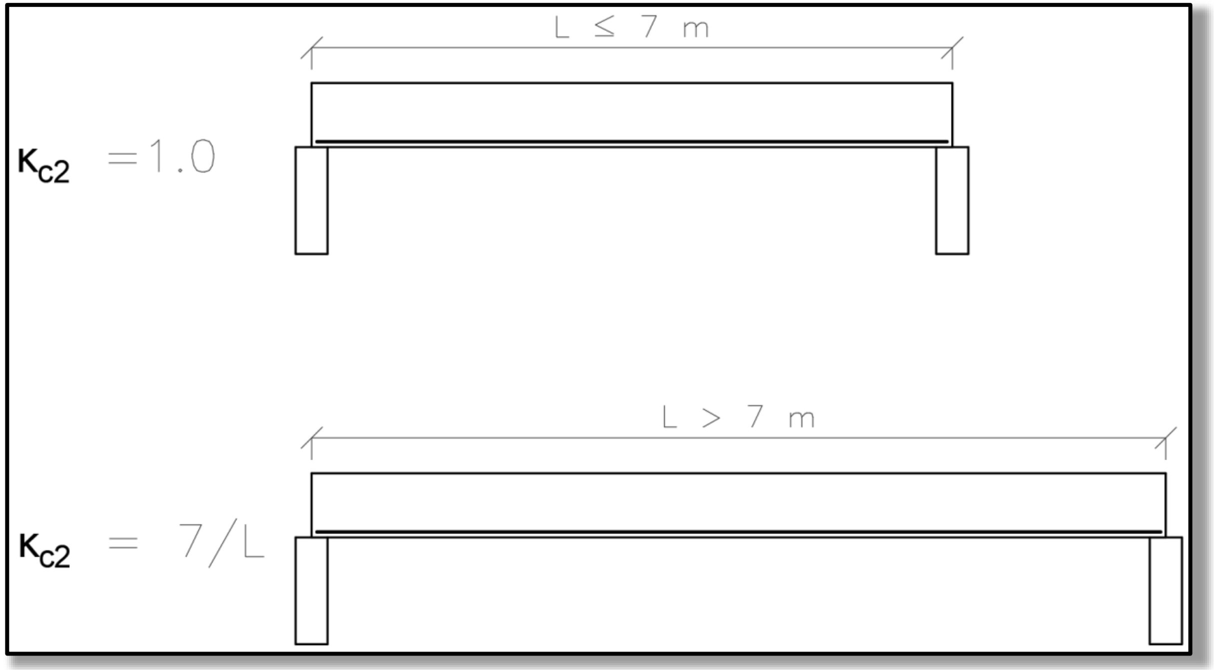


Span of the element factor κ_{c2}

The **Span of the element factor** is calculated using the equation

$$\kappa_{c2} = \min\left(1, \frac{7}{l}\right),$$

where l is the theoretical span of the element in meters.



Stress factor κ_{c3}

The **Stress factor** takes into account the actual stress in the reinforcement and is calculated using the equation

$$\kappa_{c3} = \frac{310}{\sigma_s},$$

where σ_s is the maximum* stress in the reinforcement** (see next slide).

* In the mid-span of a beam or in the support of a cantilever.

**** This is the stress under a quasi-permanent loading**. (Not the stress used in the load-bearing calculations.)

Stress factor κ_{c3}

Unfortunately, we do not know the stress in the reinforcement*. Fortunately, the standard states that the **Stress factor can be calculated in a simplified** (and conservative) way using the equation

$$\kappa_{c3} = \frac{500}{f_{yk}} \cdot \frac{A_{s,prov}}{A_{s,req}},$$

where $A_{s,prov}$ is the **designed** area of the **tensile** reinforcement in the cross-section,

$A_{s,req}$ is the **required** area of the **tensile** reinforcement in terms of the acting bending moment,

f_{yk} is the **characteristic** value of the **yield stress** of the reinforcement.

* and it is difficult to calculate

Basic limiting span-to-depth ratio $\lambda_{d,tab}$

The value of the **Basic limiting span-to-depth ratio** is determined from a table depending on the **strength class** of the concrete, the **tensile reinforcement ratio** $(A_{s,prov}/bh)^*$, and the **type of structure**.

Basic limiting span-to-depth ratio for an interior span of a multi-spaned beam.

A_{sprov} / (bh)	Concrete class								
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
0.5%	21.9	23.7	25.5	27.8	30.8	34.5	38.6	43.2	48.0
1.5%	18.3	18.9	19.5	20.3	21.0	21.8	22.5	23.3	24.0

* For values of the reinforcement ratio between 0.5% and 1.5%, the tabulated values need to be interpolated. For a reinforcement ratio of <0.5%, we take a value for 0.5%. For a reinforcement ratio of >1.5%, we take a value for 1.5%.

Basic limiting span-to-depth ratio $\lambda_{d,tab}$

The value of the **Basic limiting span-to-depth ratio** is determined from a table depending on the **strength class** of the concrete, the **tensile reinforcement ratio** $(A_{s,prov}/bh)^*$, and the **type of structure**.

Basic limiting span-to-depth ratio for a cantilever.

A_{sprov} / (bh)	Concrete class								
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
0.5%	5.8	6.3	6.8	7.4	8.2	9.2	10.3	11.5	12.8
1.5%	4.9	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4

* For values of the reinforcement ratio between 0.5% and 1.5%, the tabulated values need to be interpolated. For a reinforcement ratio of <0.5%, we take a value for 0.5%. For a reinforcement ratio of >1.5%, we take a value for 1.5%.

Basic limiting span-to-depth ratio $\lambda_{d,tab}$

The value of the **Basic limiting span-to-depth ratio** is determined from a table depending on the **strength class** of the concrete, the **tensile reinforcement ratio** $(A_{s,prov}/bh)^*$, and the **type of structure**.

Basic limiting span-to-depth ratio for end span of a multi-spaned beam.

A_{sprov} / (bh)	Concrete class								
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
0.5%	19.0	20.5	22.1	24.1	26.7	29.9	33.5	37.4	41.6
1.5%	15.9	16.4	16.9	17.6	18.2	18.9	19.5	20.2	20.8

* For values of the reinforcement ratio between 0.5% and 1.5%, the tabulated values need to be interpolated. For a reinforcement ratio of <0.5%, we take a value for 0.5%. For a reinforcement ratio of >1.5%, we take a value for 1.5%.

Basic limiting span-to-depth ratio $\lambda_{d,tab}$

The value of the **Basic limiting span-to-depth ratio** is determined from a table depending on the **strength class** of the concrete, the **tensile reinforcement ratio** $(A_{s,prov}/bh)^*$, and the **type of structure**.

Basic limiting span-to-depth ratio for interior span of a simply-supported beam.

A_{sprov} / (bh)	Concrete class								
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
0.5%	14.6	15.8	17.0	18.5	20.5	23.0	25.8	28.8	32.0
1.5%	12.2	12.6	13.0	13.5	14.0	14.5	15.0	15.5	16.0

* For values of the reinforcement ratio between 0.5% and 1.5%, the tabulated values need to be interpolated. For a reinforcement ratio of <0.5%, we take a value for 0.5%. For a reinforcement ratio of >1.5%, we take a value for 1.5%.

Basic limiting span-to-depth ratio $\lambda_{d,tab}$

The value of the **Basic limiting span-to-depth ratio** is determined from a table depending on the **strength class** of the concrete, the **tensile reinforcement ratio** $(A_{s,prov}/bh)^*$, and the **type of structure**.

Basic limiting span-to-depth ratio for interior span of a locally supported slab.

A_{sprov} / (bh)	Concrete class								
	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
0.5%	17.5	19.0	20.4	22.2	24.6	27.6	30.9	34.5	38.4
1.5%	14.6	15.1	15.6	16.2	16.8	17.4	18.0	18.6	19.2

* For values of the reinforcement ratio between 0.5% and 1.5%, the tabulated values need to be interpolated. For a reinforcement ratio of <0.5%, we take a value for 0.5%. For a reinforcement ratio of >1.5%, we take a value for 1.5%.

Span-to-depth ratio assessment

Now, when we know the Span-to-depth ratio as well as the Limiting span-to-depth ratio, we can verify the condition

$$\boldsymbol{\lambda \leq \lambda_d},$$

where λ is the Span-to-depth ratio,

λ_{d} is the Limiting span-to-depth ratio.

Span-to-depth ratio assessment

If **the Span-to-depth ratio condition is not satisfied**, it does not necessarily mean that the design is not correct!

It just means that this simplified condition is not satisfied, and that **the deflection must be assessed by calculating and assessing the deflection directly** (see the beginning of this presentation).

Thank you for your attention