EN 1996-3

Simplified calculation methods for unreinforced masonry structures

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Content

- Scope
- Actions
- Material properties
- Walls subject to vertical and wind loads
- Concentrated loads
- Shear resistance of a wall
- Walls subject to lateral earth pressure
- Walls subject to limited lateral load
- Walls subject to uniform lateral load
Scope

Methods are simplified in relation to EN 1996-1-1 and therefore:

- conservative
- limited in their use
Actions

Actions should be based on the loads from EN 1991 and the load combinations according to EN 1990

Basis of Design
Use of EN 1996-3

It should be possible to use this code without EN 1996-1-1 being on your desk. Therefore in addition to ENV 1996-3, material properties are given in EN 1996-3
Material properties

- are given in chapter 3
- values are described for the compressive strength, the flexural strengths and the shear strength
- simplified material properties of masonry can be derived from the unit- and mortar properties, using the tables in the informative annex D
- simplified properties are indicated with indices $s$, so $f_k$ will be $f_{k;s}$
Material properties in annex D

- values in annex D are based on the recommended methods and values of the ndp’s in part 1-1
- in the national annex these tables can be revised, based on the national chosen methods and values for the ndp’s.
Walls subject to vertical and wind loads

Clause 4.2

Background: Simplified method is based on several linear calculations according to 6.1.2 and annex C of part 1-1 and some non-linear elastic calculations.
Nachweis am Wand-Decken-Knoten

Grenzkurven für den Nachweis nach
EC 6 Teil 1, Anhang C
Abschnitt (1), (2) max / min
Abschnitt (3), (4) max, (min = 0)
EC 6 Teil 3 max, (min = 0)
DIN 1053-1, 6.9.1 max, (min = 0)

EC 6-1-1 (3),(4)  
EC 6-1-1  
EC 6-1-1  
EC 6-3  
DIN 1053-1

Wand:
- HLz 6 / LM21 (f₀ = 2,04 MN/m²)
- E = 2040 MN/m²
- t = 17,5 cm
- h = 2,75 m

Decke:
- B 25
- E = 30000 MN/m²
- d = 16 cm
- l = 3,00 + 6,25 m (≥ 4,5 + 10·t)
- g_{k} / \rho_{x} = 5,50 / 2,75 kN/m²
(\bar{q}_{D} = 11,55 kN/m²)

Teilrahmensystem:

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General conditions

- building height is limited (ndp)
- floor span is limited to 7 meter
- clear storey height limited to 3.2 m
- bearing length at least 0.4 m
- slenderness ratio $h_{ef}/t_{ef} \leq 27$

Concrete slabs should fulfill the requirements from EN 1992-1-1 clause 7.4 (deflection)
Additional conditions to the floorspan

If $N_{Ed} < k_G \ t \ b \ f_d$ \hspace{1cm} (\(k_G\) is 0,2 for group 1 units)

then \hspace{1cm} floor span limited to 7 m

else if $f_d > 2,5 \text{ N/mm}^2$

then \hspace{1cm} floor span limited to the lesser of 4,5 + 10 \(t\) and 7 m

else \hspace{1cm} floor span limited to the lesser of 4,5 + 10 \(t\) and 6 m
Additional conditions due to wind load:

\[ M_{Ed} = q_{Ed} \frac{h^2}{16} \]

\[ M_{Ed} = N_{Ed} \frac{e_t}{t} \]

gives

\[ \frac{e_t}{t} = q_{Ed} \frac{h^2}{(16 \ N_{Ed} \ t)} \]

assuming \( \Phi_m = 0.05 \) a relation between \( \frac{e_t}{t} \) and \( \frac{h_{ef}}{t_{ef}} \) can be found:

\[ \frac{e_t}{t} = 0.528 - 0.0122 \ \frac{h_{ef}}{t_{ef}} \]  

(figure G.2 part 1-1)
assuming \( t = t_{ef} \) and \( h_{ef} = 0.75h \) it can be found that:

\[
t \geq \frac{0.12 q_{Ed} b h^2}{N_{Ed}} + 0.017 h
\]

\( \alpha = \Phi_m = 0.05 \)

\( c_1 = 0.12 \) and \( c_2 = 0.017 \) (table 4.1)
Vertical design resistance

\[ N_{Ed} \leq N_{Rd} \quad \text{where} \quad N_{Rd} = \Phi_s f_d A \]

for internal walls, \( \Phi_s \) follows from:

\[ 0,85 - 0,0011 \left( \frac{h_{ef}}{t_{ef}} \right)^2 \]

for end walls, not at the top storey, \( \Phi_s \) follows from the lesser of:

\[ 0,85 - 0,0011 \left( \frac{h_{ef}}{t_{ef}} \right)^2 ; \quad 1,3 - \frac{l_{f,ef}}{8} \quad \text{and} \; 0,85 \]
Vertical design resistance

\[ N_{Ed} \leq N_{Rd} \]

where \( N_{Rd} = \Phi_s f_d A \)

for end walls, at the top storey, \( \Phi_s \) follows from the lesser of:

\[ 0.85 - 0.0011 \left( \frac{h_{ef}}{t_{ef}} \right)^2; \quad 1.3 - \frac{l_{f,ef}}{8} \quad \text{and } 0.4 \]
Concentrated loads

Clause 4.3

\[ N_{Rdc} = f_d \left( 1,2 + 0,4 \frac{a_1}{h_c} \right) A_b \]
\[ \leq 1,5 f_d A_b \]

Formula is a simplification of the formula in clause 6.1.3 in part 1-1
Shear resistance of a wall

Clause 4.4

\[ V_{Rd} = x_v \, t \, f_{vdo} + 0.4 \, \frac{N_{Ed}}{\gamma_M} \]

\[ = 3(0.5l - e_{Ed}) \, t \, f_{vdo} + 0.4 \, \frac{N_{Ed}}{\gamma_M} \]

\[ e_{Ed} \geq l/6 \]

when the perpend joints are not filled:

\[ f_{vdo-unfilled} = 0.5 \, f_{vdo} \]

\[ V_{Rd} = 1.5(0.5l - e_{Ed}) \, t \, f_{vdo} + 0.4 \, \frac{N_{Ed}}{\gamma_M} \]
Walls subject to lateral earth pressure

Clause 4.5

General conditions

- clear height of the wall $\leq 2.6 \text{ m}$
- wall thickness $\geq 200 \text{ mm}$
- floor over basement acts as a horizontal support
- load on ground surface limited to 5 kN/m$^2$
- no hydrostatic pressure acting on the wall
- no slip plane created by e.g. a damp proof course
Axial load on the basement wall limited

\[ N_{Ed,\text{max}} \leq \frac{t b f_d}{3} \]

\[ N_{Ed,\text{min}} \geq \frac{\rho_e b h h_e^2}{\beta t} \]

\( \beta \) is a factor related to \( b_c/h \)
Thickness of the basement wall

\[ t \geq \frac{3 N_{Ed; \text{max}}}{b f_d} \]

\[ t \geq \frac{\rho_e b h h_e^2}{\beta N_{Ed, \text{min}}} \]

\[ t \geq 200 \text{ mm} \]
Walls subject to limited lateral load

Clause 4.6
Derived from
annex F of part 1-1

No load due to
- wind,
- furniture,
- persons etc.
Walls subject to uniform lateral load
no vertical load

Clause 4.7

\[ \mu = \frac{f_{xd1}}{f_{xd2}} \]

Based on annex E of part 1-1

\[ M_{Ed1} = \mu \alpha_2 p_{Ed} l^2 \quad M_{Rd1} = f_{xd1} \frac{t^2}{6} \quad M_{Ed1} \leq M_{Rd1} \]
\[ M_{Ed2} = \alpha_2 p_{Ed} l^2 \quad M_{Rd2} = f_{xd2} \frac{t^2}{6} \quad M_{Ed2} \leq M_{Rd2} \]
both lead to:

\[ \mu \alpha_2 p_{Ed} l^2 = f_{xd1} \frac{t^2}{6} \]
Example:

\[ \frac{f_{\text{xd1}}}{p_{\text{Ed}}} = 100 \]

\[ \mu = 0.5 \]

\[ h/l = 1.25 \]

table E of annex E part 1-1: \( \alpha_2 = 0.066 \)

\[ \frac{l}{t} = \sqrt{\frac{100 \cdot 1}{6 \cdot 0.5 \cdot 0.066}} = 22.4 \]

\[ h/t = 22.4 \times 1.25 = 28 \]
EN 1996-3

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EUROCODE 6
Background and applications

\[ \frac{f_{xd1}}{f_{xd2}} = 0.5 \]

\[ \frac{l}{t} - \frac{h}{t} \]

\[ f_{xd1}/p_{Ed} \]

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \quad 30 \quad 35 \quad 40 \]

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \quad 30 \quad 35 \quad 40 \]

\[ 0 \quad 25 \quad 50 \quad 100 \quad 150 \quad 200 \quad 250 \]
Example

\[ l = 5 \text{ meter} \]
\[ h = 4 \text{ meter} \]
\[ t = 150 \text{ mm} \]
\[ f_{xd1} = 0.3 \text{ N/mm}^2 \]
\[ \mu = 0.5 \]

boundary conditions b
\[
\frac{l}{t} = 5/0,15 = 33,3 \\
\frac{h}{t} = 4/0,15 = 26,7 \\
\]

\[
f_{xd1}/p_{Ed} = 250 \\
p_{Ed} \leq f_{xd1}/250 \\
f_{xd1} = 0.3 \text{ N/mm}^2 \\
= 300 \text{ kN/m}^2 \\
p_{Ed} \leq 300/250 = 1.2 \text{ kN/m}^2 \\
\]