EN 1996-3

Simplified calculation methods for unreinforced masonry structures

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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 $f_{k;s}$

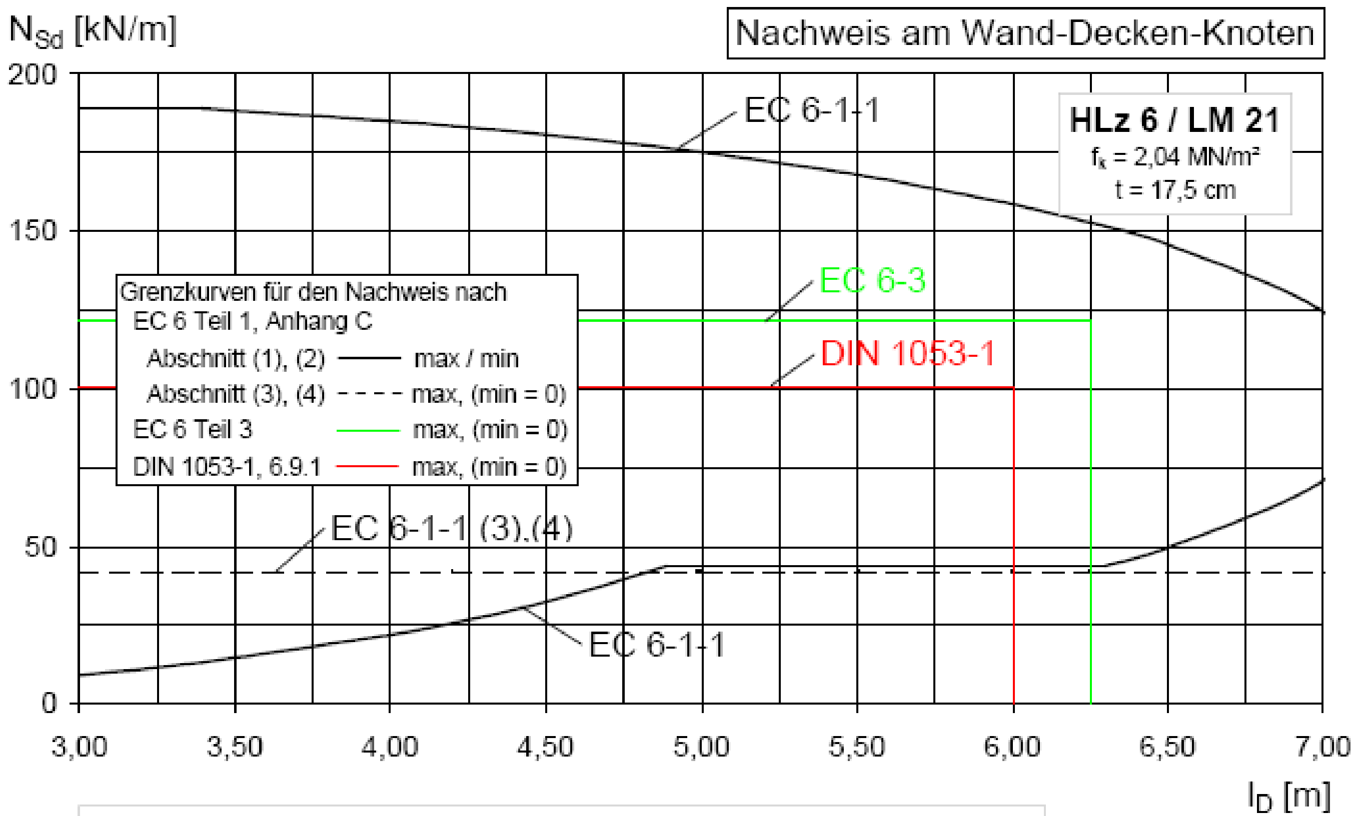
Material properties in annex D

- 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

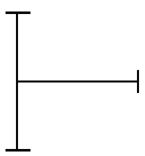
Background: Simplified method is based on several linear calculations according to 6.1.2 and annex C of part 1-1 and some non-linear elastic calculations.



Wand:
- HLz 6 / LM21 (f_k = 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 / p_k = 5,50 / 2,75 kN/m²
(q_d = 11,55 kN/m²)

Teilrahmensystem:



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 *t*
- slendernessratio $h_{ef}/t_{ef} \leq 27$

concrete slabs should fulfill the requirements from EN 1992-1-1 clause 7.4 (deflection)

Additional conditions to the floorspan

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

then floor span limited to 7 m

else if $f_d > 2,5$ N/mm²

then floor span limited to the lesser of $4,5 + 10\,t$ and 7 m

else floor span limited to the lesser of $4,5 + 10\,t$ and 6 m

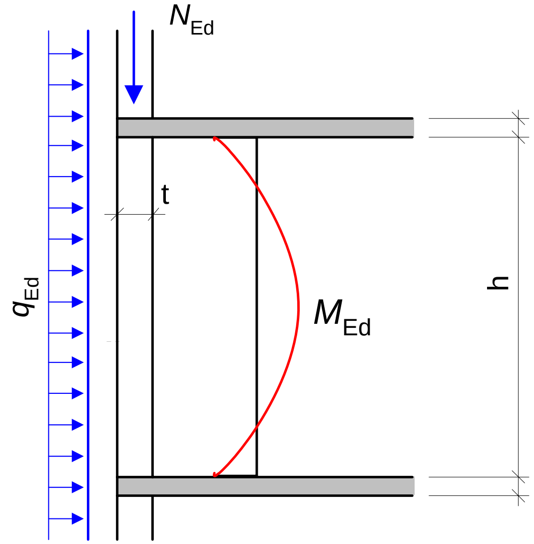
Additional conditions due to wind load:

$M_{Ed} = q_{Ed}\, h^2/16$

$M_{Ed} = N_{Ed}\, e_t$

gives

$e_t/t = q_{Ed} h^2/(16\, N_{Ed}\, t)$



assuming $\Phi_m = 0{,}05$ a relation between e_t/t and h_{ef}/t_{ef} can be found:

$e_t/t = 0{,}528 - 0{,}0122\, h_{ef}/t_{ef}$ (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

$N_{Ed} \leq N_{Rd}$ where $N_{Rd} = \Phi_s f_d A$

for internal walls, Φ_s follows from:

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

for end walls, not at the top storey, Φ_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 $N_{Rd} = \Phi_s f_d A$

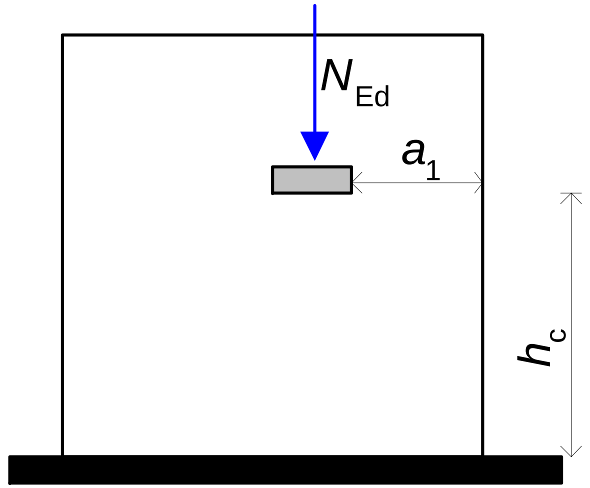
for end walls, at the top storey, Φ_s follows from the lesser of:

$$0{,}85 - 0{,}0011\left(\frac{h_{ef}}{t_{ef}}\right)^2 ; \quad 1{,}3 - \frac{l_{f,ef}}{8} \quad \text{and } 0{,}4$$

Concentrated loads

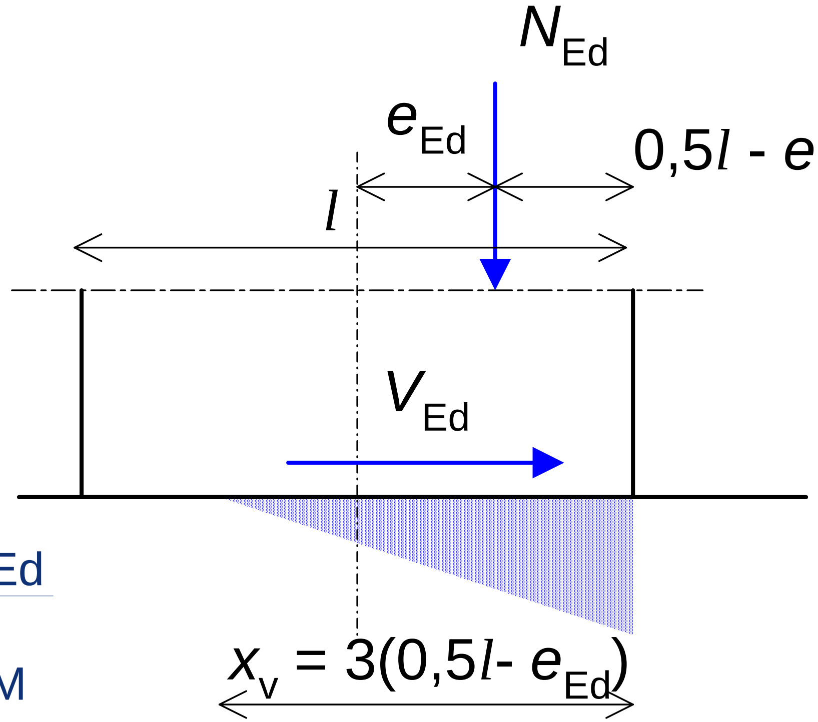
Clause 4.3

$$N_{Rdc} = f_d\,(1{,}2 + 0{,}4\,a_1/h_c)A_b$$
$$\leq 1{,}5\,f_d\,A_b$$



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:

$$f_{vdo\text{-}unfilled} = 0{,}5\, f_{vdo}$$

$$V_{Rd} = 1{,}5(0{,}5l - e_{Ed})\, t\, f_{vdo} + 0{,}4 \frac{N_{Ed}}{\gamma_M}$$

Walls subject to lateral earth pressure

Clause 4.5

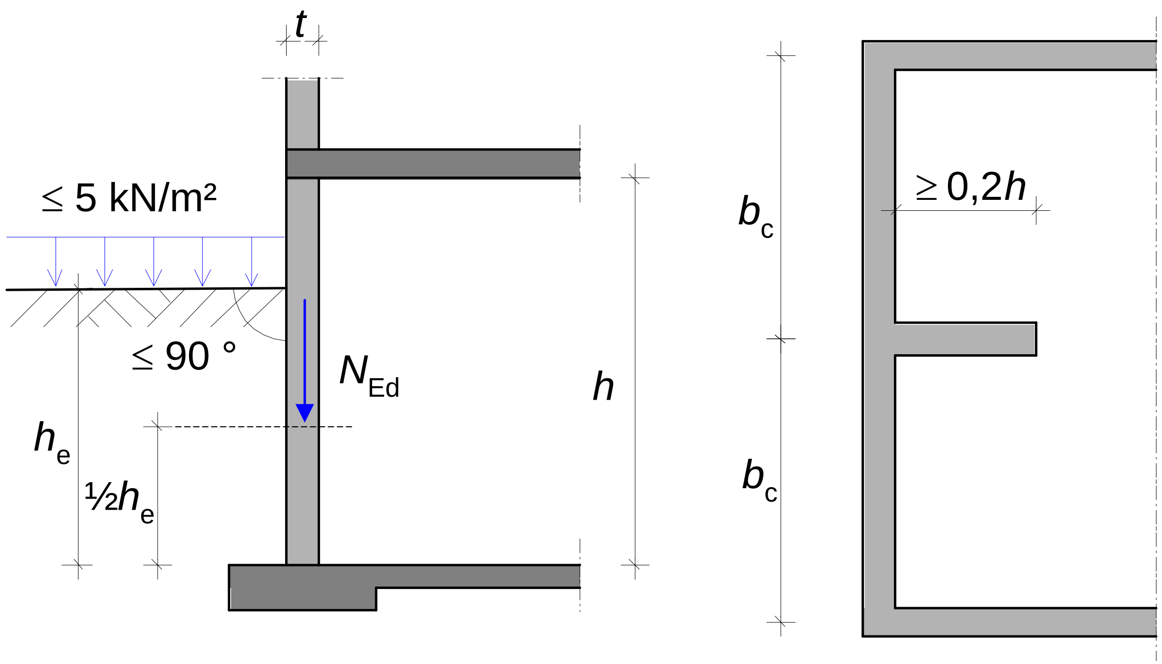
General conditions

- clear height of the wall ≤ 2,6 m
- wall thickness ≥ 200 mm
- floor over basement acts as a horizontal support
- load on ground surface limited to 5 kN/m²
- 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

$$N_{Ed,max} \leq \frac{t\,b\,f_d}{3}$$

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



vertical section

horizontal section

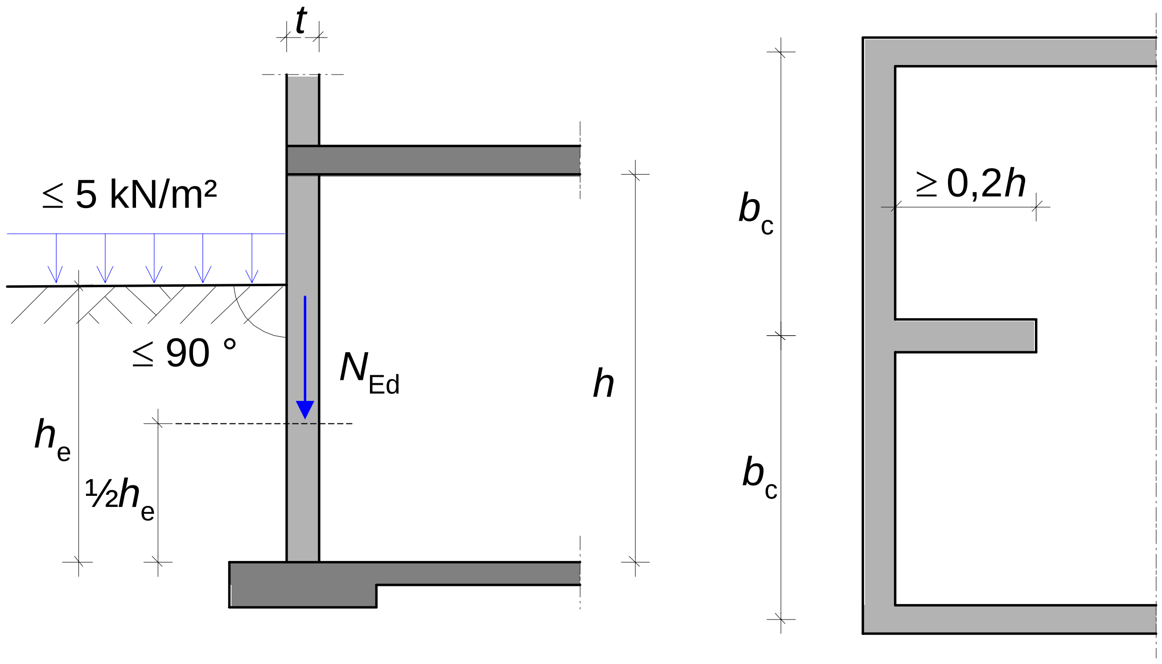
β is a factor related to b_c/h

Thickness of the basement wall

$$t \geq \frac{3\,N_{\mathrm{Ed;\,max}}}{b\,f_{\mathrm{d}}}$$

$$t \geq \frac{\rho_{\mathrm{e}}\,b\,h\,h_{\mathrm{e}}^{2}}{\beta\,N_{\mathrm{Ed,\,min}}}$$

$$t \geq 200 \text{ mm}$$



vertical section

horizontal section

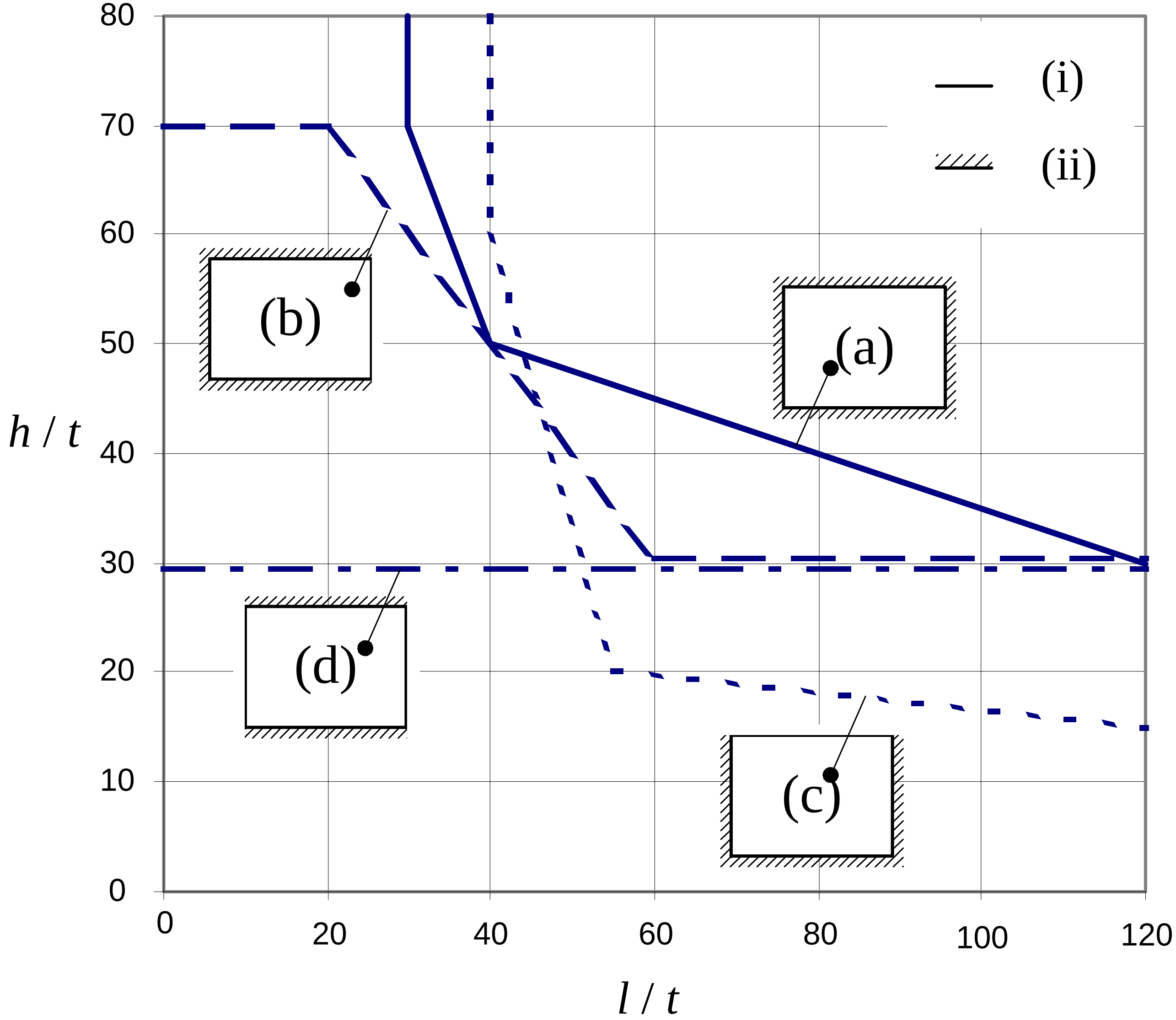
Walls subject to limited lateral load

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

$\mu = f_{xd1}/f_{xd2}$

Based on annex E of part 1-1

$M_{Ed1} = \mu\, \alpha_2\, p_{Ed}\, l^2$ $M_{Rd1} = f_{xd1}\, t^2/6$ $M_{Ed1} \leq M_{Rd1}$

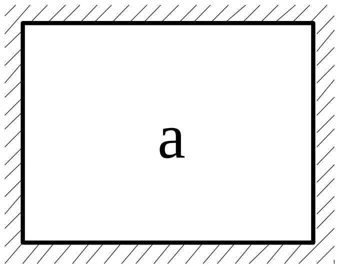
$M_{Ed2} = \alpha_2\, p_{Ed}\, l^2$ $M_{Rd2} = f_{xd2}\, t^2/6$ $M_{Ed2} \leq M_{Rd2}$

both lead to:

$\mu\, \alpha_2\, p_{Ed}\, l^2 = f_{xd1}\, t^2/6$

$$\frac{l}{t} = \sqrt{\frac{f_{xd1}}{p_{Ed}} \frac{1}{6 \mu \alpha_2}}$$

Example:



$f_{xd1}/p_{Ed} = 100$

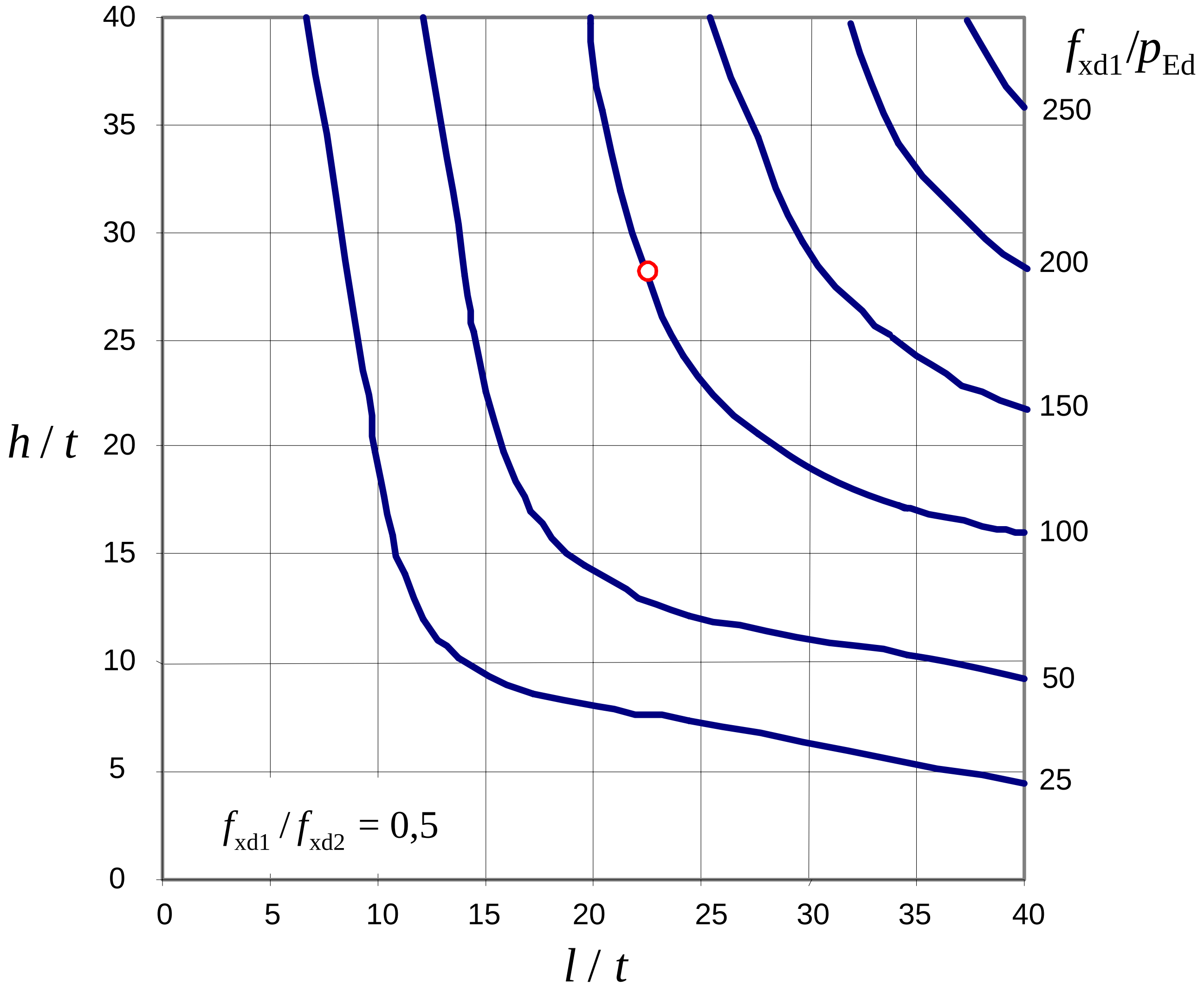
$\mu = 0,5$

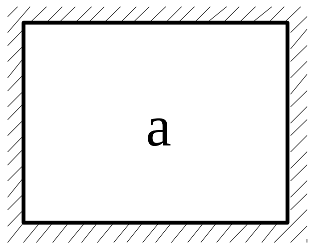
$h/l = 1,25$

table E of annex E part 1-1: $\alpha_2 = 0,066$

$$\frac{l}{t} = \sqrt{100 \frac{1}{6 \cdot 0,5 \cdot 0,066}} = 22,4$$

$h/t = 22,4 \times 1,25 = 28$


40
35
30
25
20
15
10
5
0
h / t
0
5
10
15
20
25
30
35
40
l / t
f_{xd1}/p_{Ed}
250
200
150
100
50
25
f_{xd1} / f_{xd2} = 0,5


a

Example

l = 5 meter

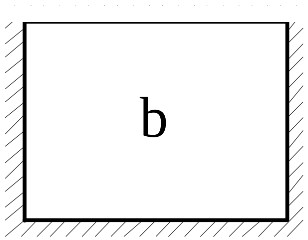
h = 4 meter

t = 150 mm

f_{xd1} = 0,3 N/mm²

μ = 0,5

boundary conditions b



$l/t = 5/0{,}15 = 33{,}3$

$h/t = 4/0{,}15 = 26{,}7$

$f_{xd1}/p_{Ed} = 250$

$p_{Ed} \leq f_{xd1}/250$

$f_{xd1} = 0{,}3\ \text{N/mm}^2$

$= 300\ \text{kN/m}^2$

$p_{Ed} \leq 300/250 = 1{,}2\ \text{kN/m}^2$