Toolbox: Unreinforced concrete wall TB-BUW

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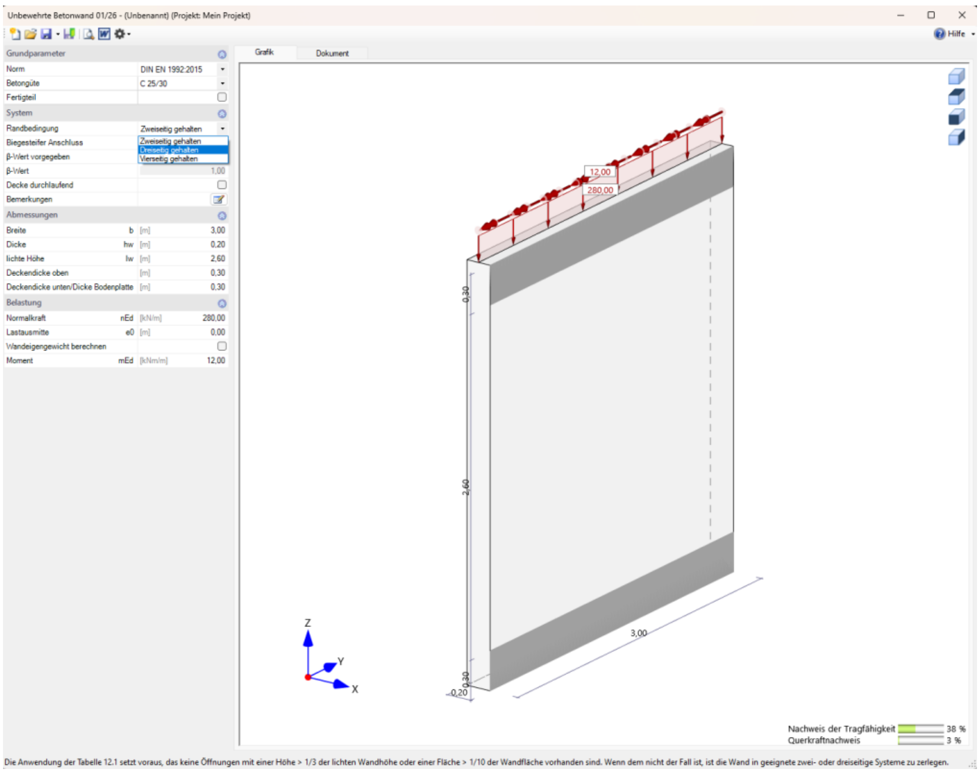


Possible use cases

Concrete walls do not necessarily need to be reinforced. If the walls are not subjected to significant bending moments but are mainly exposed to compressive forces, they can also be constructed without reinforcement.

Unreinforced concrete walls are often cheaper and quicker to build, and they also have a better carbon footprint compared to reinforced concrete walls.

This program can be used to verify unreinforced or lightly reinforced walls in typical buildings in accordance with EN 1992-1-1, Chapter 12. Components are considered lightly reinforced if the existing reinforcement is less than the minimum reinforcement for reinforced concrete.

The program performs the following calculations:

- Determination of buckling length
- Verification for bending and normal force
- Stability check (simplified verification according to Th. II. O.)
- Shear force check
- Verification of usage limits and design rules

Calculation bases

The calculation is based on EN 1992-1-1:2015. The following national annexes are available:

DIN EN 1992:2015	Germany
BS EN 1992:2015	United Kingdom
ÖNORM EN 1992:2018	Austria
NBN EN 1992:2010	Belgium
NEN EN 1992:2011	Netherlands
PN EN 1992:2010	Poland
CSN EN 1992:2011	Czechia

System

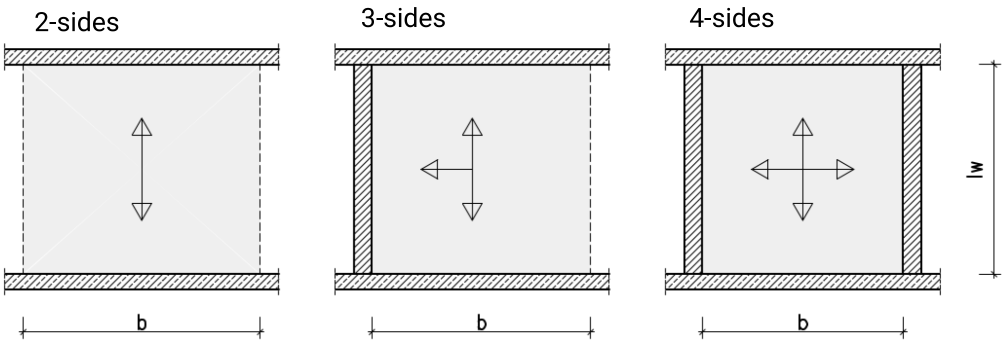
The wall is always assumed to be a structural system consisting of a hinged bar (hinged at the top and bottom of the wall).

The buckling length is determined according to EN 1992-1, Table 12.1, depending on the support conditions and wall dimensions.

Optionally, the buckling length coefficient β can also be specified by the user.

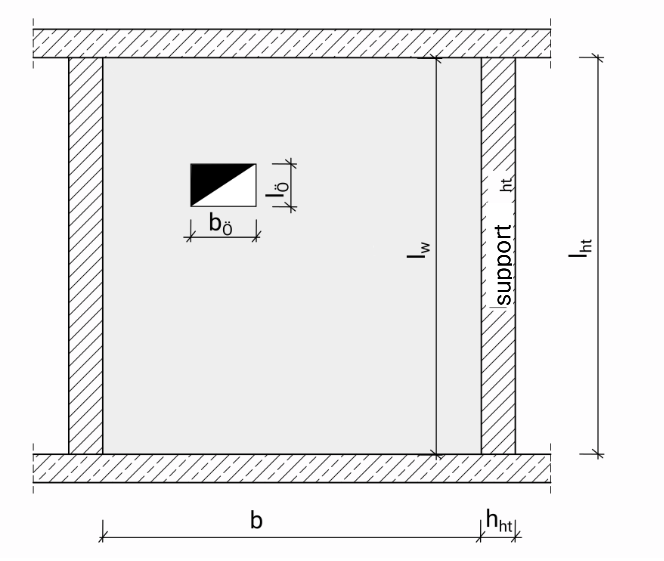
In addition, an option for rigidly connected walls is available. According to 12.6.5.1 (4), β can be reduced by a factor of 0.85 for rigidly connected walls supported on both sides at the top and bottom.

The wall can be installed or supported in the following ways:



Condition for wall openings: The use of table 12.1 requires that there are no openings with a height > 1/3 of the clear wall height or an area > 1/10 of the wall area. If this is not the case, the wall must be split into corresponding two- or three-sided systems.

- $h_{ö} < \frac{1}{3} \cdot l_W$
- $b_{ö} \cdot h_{ö} < \frac{1}{10} b \cdot l_W$



Definition of wall supports:

A transverse wall can be regarded as a bracing wall (=support) if:

- $h_{ht} \geq 0{,}5\, h_w$
- $l_{ht} = l_w$
- $b_{ht} \geq l_w / 5$
- No opening inside: $b_{ht,min} = 0{,}5\, h_w$

Material

Normal or lightweight concrete in accordance with EN 1992-1-1 can be taken into account. According to EN 1992-1-1. 11.12 (1), all rules apply in the same way when lightweight concrete is used. For lightweight concrete walls, both the strength class and the dry concrete density ρ must be specified.

Due to the lower ductility of unreinforced concrete, the values for $\alpha_{cc,pl}$ and $\alpha_{ct,pl}$ are generally lower than the values α_{cc} and α_{ct} for reinforced concrete.

When calculating according to NA-DIN, concrete strength class C35/45 is the maximum permissible strength class for normal concrete and LC20/22 for lightweight concrete. For higher concrete strength classes, the maximum concrete compressive strength is set internally to f_{ck} = 35 N/mm² (normal concrete) and f_{lck} = 20 N/mm² (lightweight concrete).

For the other implemented NA, there is no such limitation of the concrete strength class.

$$f_{cd,pl} = \alpha_{cc,pl} \cdot f_{ck}/\gamma_c$$

$$f_{ctd,pl} = \alpha_{ct,pl} \cdot f_{ctk;0,05}/\gamma_c$$

Standard	$\alpha_{cc,pl}$	$\alpha_{ct,pl}$	γ_c **(permanent/ temporary)**	**Maximum strength class**
EN	0,8	0,8	1,5	no limit
DIN	0,7	0,7	=EN	C35/45 and LC20/22
BS	0,6	=EN	=EN	=EN
ÖNORM	=EN	=EN	=EN	=EN
NBN	=EN	=EN	=EN	=EN
NEN	=EN	=EN	=EN	=EN
PN	=EN	=EN	1,4	=EN
CSN	=EN	=EN	=EN	=EN

If the wall is designed as a prefabricated element, this can be taken into account within the program by applying reduced partial safety factors for concrete (according to Appendix A).

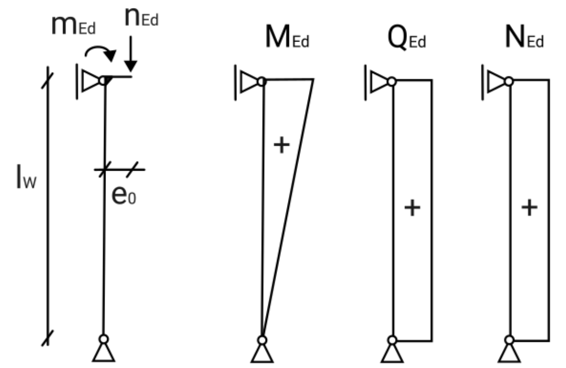
Loads

The load is entered for the wall top using design values.

The possible load inputs include a normal force n_{Ed} with load center e_0, if applicable, and a moment m_{Ed}.

The wall's self-weight is optionally taken into account with γ = 24 kN/m³ and a partial safety factor of γ_G = 1.35 and added to the entered normal force.

The verifications are performed for the static system and load shown below, with the resulting internal forces.



Verifications

Bending with normal force

$$N_{Ed} \leq N_{Rd}$$

$$N_{Rd} = \eta \cdot f_{cd,pl} \cdot b \cdot h_w \cdot \left(1 - 2 \cdot \frac{e}{h_w}\right)$$

b wall width

h_W wall thickness

e Load eccentricity according to Th. I. O. (N_{Ed} in direction of h_w)

$e = e_0 + e_1$

with: e_1 Eccentricity due to the moment: m_{Ed}: $e_1 = m_{Ed}/n_{Ed}$

e_0 the load eccentricity of n_{Ed}

$\eta \cdot f_{cd,pl}$ Design compressive strength with:

$\eta = 1{,}0$ for $f_{ck} \leq 50 \frac{N}{mm^2}$

$\eta = 1{,}0 - (f_{ck} - 50)/200$ for $50\ N/mm^2 \leq f_{ck} \leq 100\ N/mm^2$

Shear force verification

$\boldsymbol{\tau_{cp} \leq f_{cvd}}$

$\tau_{cp} = k \cdot \frac{V_{Ed}}{A_{cc}}$ (Rectangular cross-section)

With:

k Country-specific value k. The following applies to all NA offered: k = 1,5

A_{cc} Compression zone

the following still applies:

$$\sigma_{cp} = \frac{N_{Ed}}{A_{cc}}$$

$$\sigma_{\mathrm{c,lim}} = f_{\mathrm{cd,pl}} - 2 \cdot \sqrt{f_{\mathrm{ctd,pl}} \cdot (f_{\mathrm{ctd,pl}} + f_{\mathrm{cd,pl}})}$$

if $\sigma_{cp} \leq \sigma_{\mathrm{c,lim}}$

$$f_{cvd} = \sqrt{f_{\mathrm{ctd,pl}}^2 + \sigma_{cp} \cdot f_{\mathrm{ctd,pl}}}$$

if $\sigma_{cp} > \sigma_{\mathrm{c,lim}}$

$$f_{cvd} = \sqrt{f_{\mathrm{ctd,pl}}^2 + \sigma_{cp} \cdot f_{\mathrm{ctd,pl}} - \left(\frac{\sigma_{cp} - \sigma_{\mathrm{c,lim}}}{2}\right)^2}$$

To determine the compression zone area A_{CC}:

The compression zone area is determined on the uncracked remaining cross-section, if applicable. According to 12.6.3 (3), a cross-section can be considered uncracked if the principal tensile stress σ_{ct1} in the concrete does not exceed the value $f_{ctd,pl}$. The principal stress for the single-axis case is derived from the normal stress σ_x and the transverse stress τ.

$$\sigma_{ct1} = \frac{\sigma_x}{2} \pm \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau^2}$$

The pressure zone area is thus determined iteratively.

Verification according to Th. II. O. - Simplified procedure

For slender columns, the design value of the normal force can be calculated in a simplified manner as follows:

$N_{Ed} \leq N_{Rd}$

$N_{Rd} = f_{cd,pl} \cdot b \cdot h_w \cdot \Phi$

$\phi = 1{,}14 \cdot (1 - 2 \cdot e_{tot}/h_w) - 0{,}02 \cdot l_0/h_w \leq (1 - 2 \cdot e_{tot}/h_w)$

$e_{tot} = e_0 + e_1 + e_i + e_\varphi$

e_0 the load eccentricity of n_{Ed}

e_1 Eccentricity due to the moment m_{Ed}

e_i Eccentricity due to geometric imperfections according to 5.2

e_φ Eccentricity due to creep

l_0 Buckling length

In general, a wall or column is considered slender (i.e., verification according to Th. II. O. is required) if the slenderness λ is not below a limit value λ_{lim}.8.3.1).

According to DIN, verification in accordance with Th. II. O. must be provided for unreinforced walls if the following slenderness criterion applies:

$l_{col}/h \geq 2{,}5$

Standard	k	θ_0 für e_i (5.2)	e_φ	Condition for verification according to Th. II. O.
EN	1,5	1/200	inputable	$\lambda \geq \lambda_{lim}$
DIN	=EN	=EN	negligible	$l_{col}/h \geq 2{,}5$
BS	=EN	=EN	=EN	EN
ÖNORM	=EN	=EN	=EN	EN
NBN	=EN	=EN	=EN	EN
NEN	=EN	1/300	$0{,}001 \cdot l\_0$	EN
PN	=EN	=EN	=EN	EN
CSN	=EN	=EN	=EN	$\lambda_{lim} \leq 75$ $\lambda_{lim} = 25, if\ \lvert n \rvert \geq 0{,}41$

Usage limits and design rules

Design rules

According to EN 1992-1-1, the total thickness of the walls should generally not be less than 120 mm. The program performs a corresponding check.

If calculations are performed according to NA-DIN, the minimum wall thicknesses are checked in accordance with Table DIN EN 1992-1 NA, 12.2. For concrete with very low strength or non-continuous slabs, greater wall thicknesses are required. Precast walls with continuous slabs, on the other hand, may be constructed with low minimum wall thicknesses. If lightweight concrete is used, the table for LC12/13 (instead of C12/15) and for ≥ LC16/28 (instead of ≥ C16/20) can also be used analogously in accordance with 11.12.(1).

Usage limits

The following additional checks of the usage limits are performed:

- $\lambda \leq 86$ (Limiting slenderness according to 12.6.5.1 (5))
- Prevention of local failure (according to 12.6.2) by limiting the permissible load eccentricity (only for DIN and ÖNORM)
- According to 12.6.2, large cracks must be avoided. Since there is no definition of the permissible load eccentricity for NA outside DIN and ÖNORM, at least the edge stresses (lying inside or outside the core)

must be calculated. An assessment should currently be made by the user. From an eccentricity of $etot > h_w/3$, excessive crack formation is assumed.

Standard	Load eccentricity limitation	Minimum wall thicknesses
EN	No information provided	120 mm
DIN	e_{tot}/h_w <0,4	Table NA 12.2, Precast element and continuous slab option
BS	= EN	=EN
ÖNORM	$\lambda \leq 35$: e_{tot}/h_w = 0,33 $35 \leq \lambda \leq 70$: e_{tot}/h_w = 0,25 $70 \leq \lambda \leq 86$: e_{tot}/h_w = 0,15	=EN
NBN	=EN	=EN
NEN	=EN	=EN
PN	=EN	=EN
CSN	=EN	=EN

References

/1/ EN 1992-1-1 A1:2015