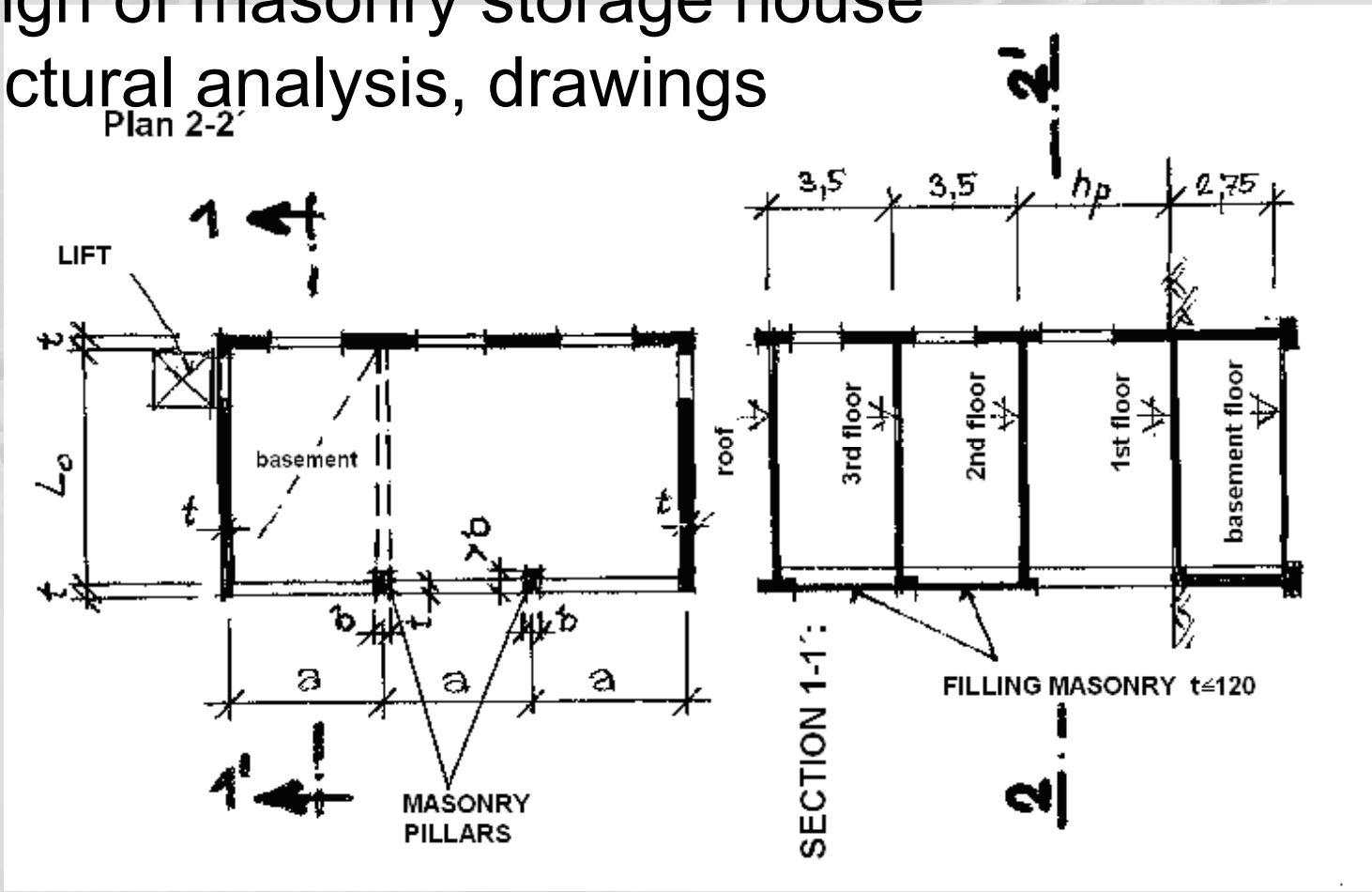
Masonry Structures

7th Seminar

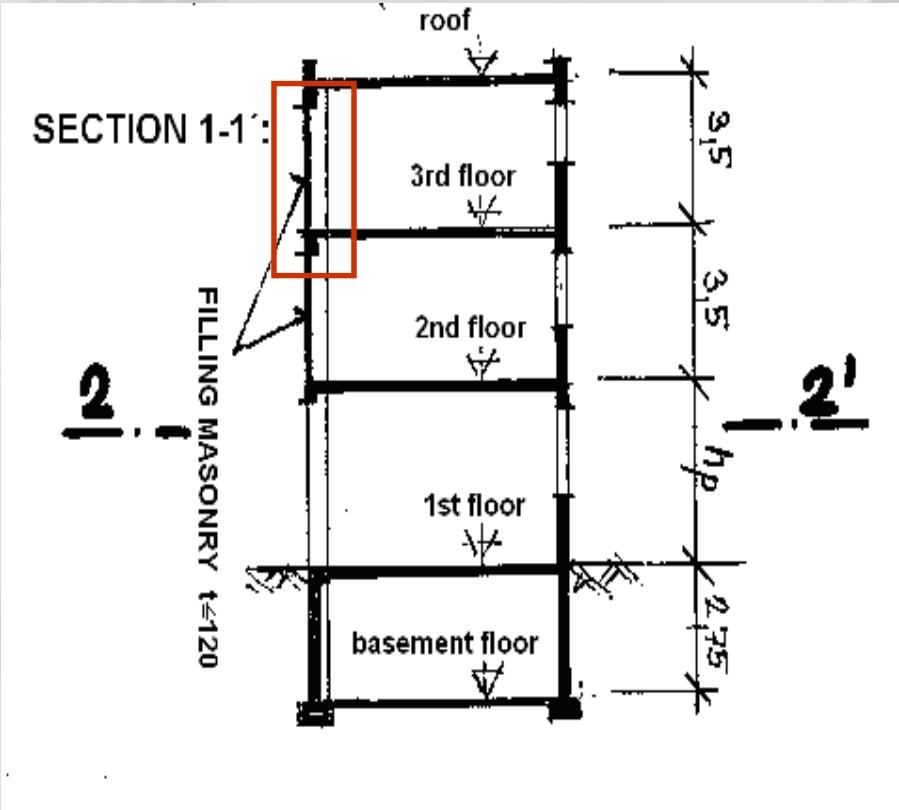
Seminar task

- Design of masonry storage house
- Structural analysis, drawings



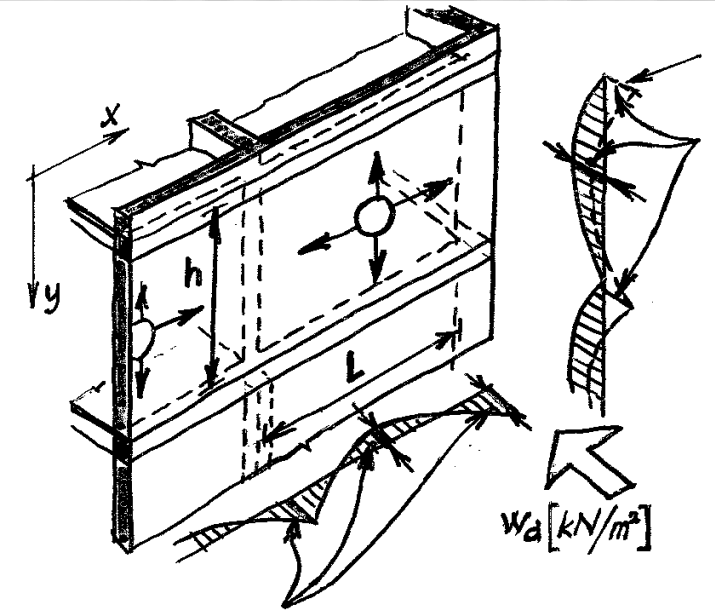
7th homework

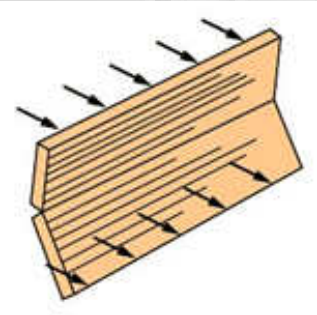
- Check load-bearing capacity of wind-loaded masonry wall (cladding in 2nd and 3rd floor)

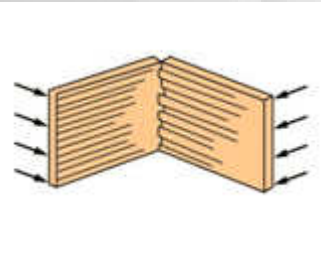


7th homework

- Filling masonry is laterally loaded, vertical load is very small => possibility of flexural failure
- Wall = „two-way slab“







Wind load

- **Design wind load:** $w_d = w_k * 1{,}5$ (partial factor)
- Characteristic wind load w_k [kN/m^2]

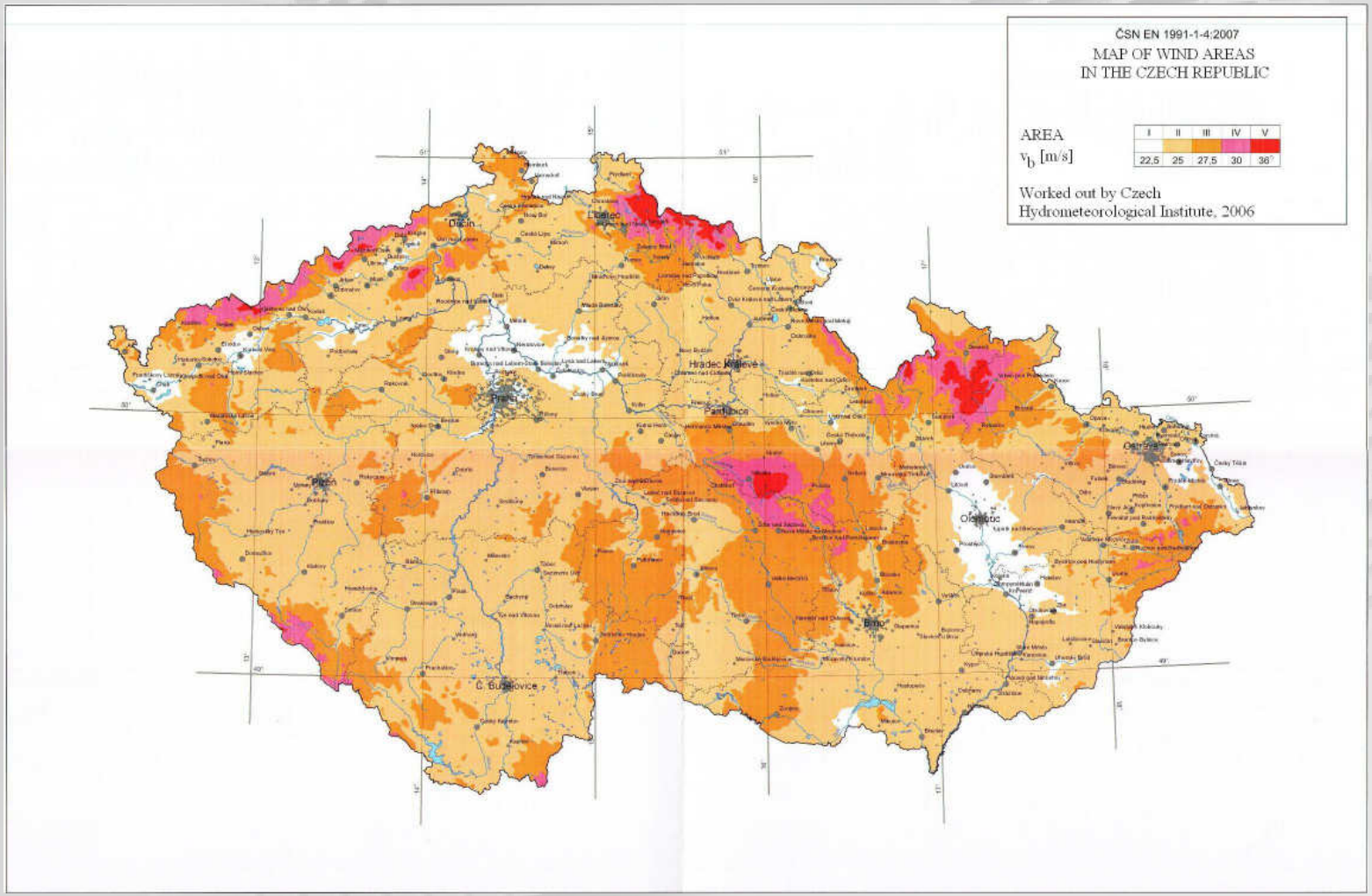
$$w_k = q_b c_e c_{pe}$$

- q_b – reference mean velocity pressure [kN/m^2]

$$q_b = \frac{1}{2}\rho v_b^2$$

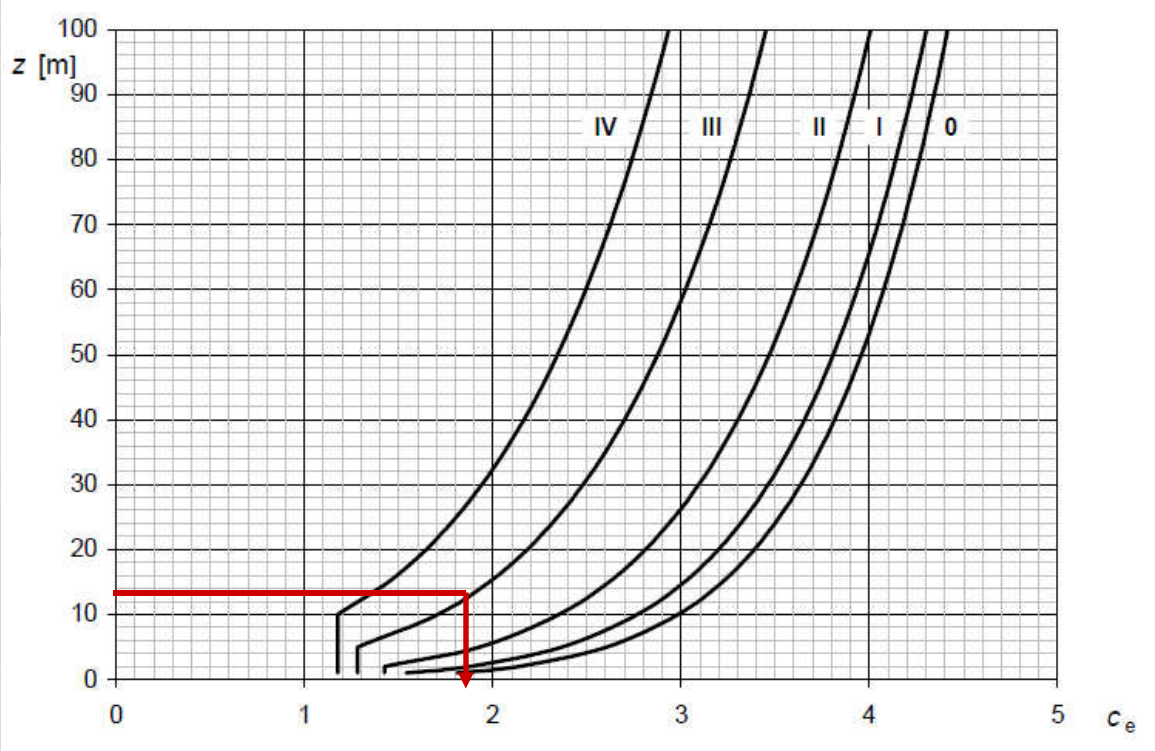
- ρ – air density, 1,25 kg.m^{-3}
- v_b – basic wind velocity (defined from a map in EC 1991-1-4), see assignment

Wind load


ČSN EN 1991-1-4:2007
MAP OF WIND AREAS
IN THE CZECH REPUBLIC
AREA
I II III IV V
v_b [m/s]
22,5 25 27,5 30 36
Worked out by Czech
Hydrometeorological Institute, 2006
Ústí n.L.
Liberec
Hradec Králové
Pardubice
Plzeň
Praha
Olomouc
Brno
Č. Budějovice

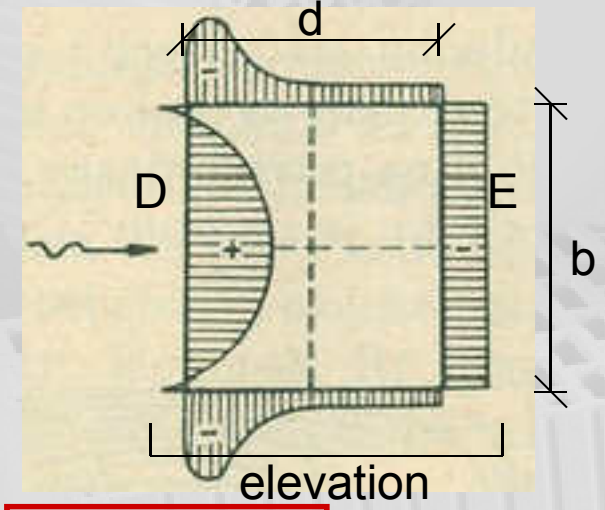
Wind load

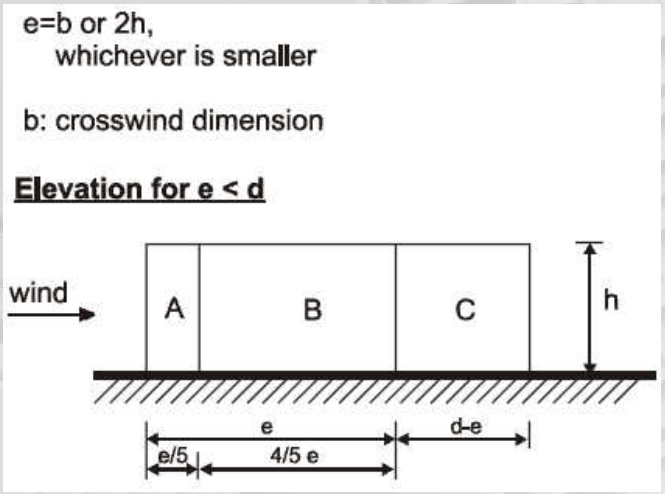
- c_e – exposure factor, see graph below
  - Terrain category – III (suburb) or IV (dowtown)
  - z – in our case, the height of the building



Wind load

- c_{pe} – pressure coefficient



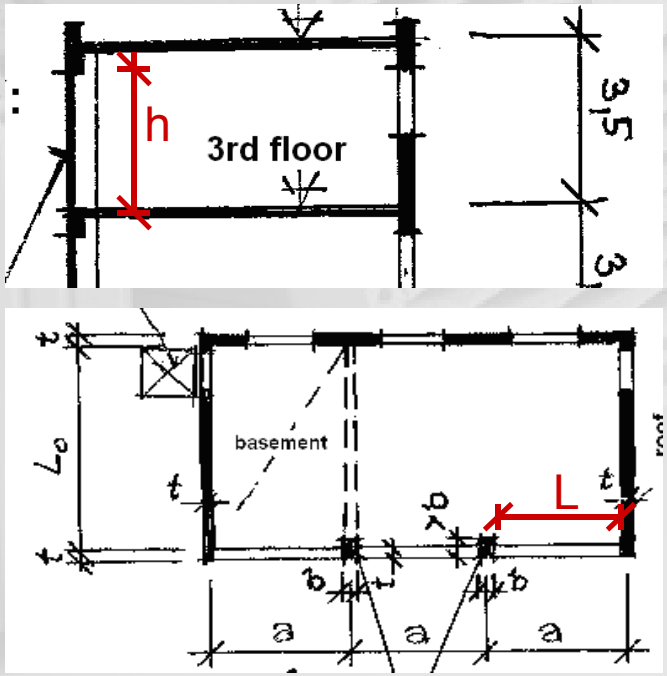


Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

Wind load

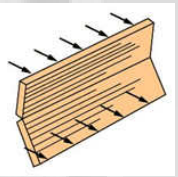
- *h* – height of the wall, clear distance between horizontal supports [m]
- L – clear distance between vertical supports
- If h*L ≥ 10 m^2 => $c_{pe,10}$
- If h*L ≤ 1 m^2 => $c_{pe,1}$
- If 1 m^2 < h*L < 10 m^2 =>

$$c_{pe} = \frac{hL - 1}{45} - 1,4$$



Flexural strength of masonry

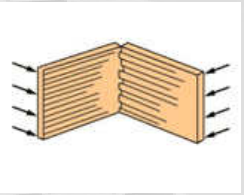
- f_{xk1} – characteristic flexural strength in the plane of failure parallel to the bed joints



Masonry Unit	f_{xk1} [MPa]			
	General purpose mortar		Thin layer mortar	Lightweight mortar
	$f_m <$ 5 MPa	$f_m \geq$ 5 MPa		
Clay	0,10	0,10	0,15	0,10
Calcium silicate	0,05	0,10	0,20	not used
Aggregate concrete	0,05	0,10	0,20	not used
Autoclaved aerated concrete	0,05	0,10	0,15	0,10
Manufactured stone	0,05	0,10	not used	not used
Dimensioned natural stone	0,05	0,10	0,15	not used

Flexural strength of masonry

- f_{xk2} – char. flex. strength in the plane of failure perpendicular to the bed joints

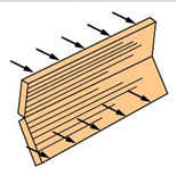


Masonry Unit		f_{xk2} [MPa]			
		General purpose mortar		Thin layer mortar	Lightweight mortar
		$f_m <$ 5 MPa	$f_m \geq$ 5 MPa		
Clay		0,20	0,40	0,15	0,10
Calcium silicate		0,20	0,40	0,30	not used
Aggregate concrete		0,20	0,40	0,30	not used
Autoclaved aerated concrete	$\rho < 400$ kg/m^3	0,20	0,20	0,20	0,15
	$\rho \geq 400$ kg/m^3	0,20	0,40	0,30	0,15
Manufactured stone		0,20	0,40	not used	not used
Dimensioned natural stone		0,20	0,40	0,15	not used

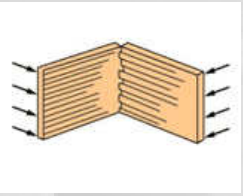
Flexural strength of masonry

- Design values of flexural strength:

$$f_{xd1} = \frac{f_{xk1}}{\gamma_M} + \sigma_d$$



$$f_{xd2} = \frac{f_{xk2}}{\gamma_M}$$

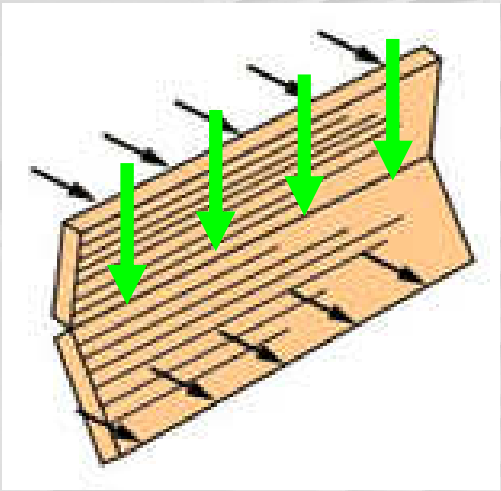


- γ_M = 2,2 (prescribed mortar)

Flexural strength of masonry

- σ_d – stress from the vertical loading in the critical cross-section, i.e. the stress from the self-weight of upper half of the wall

$$\sigma_d = \frac{\rho_m}{10^3} \cdot \frac{h}{2} \quad [\mathrm{MPa}]$$



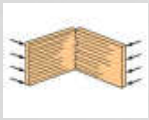
- ρ_m – density of filling masonry (14 kN.m^{-3})

Design bending moment

- Formulae [kNm/m]:

$$M_{\mathrm{Ed,y}} = \mu \alpha w_{\mathrm{d}} L^2$$

$$M_{\mathrm{Ed,x}} = \alpha w_{\mathrm{d}} L^2$$



- μ – orthogonal ratio of flexural strengths

$$\mu = \frac{f_{\mathrm{xd1}}}{f_{\mathrm{xd2}}}$$

Design bending moment

- α – bending moment coefficient, see table

Wall support condition E
= wall is simply supported
at all edges

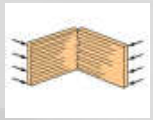
E	h/L							
μ	0,30	0,50	0,75	1,00	1,25	1,50	1,75	2,00
0,05	0,054	0,076	0,090	0,098	0,103	0,107	0,109	0,110
0,10	0,039	0,062	0,078	0,088	0,095	0,100	0,103	0,106
0,15	0,032	0,053	0,070	0,081	0,089	0,094	0,098	0,103
0,20	0,026	0,046	0,064	0,076	0,084	0,090	0,095	0,099
0,25	0,023	0,042	0,059	0,071	0,080	0,087	0,091	0,096
0,30	0,020	0,038	0,055	0,068	0,077	0,083	0,089	0,093
0,35	0,018	0,035	0,052	0,064	0,074	0,081	0,086	0,090
0,40	0,017	0,032	0,049	0,062	0,071	0,078	0,084	0,088
0,50	0,014	0,028	0,044	0,057	0,066	0,074	0,080	0,085
0,60	0,012	0,025	0,040	0,053	0,062	0,070	0,076	0,081
0,70	0,011	0,023	0,037	0,049	0,059	0,067	0,073	0,078
0,80	0,010	0,021	0,035	0,046	0,056	0,064	0,071	0,076
0,90	0,009	0,019	0,032	0,044	0,054	0,062	0,068	0,074
1,00	0,008	0,018	0,030	0,042	0,051	0,059	0,066	0,072

Moment of resistance

- Formulae [kNm/m]:

$$M_{\mathrm{Rd,y}} = f_{\mathrm{xd1}} Z$$

$$M_{\mathrm{Rd,x}} = f_{\mathrm{xd2}} Z$$



- Z – elastic section modulus per 1 meter of the wall [m^3/m]:

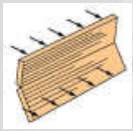
$$Z = \frac{t^2}{6}$$

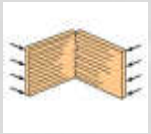
- t – thickness of the wall, t = 115 mm (thickness „without plaster“)

Resistance check

$$M_{\mathrm{Rd,y}} \geq M_{\mathrm{Ed,y}}$$

$$M_{\mathrm{Rd,x}} \geq M_{\mathrm{Ed,x}}$$





- *In practice:* If any of the criteria is not met, the wall should be redesigned!!!
- *In the homework:* If any of the criteria is not met, propose a change to improve load-bearing capacity of the wall (reinforced masonry, higher thickness…)

Thank you for your attention

Any questions?