Concrete and Masonry Structures 2

Part M: Masonry

Introduction

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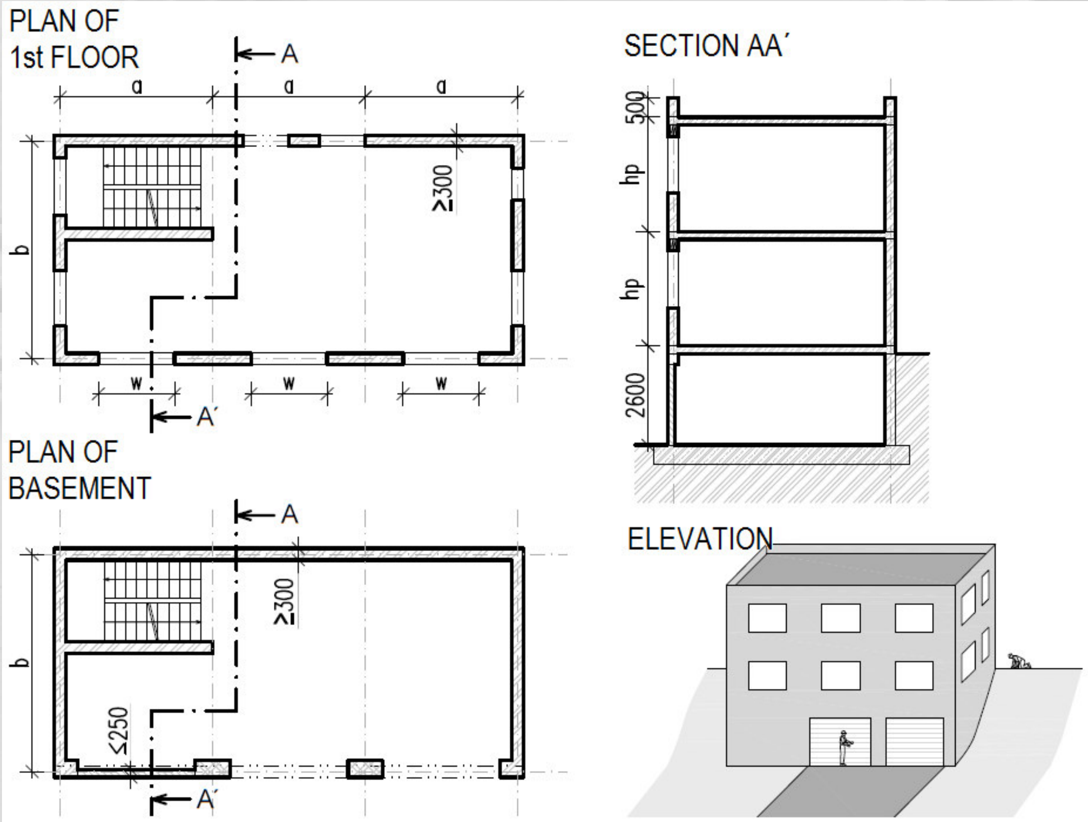
  Friday 09:00

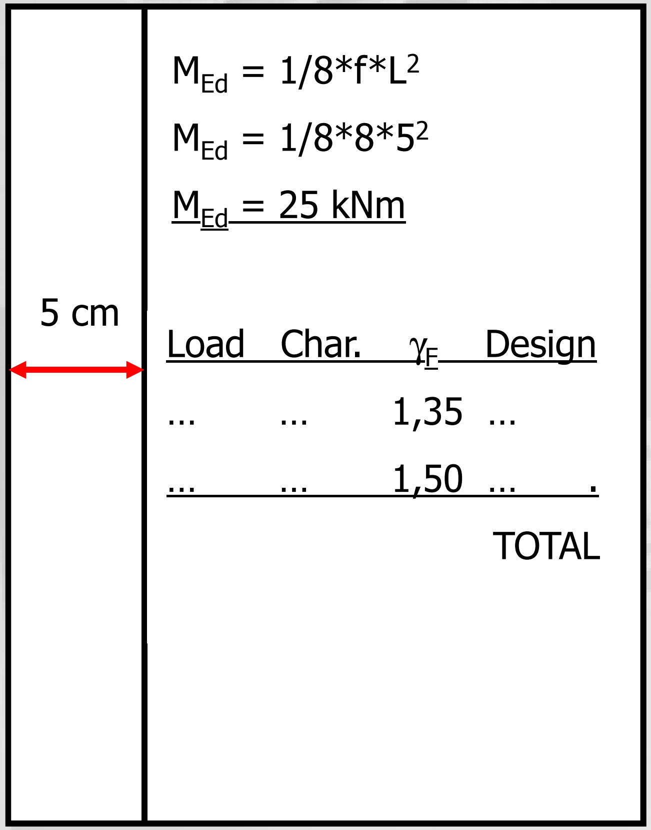
Seminar task

- Design of masonry house in sloping terrain
- Structural analysis, drawings



Homework - page layout

- A4 onesided, handwritten by pencil
- Each calculation:
  - General formula
  - Substitution of numbers
  - Result
- Loads – in tables
- Quote units
- WELL-ARRANGED!!!



Advice for calculations

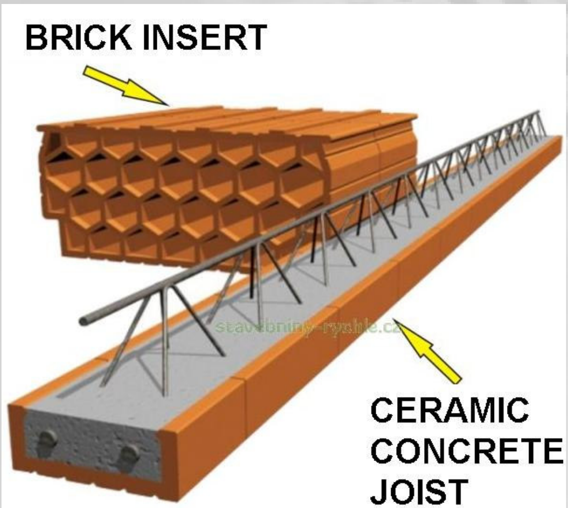
- Use N, mm and MPa units and you will not have any problems with the units anymore ☺
- The only problem is with moments – you get moments in Nmm. This unit is not used in practice => divide by 1,000,000 to get kNm

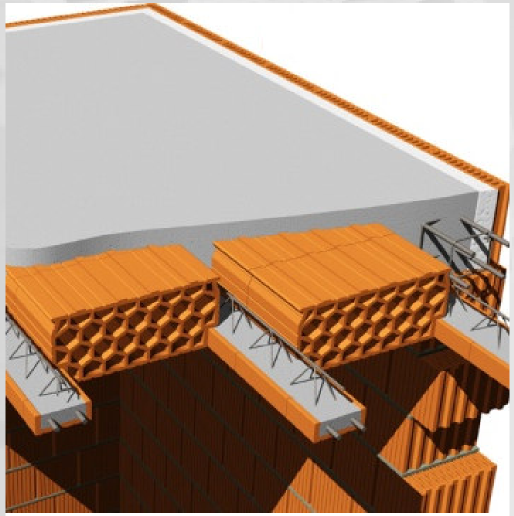
Before you begin…

- Visit teacher´s website
- Read the task
- Find your individual parameters
- Get familiarized with masonry units used in our building

1st part: Design of slab

- Preliminary design of combined slab above 1st floor using tables
- Draw a detail of slab-wall joint





Preliminary design

- Calculation of loadings – self-weight not included in this stage

Load	Char.	γ_F	Design
…	…	1,35	…
…	…	1,50	…
			TOTAL

Dead load

Live load

- Slab depth estimation

$$h \approx \left(\frac{1}{25} - \frac{1}{20} \right) L$$

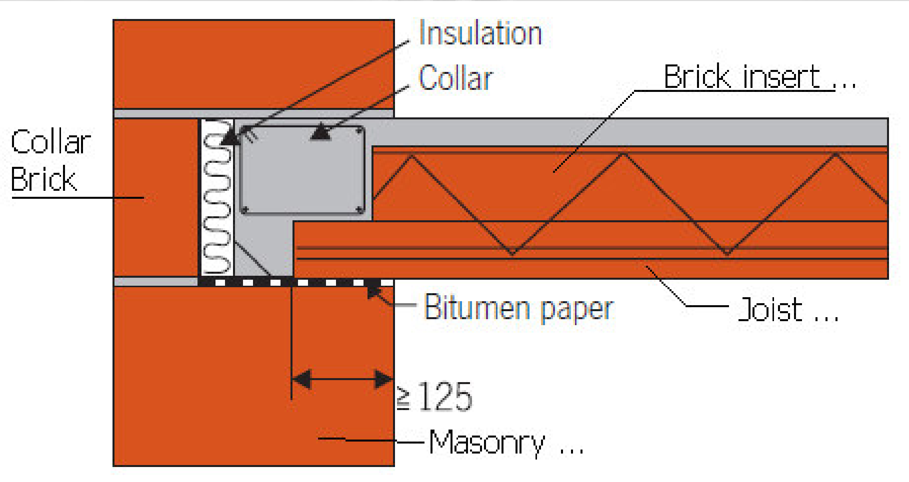
Preliminary design

- Design of the slabs using tables
  - Length and spacing of girders
  - Depth of the slab
  - Type of brick inserts

Resistance of the slab for girders in spacing 500 mm

Length of the girder	Clear span	Reinforcement	MIAKO 15/62,5 PTH				MIAKO 19/62,5 PTH				MIAKO 23/62,5 PTH			
			190		210		230		250		270		290	
[mm]	[mm]	Profile	q_d	q_n	q_d	q_n	q_d	q_n	q_d	q_n	q_d	q_n	q_d	q_n
1 750	1 500	2ø8	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
2 000	1 750	2ø8	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
2 250	2 000	2ø8	17.28	15.30	19.61	17.40	20.00	[illegible]	20.00	20.00	20.00	20.00	20.00	20.00

Slab-wall joint



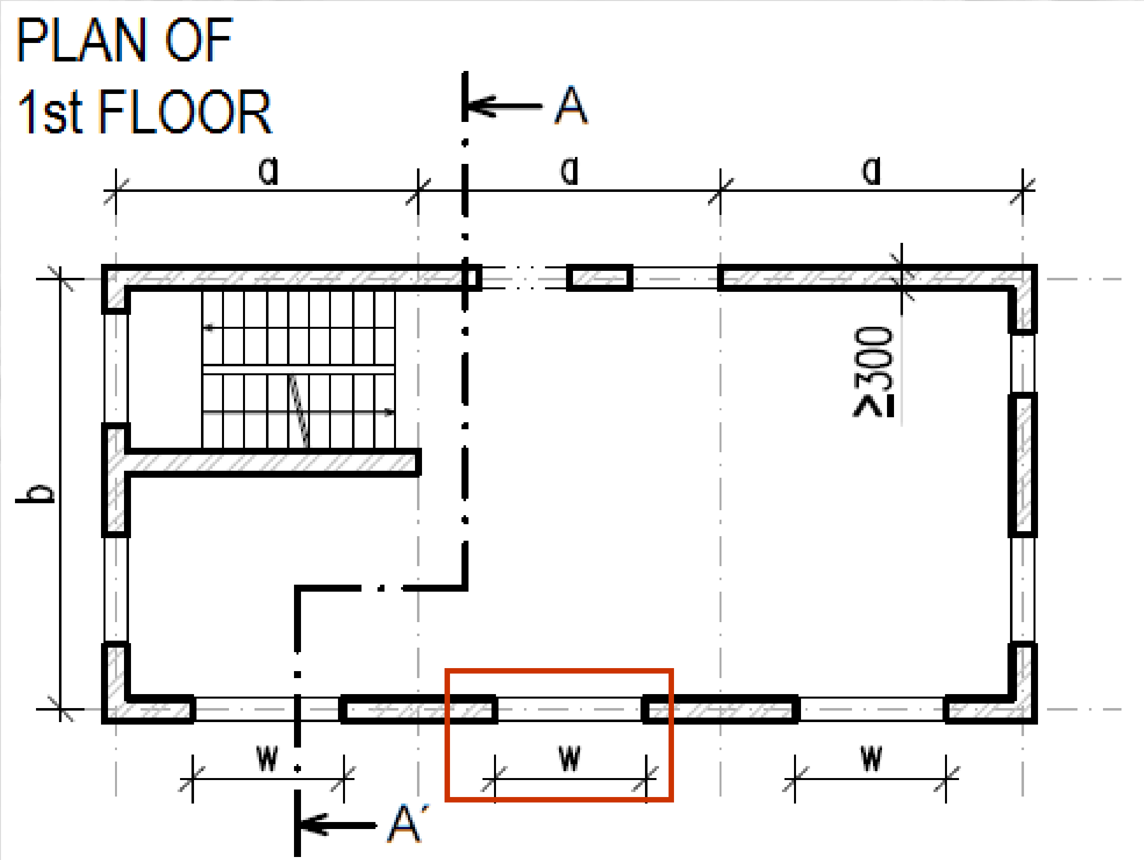
- + Dimensions
- + Annotate all the elements
- - Do not use internal insulation
- ! Collar min. 200 mm

2nd part: Design of lintels

- Design of ceramic lintels using tables
- Details of lintel-slab joint and window head

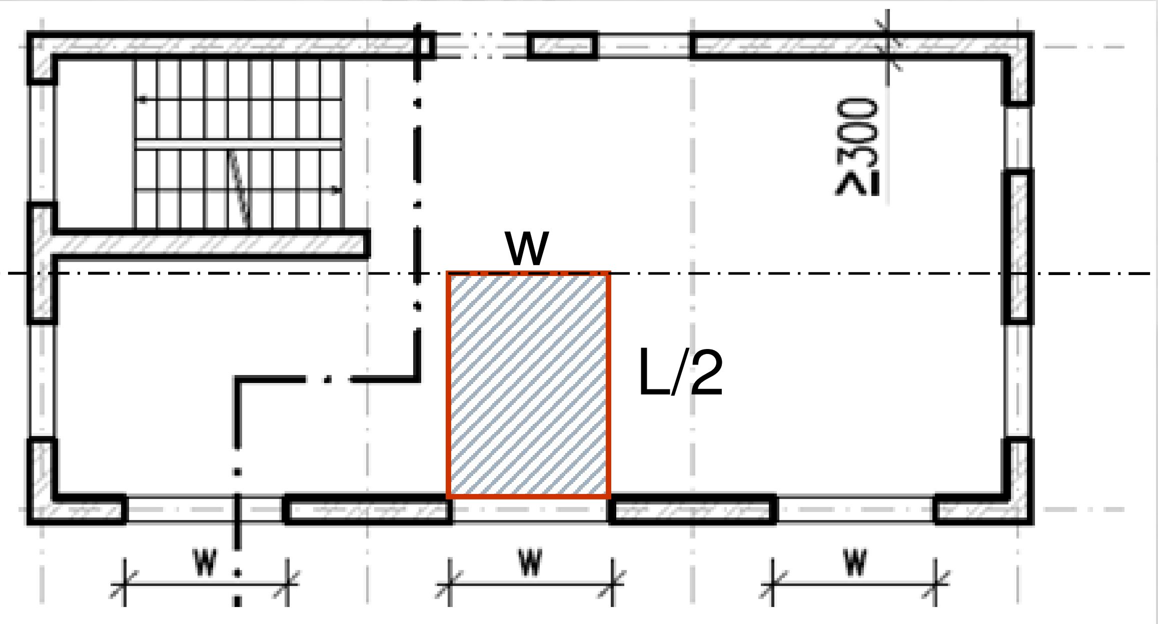
Design of ceramic lintels

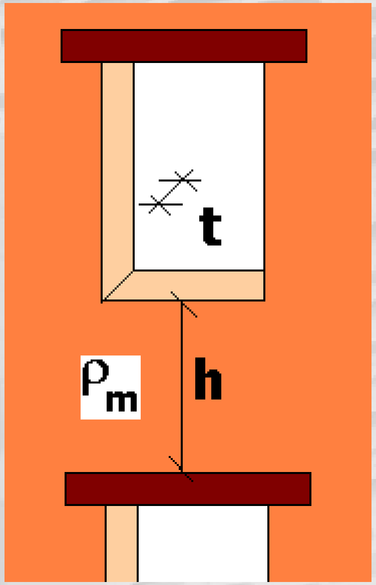
- Lintels above the widest window opening (*w*)



Design of ceramic lintels

- Calculation of load





- $f_{lintel,d} = f_{slab,d} * L/2 + \rho_{m,d} * t * h$ [kN/m]
- $kN/m^3 = kg/m^3 / 100$

Including self-weight

Design of ceramic lintels

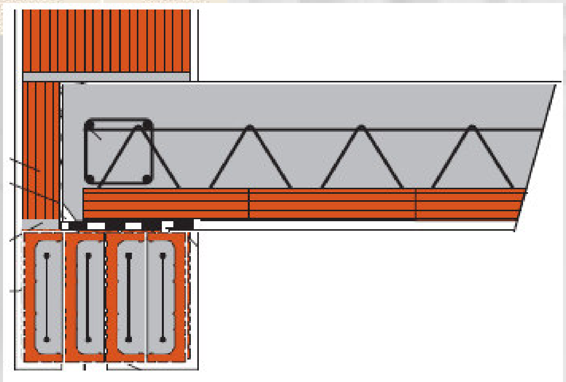
- Design of lintels using tables
  - Type of lintel used
  - Clear span and bedding length of lintel
  - Number of lintels required

Load-bearing capacity of lintels

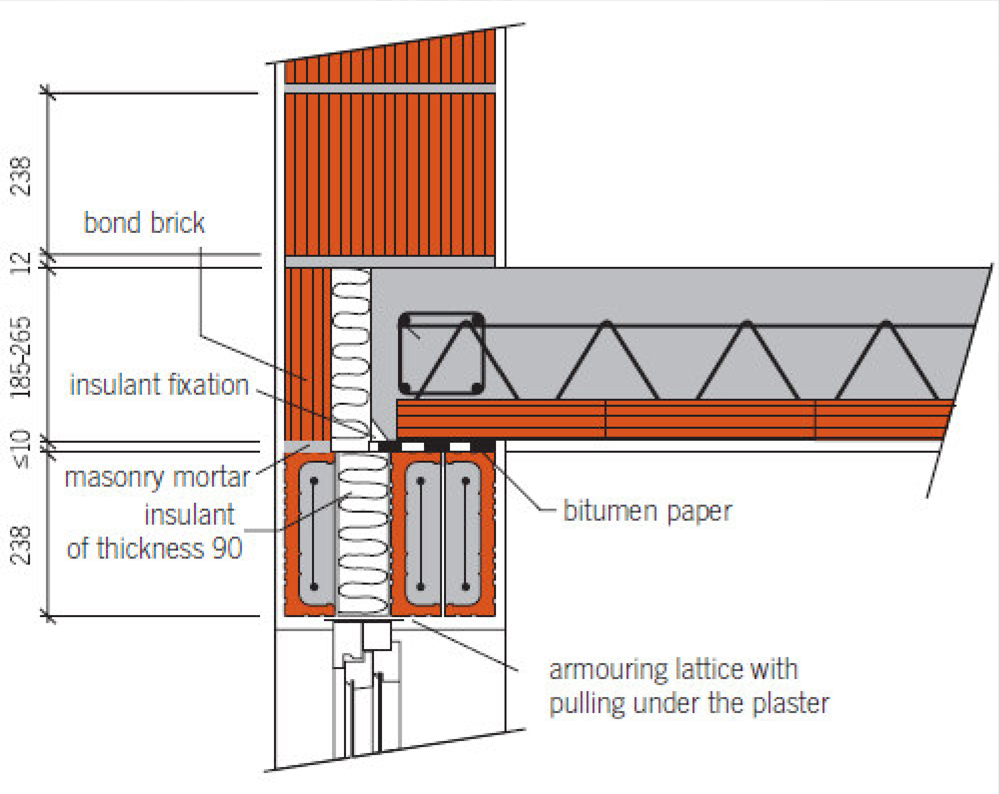
Maximum design load [kN/m]

Length mm	Bedding mm	Clear span mm	Q_u	M_u	1 lintel q_d ①	Load - combination of lintels q_d ②	q_d ③	q_d ④
1000	125	750	8,50	1,82	18,4	36,8	55,2	73,6
1250		1000	8,75	3,13	17,1	34,2	51,3	68,4
1500		1250	8,75	3,13	12,7	25,5	38,2	51,0
1750		1500	9,00	4,65	11,6	23,2	[illegible]	[illegible]

- If collar brick is used, the lintel beneath it can not be considered to resist the loading!

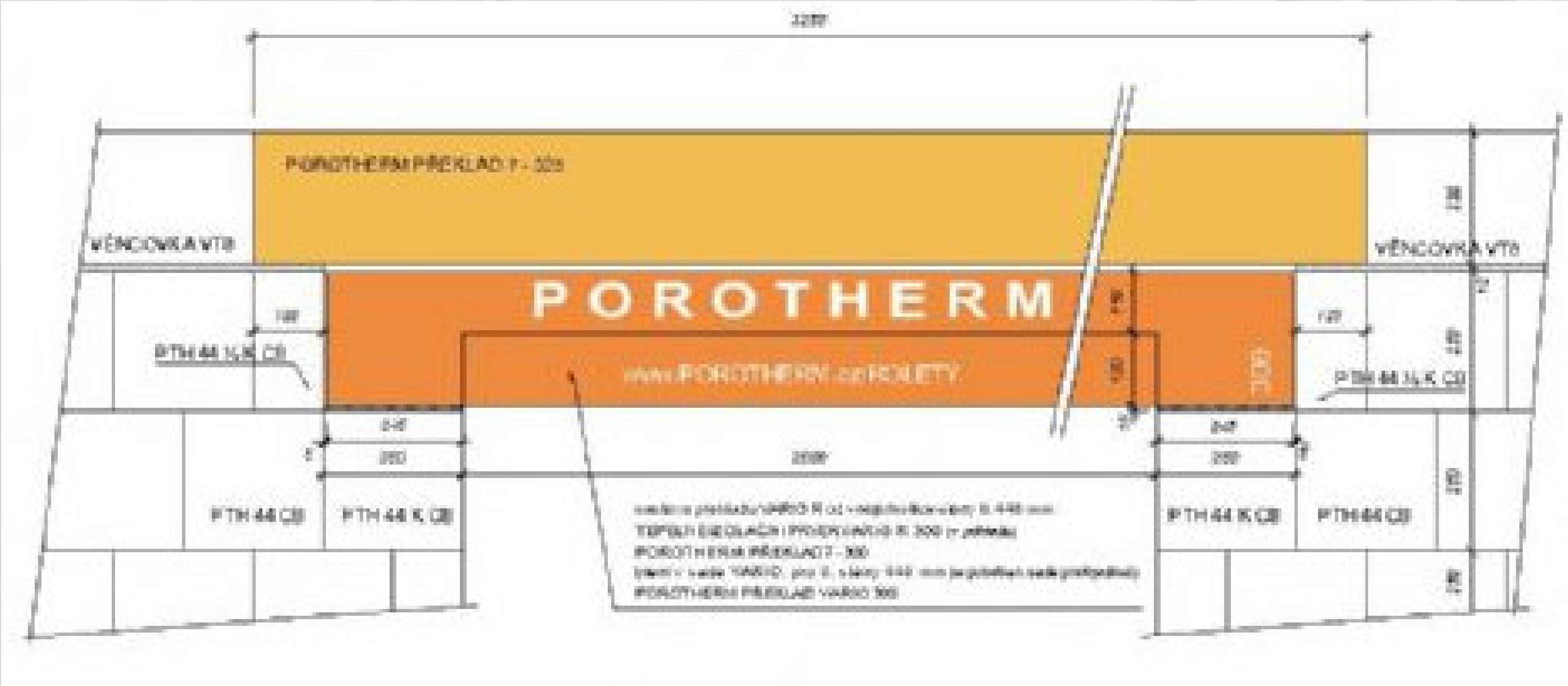


Detail of lintel-slab joint



+ Dimensions
+ Annotate all the elements
- Do not use internal insulation
! Collar min. 200 mm

Detail of window head



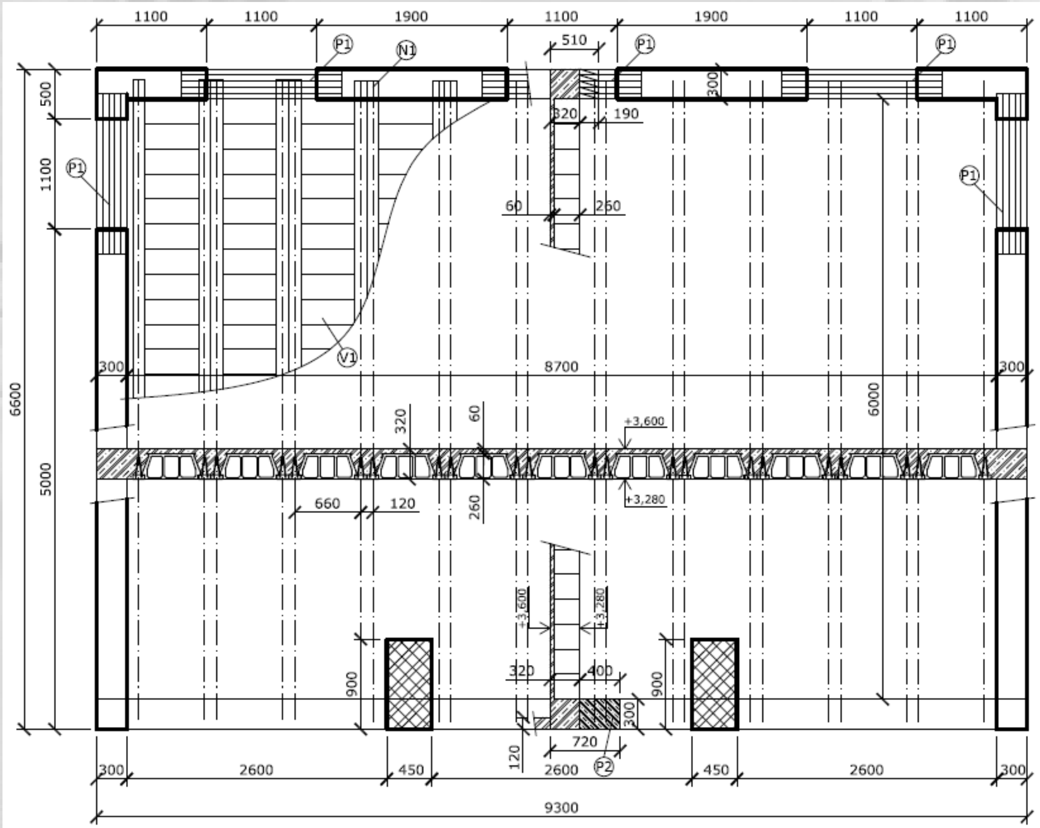
+ Dimensions
+ Annotate all the elements

3rd part: Assembling drawing

- Use scale 1:50
- CAD system or handmade drawing – your choice
- Leave free space for staircase (don´t design the staircase)
- Adjust the dimensions of the structure in accordance with modular dimensions of masonry used

Assembling drawing

- Plan of ceiling + vertical supports
- One section in each direction



Assembling drawing

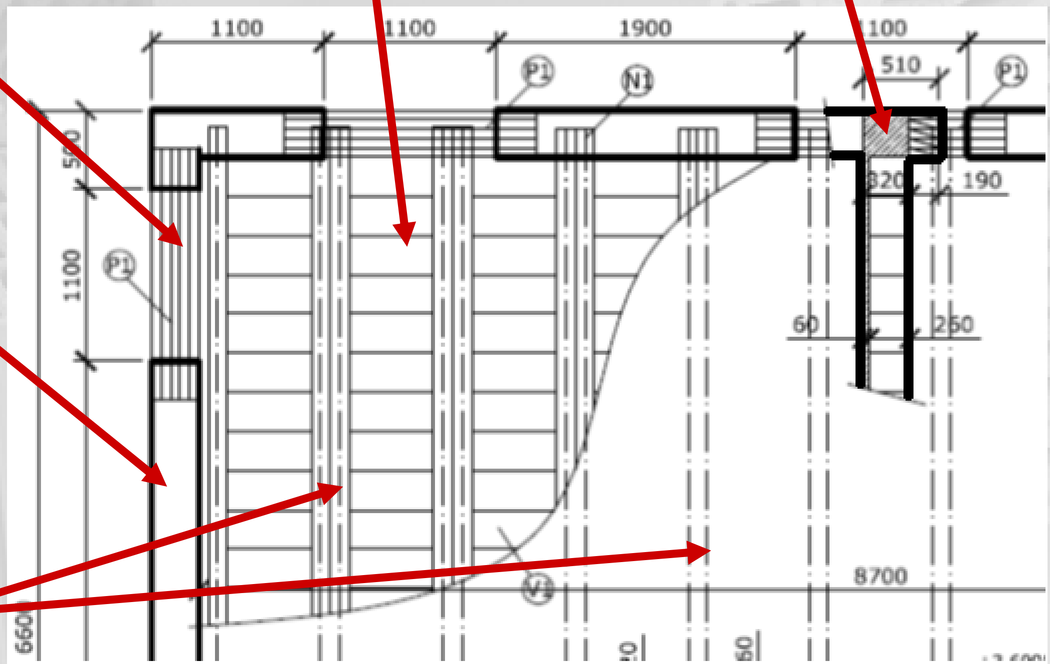
Horizontal structures = narrow solid line

Detailed assembling - only for a part of the plan

Sections = bold solid line

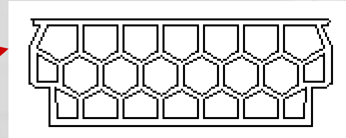
Vertical structures = heavy solid line

Axes of girders = narrow dash-dot line



Assembling drawing

Joists, brick inserts in section - schematically



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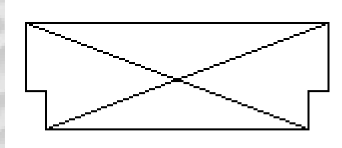
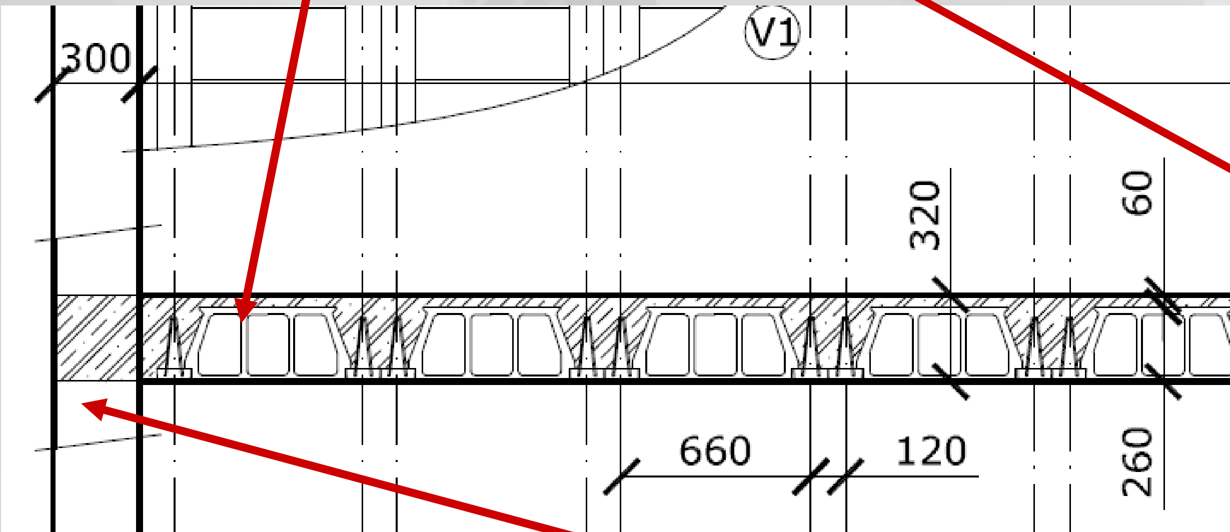
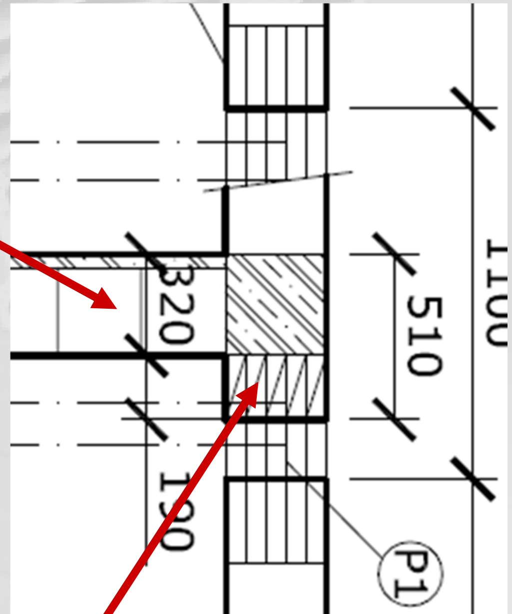






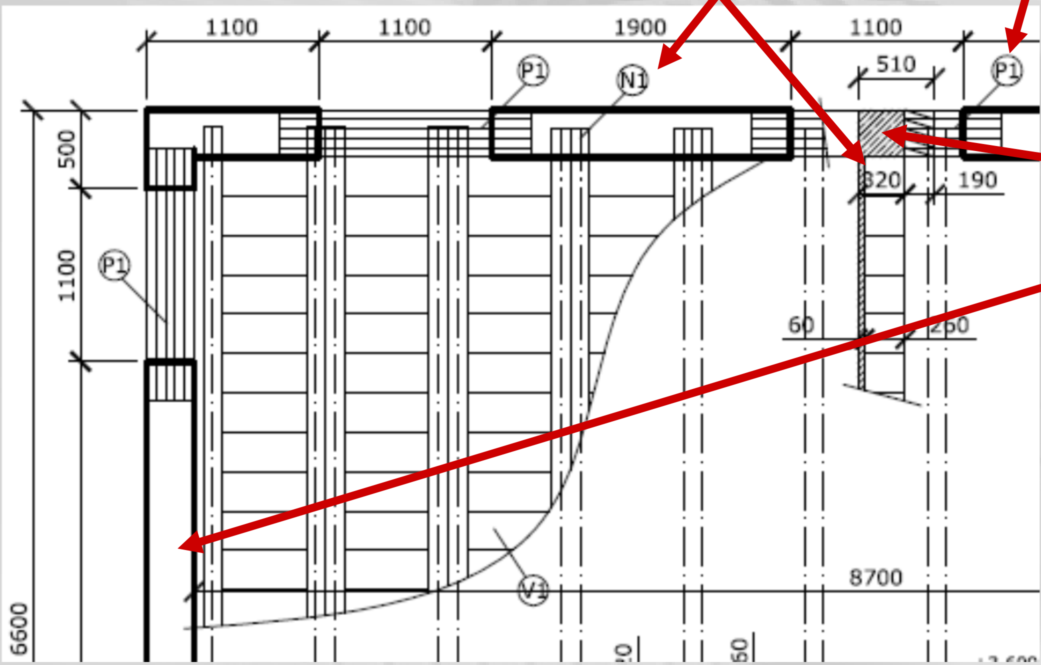
Details of connections to walls/lintels

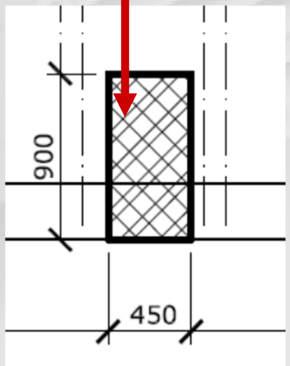
Assembling drawing

Dimensions – openings, walls, depth of the slab, thickness of the wall…

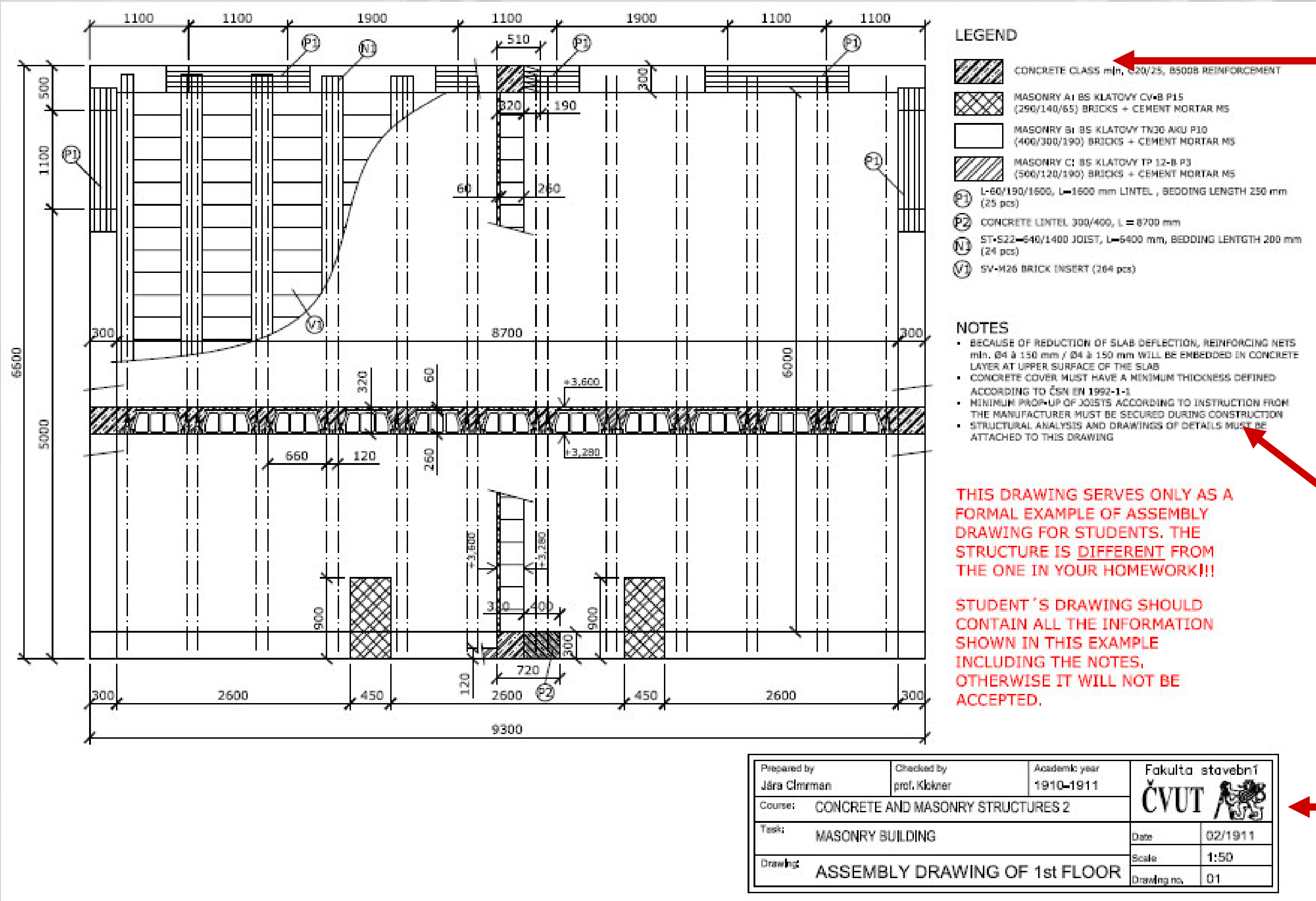
Annotations – lintels, joists, brick inserts

Hatches – types of masonry, concrete





Assembling drawing



Legend of materials and elements

Masonry = bricks + mortar!!!

Notes

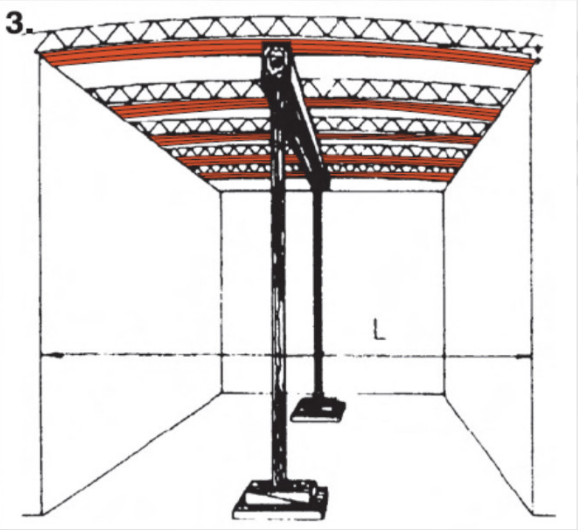
Drawing Title

The example drawing shows DIFFERENT structure – apply the rules to YOUR structure

Assembling drawing

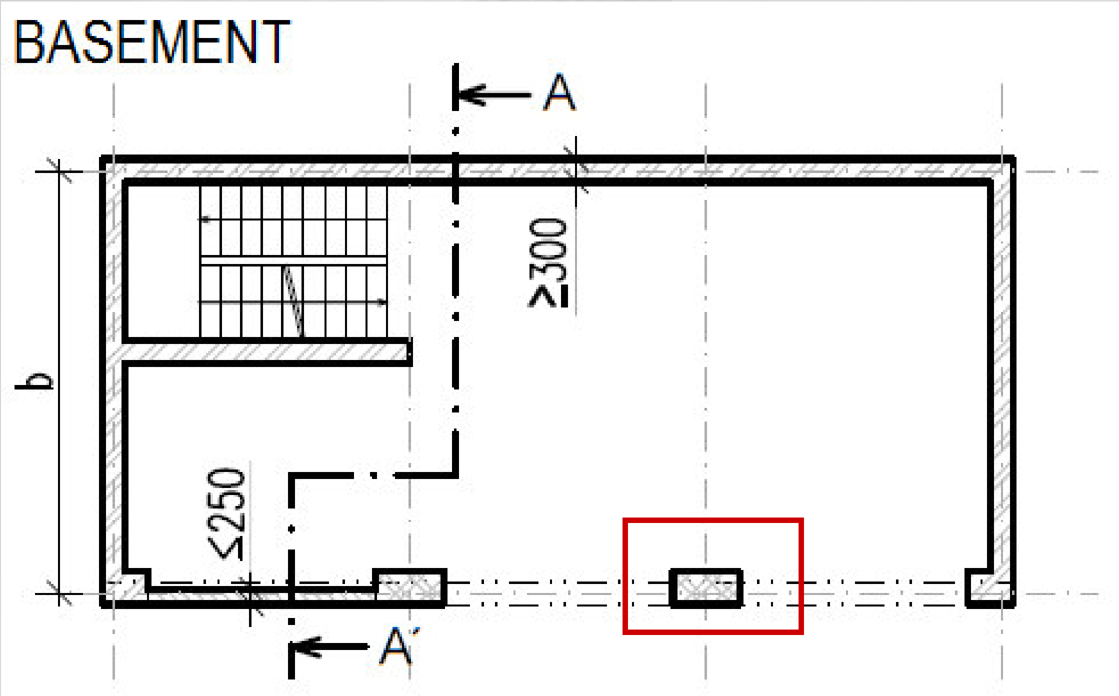
NOTES

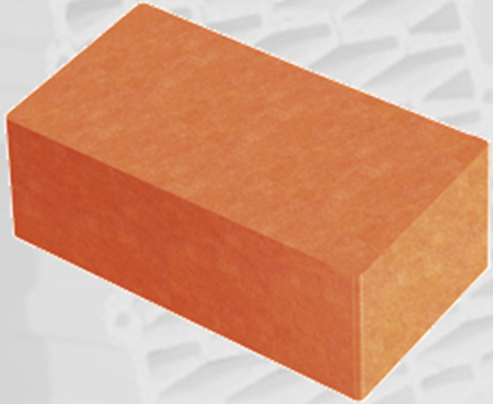
- BECAUSE OF REDUCTION OF SLAB DEFLECTION, REINFORCING NETS mln. Ø4 à 150 mm / Ø4 à 150 mm WILL BE EMBEDDED IN CONCRETE LAYER AT UPPER SURFACE OF THE SLAB
- CONCRETE COVER MUST HAVE A MINIMUM THICKNESS DEFINED ACCORDING TO ČSN EN 1992-1-1
- MINIMUM PROP-UP OF JOISTS ACCORDING TO INSTRUCTION FROM THE MANUFACTURER MUST BE SECURED DURING CONSTRUCTION
- STRUCTURAL ANALYSIS AND DRAWINGS OF DETAILS MUST BE ATTACHED TO THIS DRAWING



4th part: Design of pillar

- Design dimensions and check load-bearing capacity of masonry pillar between garage doors in the basement





Full bricks + general purpose mortar

Strength of masonry

- f_u – strength of the material, matches the strength label of the units: Pxy => f_u = xy MPa. Determined by laboratory tests.
- f_b – compressive strength of the units, $f_b = \delta . f_u$
- f_m – strength of the mortar. MCxy => xy MPa
- δ – factor expressing the effect of dimensions of the brick, see table

The δ coefficient expressing effect of width and height of the brick

h_p [mm]	b_p [mm]				
	50	100	150	200	250
50	0,85	0,75	0,70	0,70	0,65
65	0,95	0,85	0,75	0,70	0,65
100	1,15	1,00	0,90	0,80	0,75
150	1,30	1,20	1,10	1,00	0,95
200	1,45	1,35	1,25	1,15	1,10
250	1,55	1,45	1,35	1,25	1,15

Strength of masonry

- f_k – characteristic compressive strength of masonry

$$f_k = K f_b^{0.7} f_m^{0.3}$$

- K – coefficient, see table

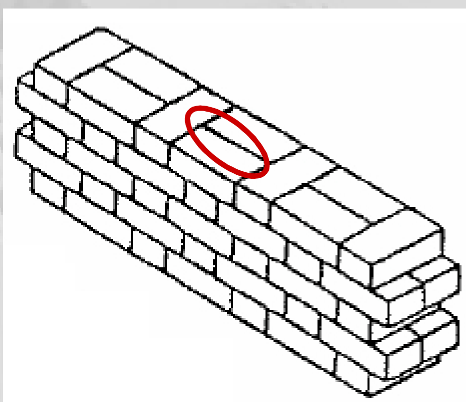
Groups of masonry units				
Type of masonry units	Group			
	1	2	3	4
	Volume of all holes (% of the gross volume)			
	-	Vertical holes		Horizontal holes
concrete	≤ 25	25 - 60	60 - 70	25 - 70
dimensioned natural stone	≤ 25	not used	not used	not used
clay	≤ 25	25 - 55	55 - 70	25 - 70
autoclaved aerated concrete	≤ 25	not used	not used	not used
manufactured stone	≤ 25	not used	not used	not used
calcium silicate	≤ 25	25 - 55	not used	not used

Strength of masonry

K coefficient					
Type of masonry units	Group	Mortar			
		general purpose	thin layer (0,5-3 mm)	lightweight (600 - 800 kg.m^{-3})	lightweight (800-1300 kg.m^{-3})
clay	1	0,55	0,75	0,30	0,40
	2	0,45	0,70	0,25	0,30
	3	0,35	0,50	0,20	0,25
	4	0,35	0,35	0,20	0,25
calcium silicate	1	0,55	0,80	X	X
	2	0,45	0,65	X	X
concrete	1	0,55	0,80	0,45	0,45
	2	0,45	0,65	0,45	0,45
	3	0,40	0,50	X	X
	4	0,35	X	X	X
autoclaved aerated concrete	1	0,55	0,80	0,45	0,45
manufactured stone	1	0,45	0,75	X	X
dimensioned natural stone	1	0,45	X	X	X

Strength of masonry

- K coefficient – the value from the table has to be multiplied by 0,8 if longitudinal perpend joint exists in the pillar/wall



- Solid clay bricks => volume of pores = 0 %

Strength of masonry

- f_d – design compressive strength of masonry

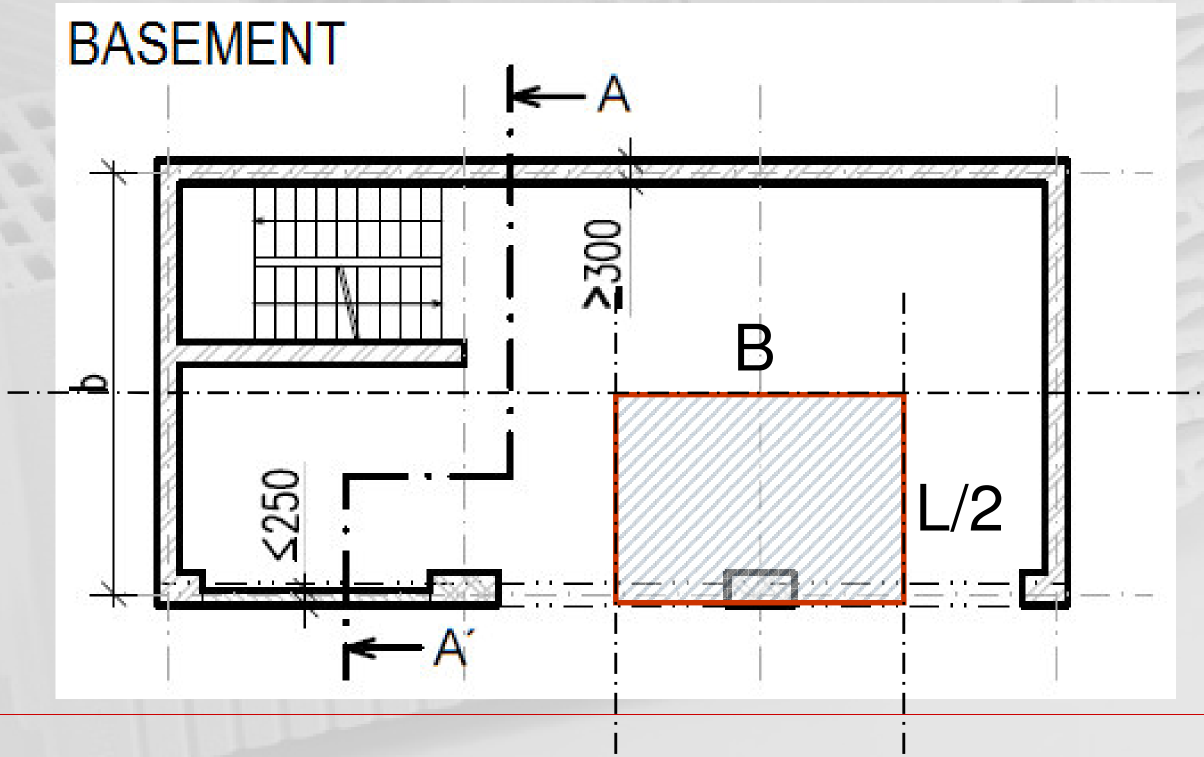
$$f_d = \frac{f_k}{\gamma_M}$$

- γ_M – partial factor for material, use 2,2

Partial factor for material γ_M (according to czech national annex NA.2.1)		
Masonry made with	Material of units	
	Autoclaved aerated concrete	Other
units of category I, designed mortar	2,5	2,0
units of category I, prescribed mortar	2,7	2,2
units of category II	3,0	2,5

Load

- Load from slabs, self-weight of the walls, parapet on the roof from tributary area from all floors



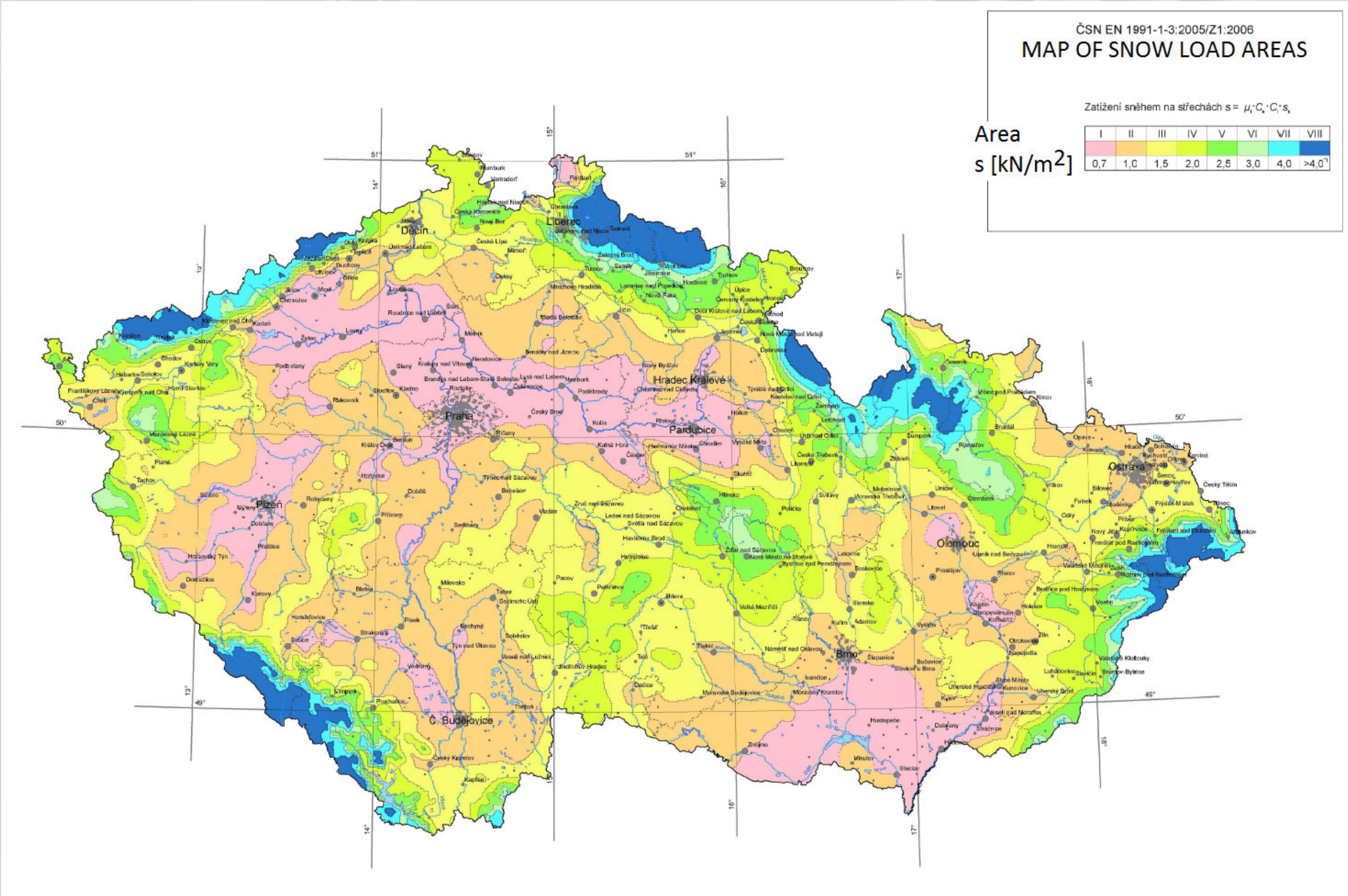
Snow load

- Characteristic snow load:

$$s_k = \mu_i C_e C_t s$$

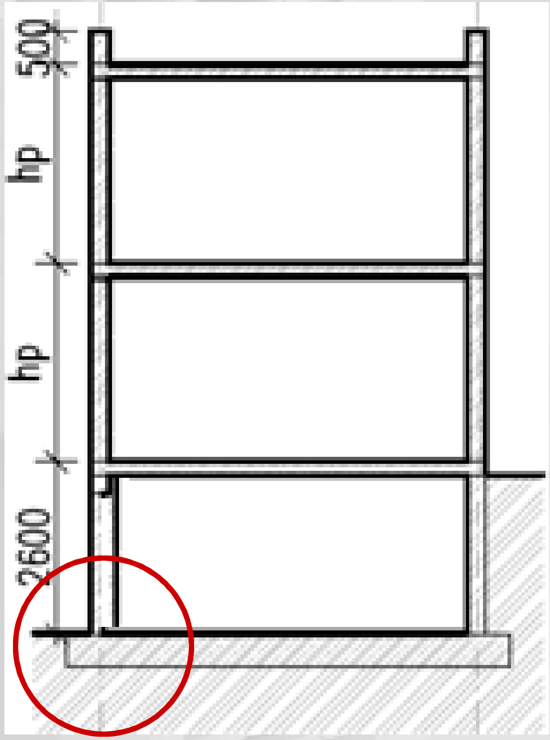
- μ_i – snow load shape coefficient, for flat roof 0,8
- C_e – exposure coefficient, for normal topography 1,0
- C_t – thermal coefficient, for normal conditions 1,0
- s – basic snow load according to snow map

Snow load


ČSN EN 1991-1-3:2005/Z1:2006
MAP OF SNOW LOAD AREAS
Zatížení sněhem na střechách s = μi·Ce·Ct·sk
Area
s [kN/m2]
I II III IV V VI VII VIII
0,7 1,0 1,5 2,0 2,5 3,0 4,0 >4,0
Děčín
Liberec
Hradec Králové
Pardubice
Praha
Plzeň
Olomouc
Ostrava
Brno
Č. Budějovice

Design of dimensions

- Maximum normal force in the bottom of the pillar in basement (without self-weight of the pillar) => N_{max}



- Estimation:

$$A_{req} = \frac{N_{max}}{0,7 f_d}$$

- Design (with respect to the dimensions of masonry units):

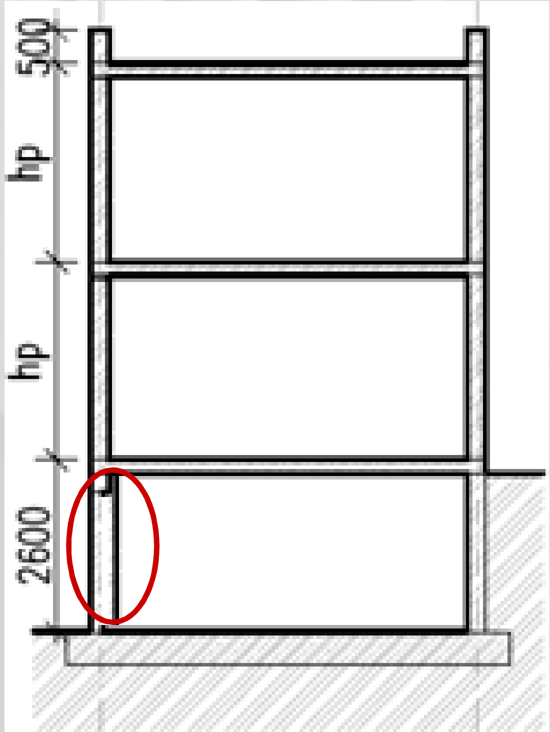
$$A \geq A_{req} \rightarrow b \times t$$

Slenderness ratio

- Criterion:

$$\frac{h_{ef}}{t_{ef}} \leq 27$$

- $h_{ef} = \rho_n . h_p$, h_p = clear height of the pillar
- For walls restrained at the top and bottom by solid slabs, take $\rho_n = 0{,}75$
- $t_{ef} = \min(b, t)$



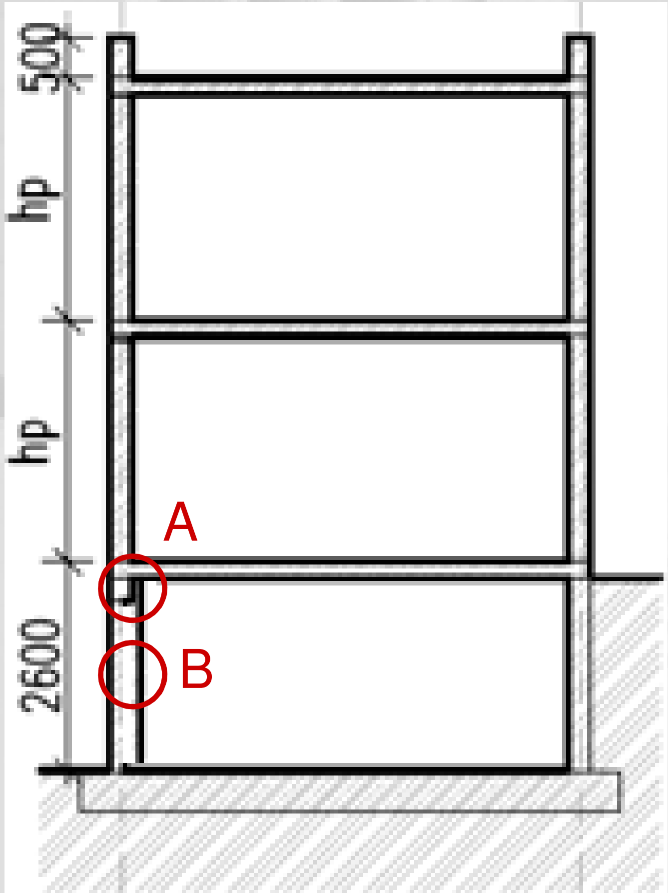
Cross-sections to be checked

A. Top of the pillar – eccentric load, high vertical load

B. Effect of slenderness (possibility of buckling)

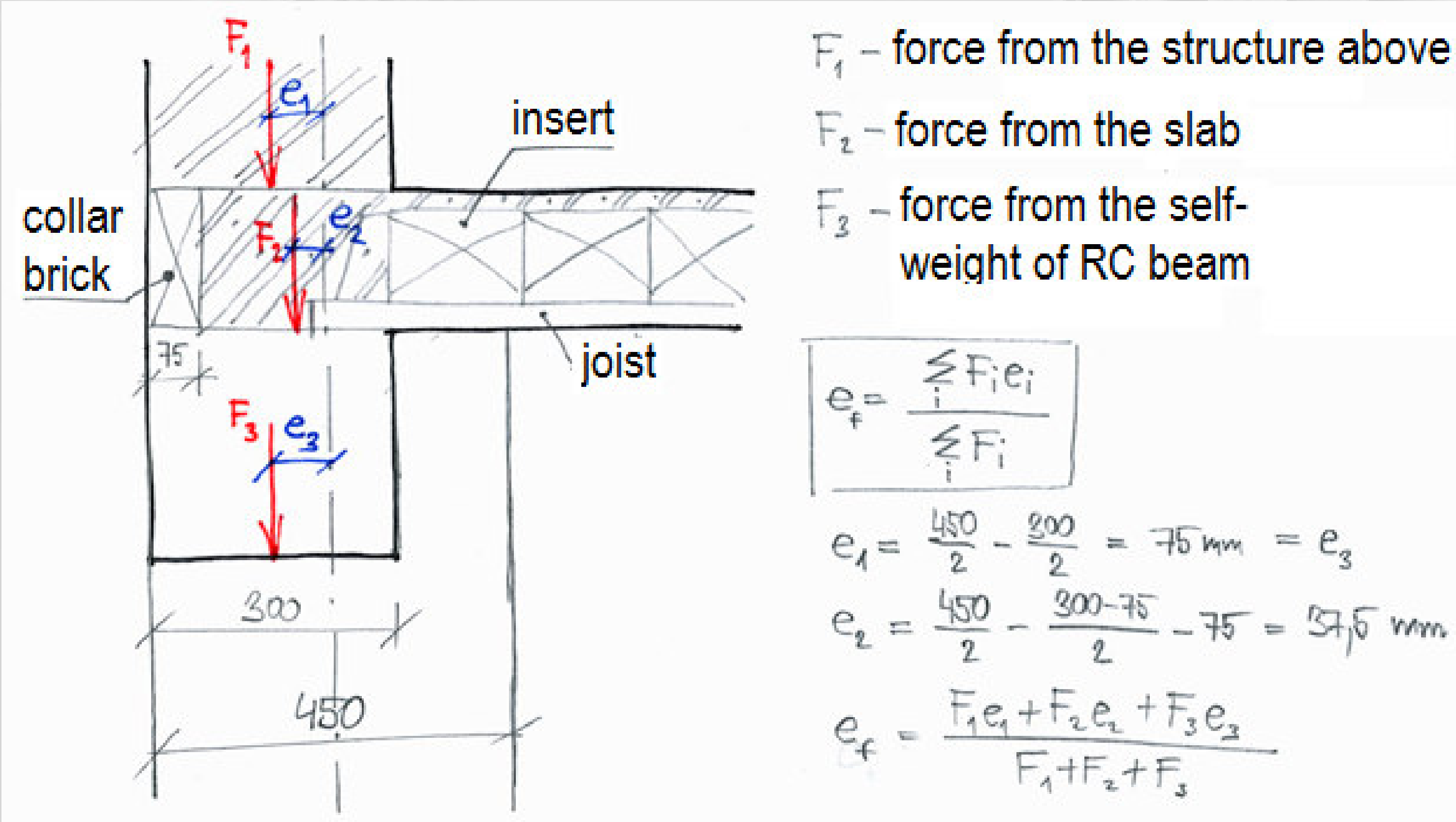
$N_{Ed,A} = N_{max}$

$N_{Ed,B} = N_{max}$ + ½ self-weight of the pillar



Eccentricity due to loads

A. Draw detail and calculate eccentricity. *Example:*



B. One half of eccentricity in A

Vertical resistance – A

$$N_{\mathrm{Rd,i}} = \Phi_{\mathrm{i}} A f_{\mathrm{d}}$$

- A – cross-sectional area of the wall
- Φ_i – capacity reduction factor

$$\Phi_{\mathrm{i}} = 1 - \frac{2e_{\mathrm{i}}}{t}$$

$$e_{\mathrm{i}} = e_{\mathrm{if}} + e_{\mathrm{ia}} \geq 0.05t$$

$$e_{\mathrm{ia}} = \frac{h_{\mathrm{ef}}}{450}$$

Minimum eccentricity: $0.05t$

Thickness of the pillar: t

Total eccentricity: e_{i}

Eccentricity due to loads: e_{if}

Initial eccentricity: e_{ia}

Vertical resistance – B

$$N_{\mathrm{Rd,m}} = \Phi_{\mathrm{m}} A f_{\mathrm{d}}$$

- Φ_{m} – capacity reduction factor, see table

Eccentricity due to loads — Initial eccentricity — Eccentricity due to creep

$$\frac{e_{\mathrm{mk}}}{t} = \frac{e_{\mathrm{mf}} + e_{\mathrm{ma}} + e_{\mathrm{k}}}{t} \geq 0.05$$

Relative eccentricity — Minimum relative eccentricity

$$e_{\mathrm{mf}} \approx 0.5 e_{\mathrm{if}}$$

$$e_{\mathrm{ma}} = \frac{h_{\mathrm{ef}}}{450}$$

$$e_{\mathrm{k}} \approx 0$$

Vertical resistance – B

Slenderness ratio	Eccentricity e_{mk}/t						
h_{ef}/t_{ef}	0,05	0,10	0,15	0,20	0,25	0,30	0,33
0	0,90	0,80	0,70	0,60	0,50	0,40	0,34
1	0,90	0,80	0,70	0,60	0,50	0,40	0,34
2	0,90	0,80	0,70	0,60	0,50	0,40	0,34
3	0,90	0,80	0,70	0,60	0,50	0,40	0,34
4	0,90	0,80	0,70	0,60	0,49	0,39	0,33
5	0,89	0,79	0,69	0,59	0,49	0,39	0,33
6	0,88	0,78	0,68	0,58	0,48	0,38	0,32
7	0,88	0,77	0,67	0,57	0,47	0,37	0,31
8	0,86	0,76	0,66	0,56	0,46	0,35	0,29
9	0,85	0,75	0,65	0,54	0,44	0,34	0,28
10	0,84	0,73	0,63	0,53	0,42	0,32	0,26
11	0,82	0,72	0,61	0,51	0,40	0,30	0,24
12	0,81	0,70	0,59	0,49	0,38	0,28	0,22
13	0,79	0,68	0,57	0,47	0,36	0,26	0,20
14	0,77	0,66	0,55	0,45	0,34	0,24	0,18
15	0,75	0,64	0,53	0,43	0,32	0,22	0,17
16	0,72	0,62	0,51	0,40	0,30	0,20	0,15
17	0,70	0,59	0,49	0,38	0,28	0,18	0,13
18	0,68	0,57	0,46	0,36	0,26	0,16	0,12
19	0,65	0,54	0,44	0,33	0,23	0,15	0,10
20	0,63	0,52	0,41	0,31	0,21	0,13	0,09

Resistance check

$$N_{\mathrm{Rd,i}} \geq N_{\mathrm{Ed,A}}$$

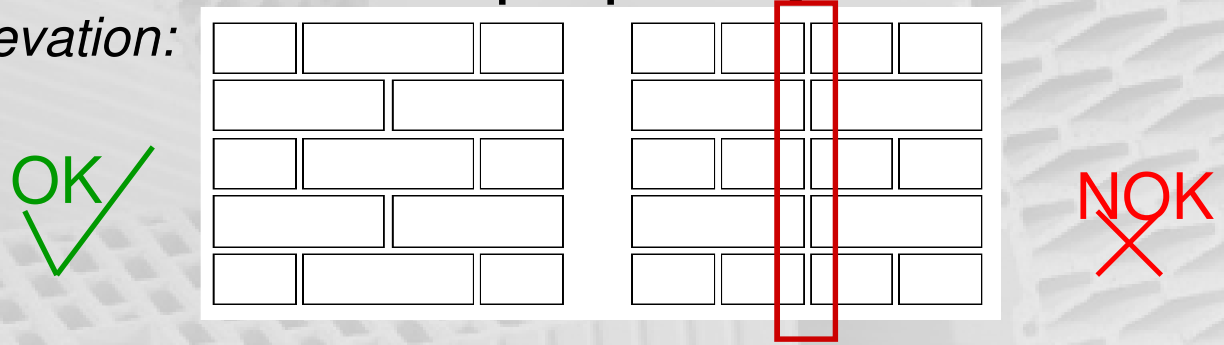
$$N_{\mathrm{Rd,m}} \geq N_{\mathrm{Ed,B}}$$

- *In practice:* If any of the criteria is not met, the pillar should be redesigned!!!
- *In the homework:* If any of the criteria is not met, propose a change to improve load-bearing capacity of the pillar

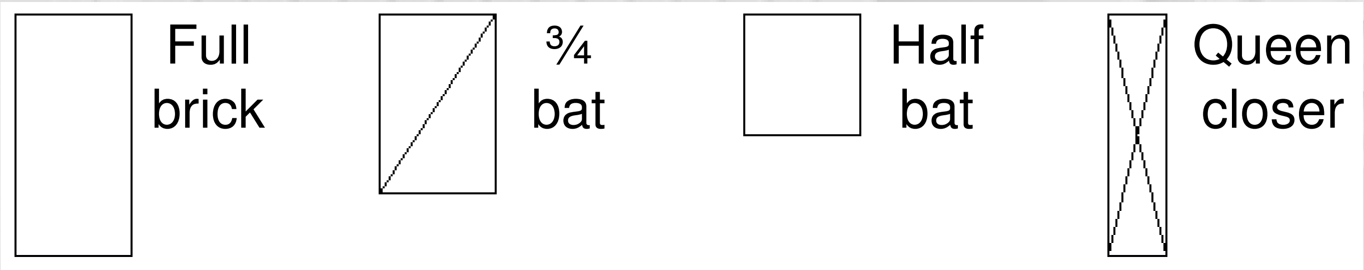
Bond of bricks

- Important for good load distribution
- RULE: Continuous perpend joint is not allowed

Elevation:



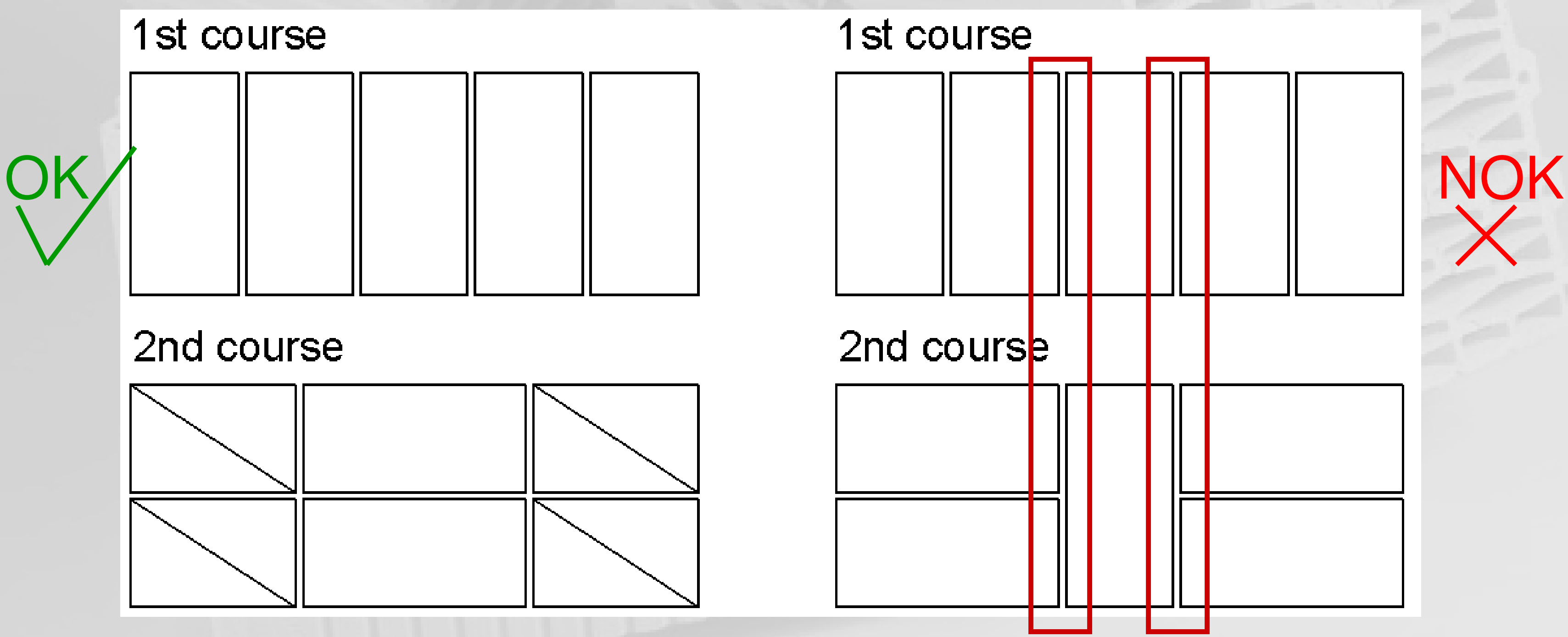
- Bricks you can use



- RULE: Queen closer should not be placed on the edge of the cross-section

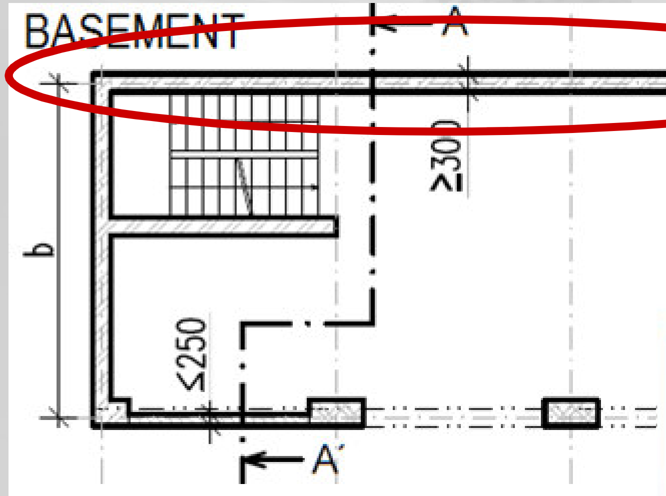
Bond of bricks

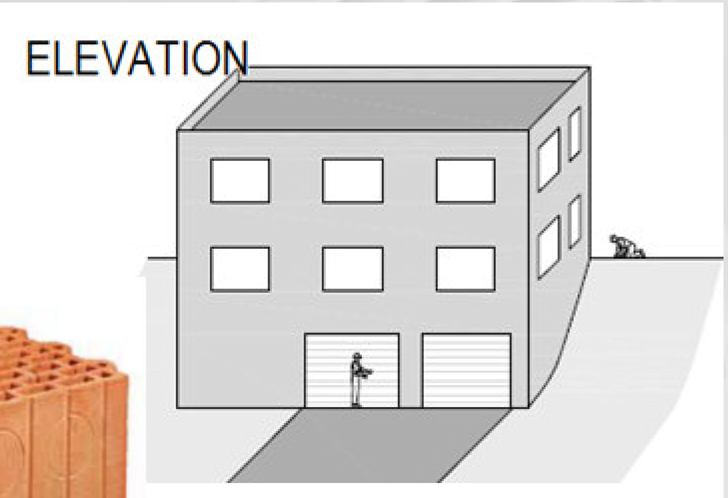
- *Example*: Pillar 300 x 750 mm made from classic full bricks (290/140/65 mm)
- *Plan:*



5th part: Basement wall

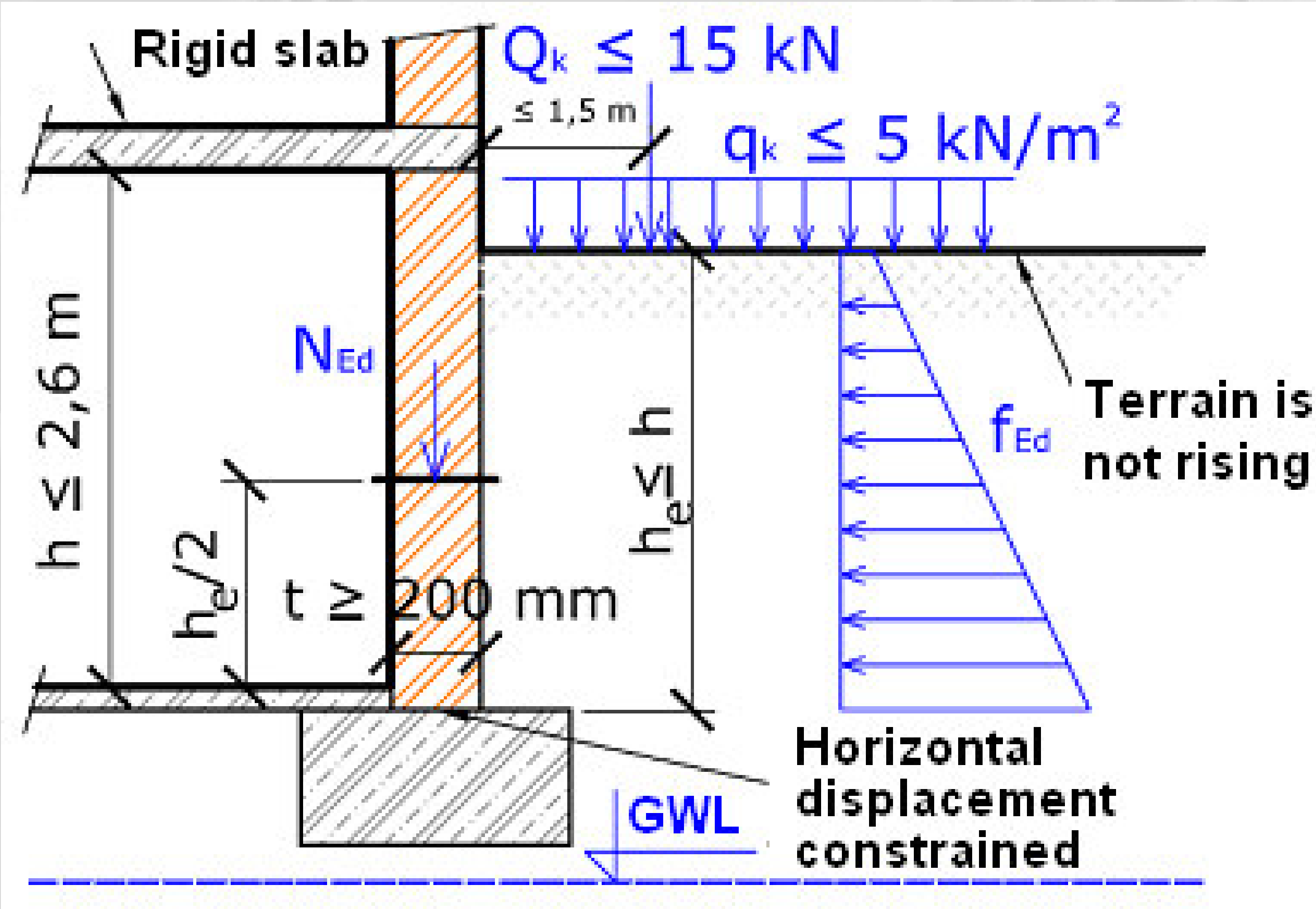
- Using simplified method according to Eurocode 6, check the load-bearing capacity of basement wall loaded by earth pressure at rest





Hollow bricks + thin layer mortar or foam

Simplified Method: Rules



Simplified Method: Conditions

- Lateral: $$N_{\mathrm{Ed,min}} \geq F_{\mathrm{Ed}} = \frac{\gamma b h h_{\mathrm{e}}^{2}}{\beta_{\mathrm{e}} t}$$
- Vertical: $$N_{\mathrm{Ed,max}} \leq N_{\mathrm{Rd}} = \frac{b t f_{\mathrm{d}}}{3}$$
- $N_{Ed,min}$ ≡ characteristic value of vertical dead loads in the section of the wall in the middle of backfill height
- $N_{Ed,max}$ ≡ design value of vertical dead+live loads in the section of the wall in the middle of backfill height
- F_{Ed} = lateral force effect of the backfill
- N_{Rd} = vertical load-bearing capacity of the wall

Simplified Method: Conditions

- γ – density of soil (backfill), see assignment
- b – width of the wall, take b = 1 m and calculate the forces per 1 m
- h – clear height of the wall
- h_e – height of the backfill, $h_e = h$
- t – thickness of basement wall, 300 mm for POROTHERM 30
- f_d – design strength of masonry

Simplified Method: Equations

- β_e – coefficient to involve horizontal spanning (L) of the wall

$$L \geq 2h \rightarrow \beta_e = 20$$

$$L \leq h \rightarrow \beta_e = 40$$

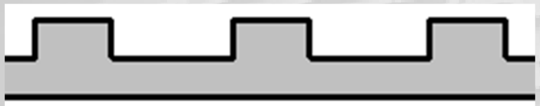
$$h < L < 2h \rightarrow \beta_e = 60 - 20\frac{L}{h}$$

Strength of masonry

- Use the same approach as for pillar with following changes:
  - Blocks connected by thin layer mortar or foam => no effect of mortar, characteristic strength is: $f_k = K f_b^{0.7}$
  - Volume of pores (holes) = 52 %
  - No longitudinal perpend joint => don´t multiply K by 0,8
  - Use γ_M = 2,0 (designed, not prescribed mortar)

If the capacity is not enough:

- Increase thickness of the wall
- Use masonry of higher strength (applicable only if vertical condition is not met)
- Use reinforced masonry (ditto)
- Design strengthening pillars

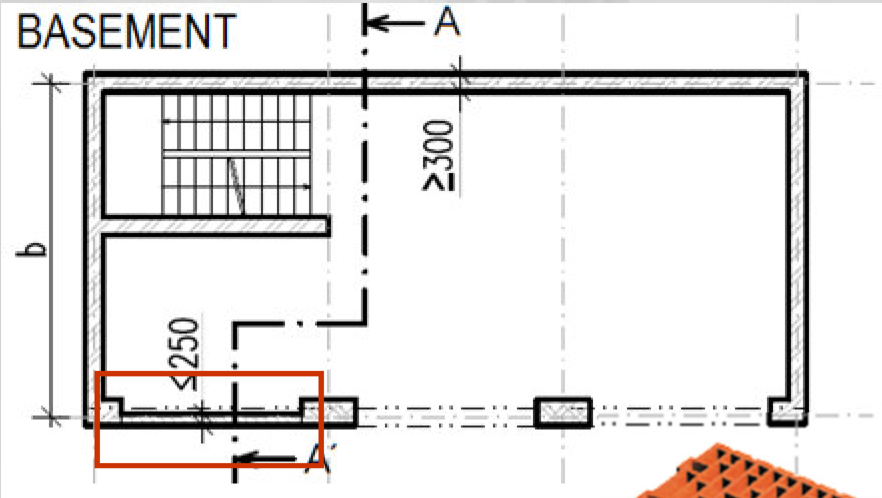


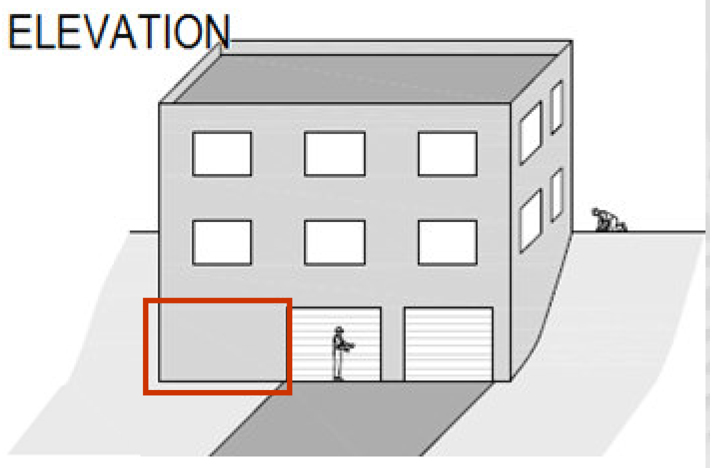
- Design reinforced concrete basement

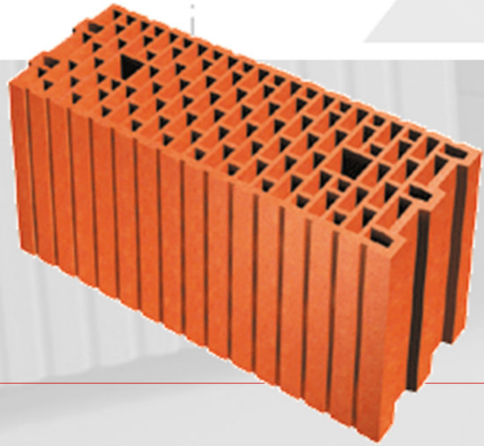
=> Choose one of the measures if your wall doesn‘t meet the criteria!

6th part: Wind loaded wall

- Check load-bearing capacity of wind-loaded non-bearing masonry wall next to garage doors



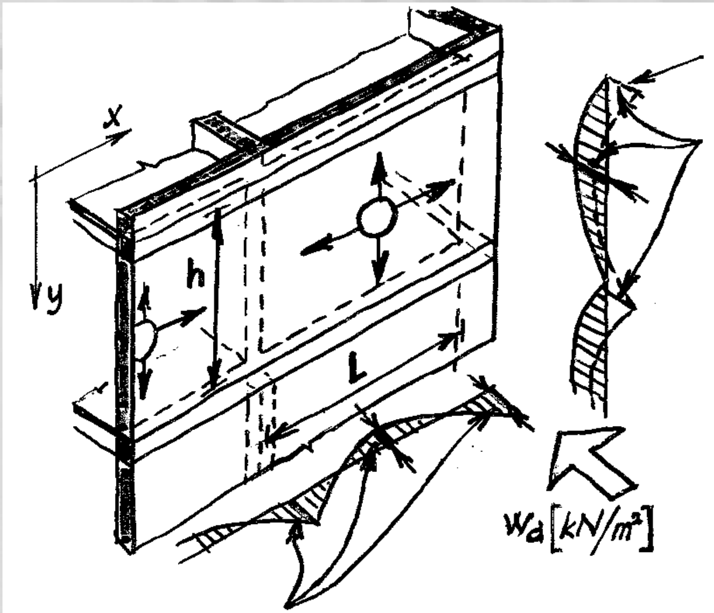


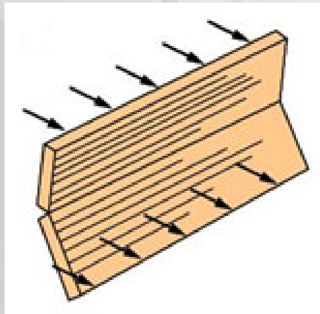


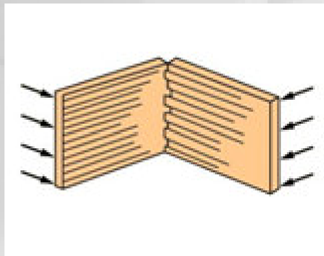
Hollow bricks + general purpose mortar

Wind loaded masonry

- Non-bearing 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/m²]

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

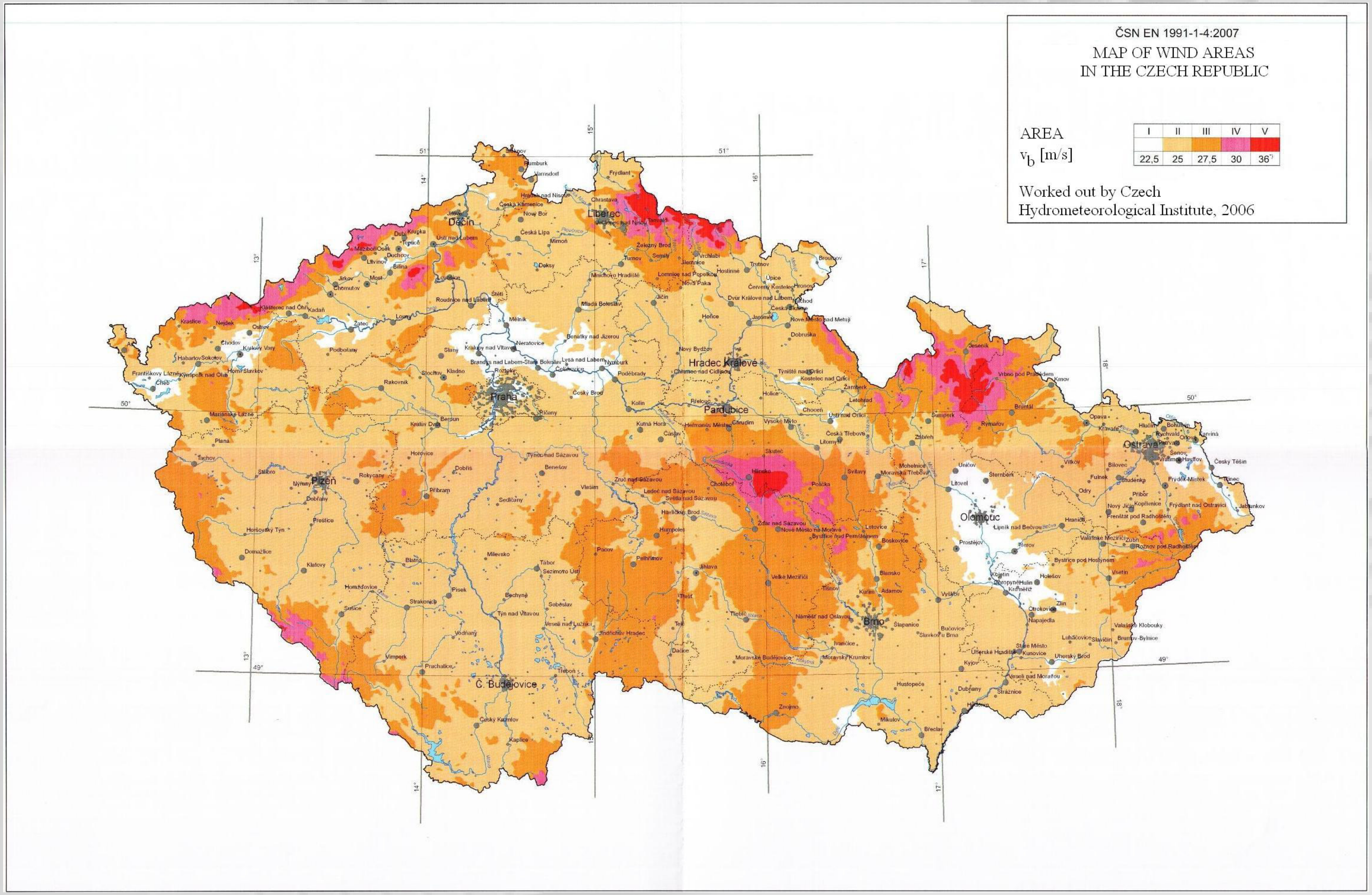
- q_b – reference mean velocity pressure [kN/m²]

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

You will recieve the value in [Pa] = [N/m²] => divide by 1000 to recieve kN/m²

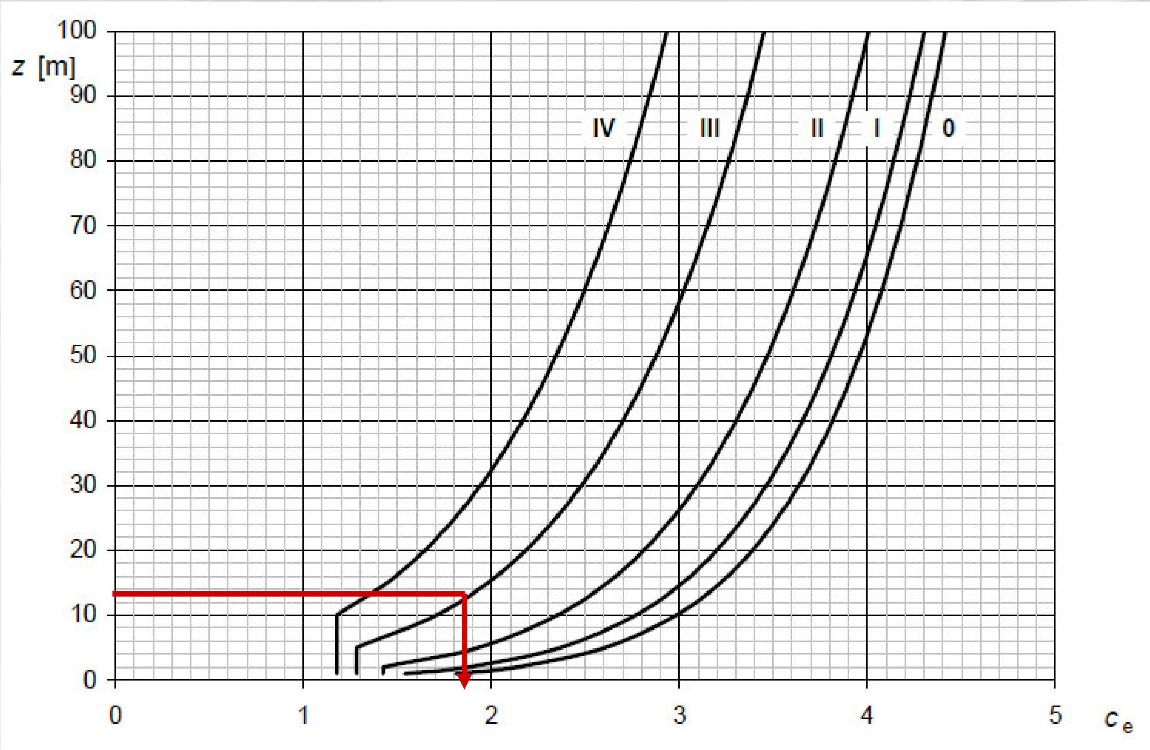
- ρ – air density, 1,25 kg.m^{-3}
- v_b – basic wind velocity (defined from a map in EC 1991-1-4), see assignment

Wind load


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

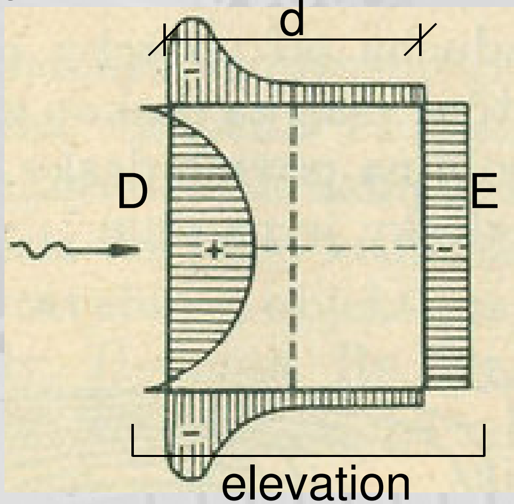
Wind load

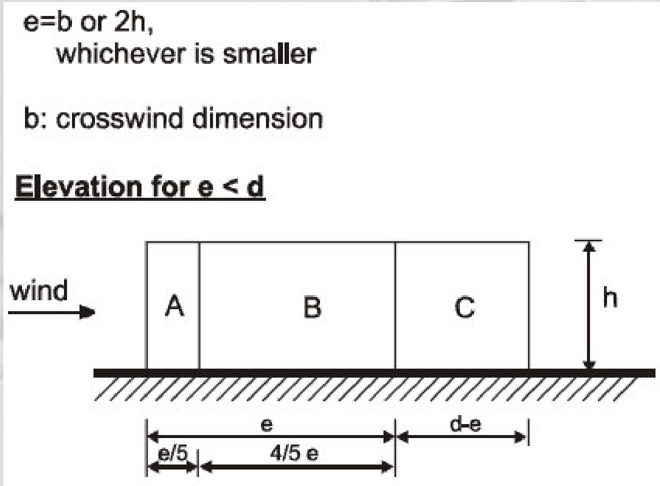
- c_e – exposure factor, see graph below
  - Terrain category – III (suburb) or IV (dowtown)
  - *z* – in our case, the height of the building



Wind load

- c_{pe} – pressure coefficient

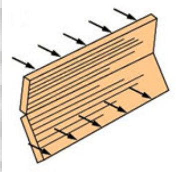




Zone	A		B		C		D		E	
h/d	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
$\leq$ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

Flexural strength of masonry

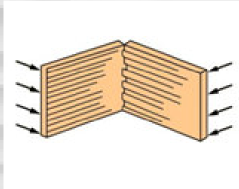
- f_{xk1} – characteristic flexural strength in the plane of failure parallel to the bed joints



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

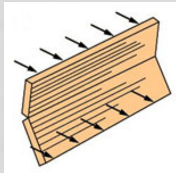


Masonry Unit		f_{xk2} [MPa]			
		General purpose mortar		Thin layer mortar	Lightweight mortar
		$f_m <$ 5 MPa	$f_m \geq$ 5 MPa		
Clay		0,20	0,40	0,15	0,10
Calcium silicate		0,20	0,40	0,30	not used
Aggregate concrete		0,20	0,40	0,30	not used
Autoclaved aerated concrete	$\rho < 400$ kg/m^3	0,20	0,20	0,20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

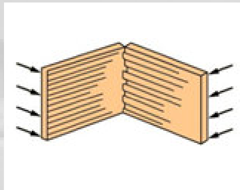
Flexural strength of masonry

- Design values of flexural strength:

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



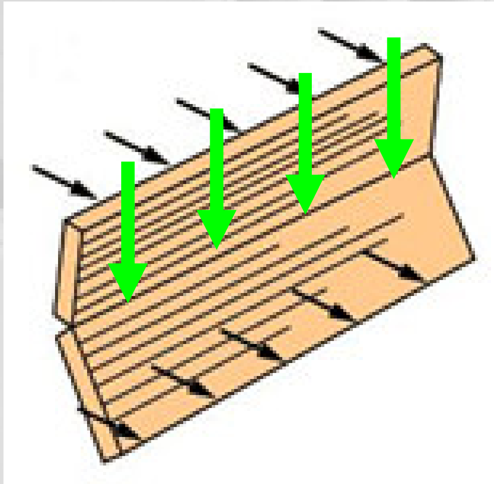
$$f_{xd2} = \frac{f_{xk2}}{\gamma_M}$$



- 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



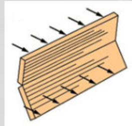
$$\sigma_{\mathrm{d}} = \frac{\rho_{\mathrm{m}}}{1000t} \cdot \frac{h}{2} \quad [\mathrm{MPa}]$$

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

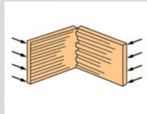
Design bending moment

- 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

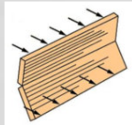
Wall support condition E = wall is simply supported on all four edges

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

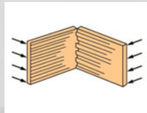
Moment of resistance

- Formulae [kNm/m]:

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



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



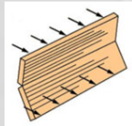
- Z – elastic section modulus per 1 meter of the wall [m^3/m]:

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

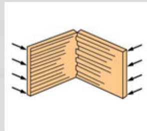
- t – thickness of the wall, t = 175 mm (thickness „without plaster“)

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