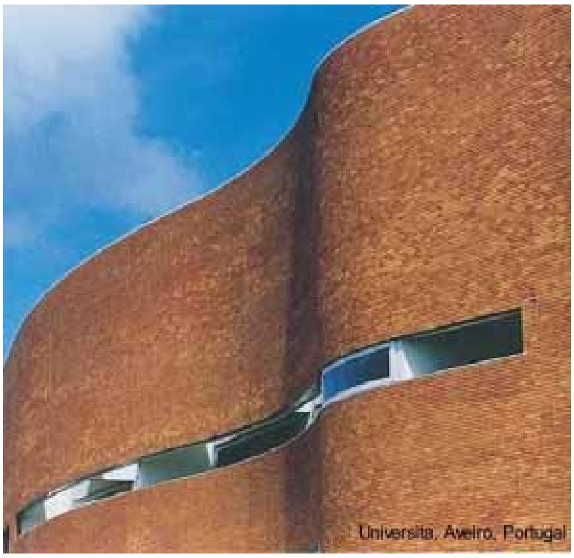
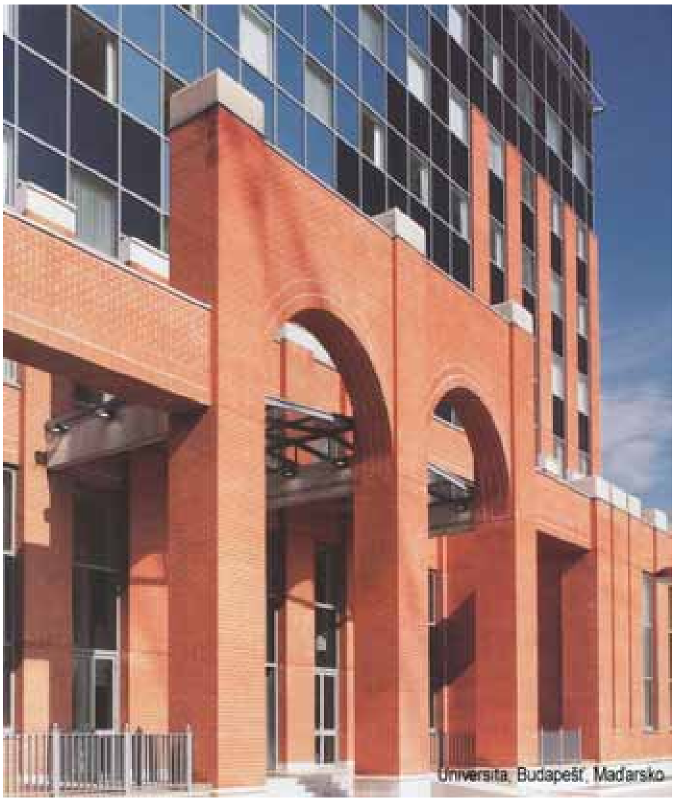
Masonry





Masonry as a structural material

Components

- Masonry units EN 720, strengtht $f_b = \delta \times f_u$,
  - δ the coefficient of units dimensions,
  - f_u the mean of unit strength,
- Mortal EN 1015-11, e.g. M10, f_m = 10 MPa
  - cement: lime: sand (commonly) 1:1:5

Masonry

- plain masonry
  - normal mortal
  - thin joints
  - light mortal
- reinforced masonry
- prestressed masonry

EN 1996 - Characteristic strength

Masonry strength of plain masonry:

$$f_k = K\, f_b^{0,65}\, f_m^{0,25} \text{ (nově } f_k = K\, f_b^{0,7}\, f_m^{0,3}\text{)}$$

- K constant dependent on masonry type and units, for masonry without longitudinal joints0,45 až 0,55
- $f_b = \delta \times f_u$ strength of units< 50 Mpa
- δ effect of units dimensions, for CP 290/140/65 $\delta = 0,77$
- f_m strength of mortal < 20 MPa or < 2 f_b

An example: $K = 0,5$ (units 2a, without longitudinal joints)

$f_b = 25$ MPa, $f_m = 15$ MPa

$f_k = 0,5 \times 25^{0,65} \times 15^{0,25} = 8,0$ MPa

Partial factors γ_M in ENV 1996

Units class	Production class		
	A	B	C
I	1,7	2,2	2,7
II	2,0	2,5	3,0

Design strength

$$f_d = f_k / \gamma_M$$

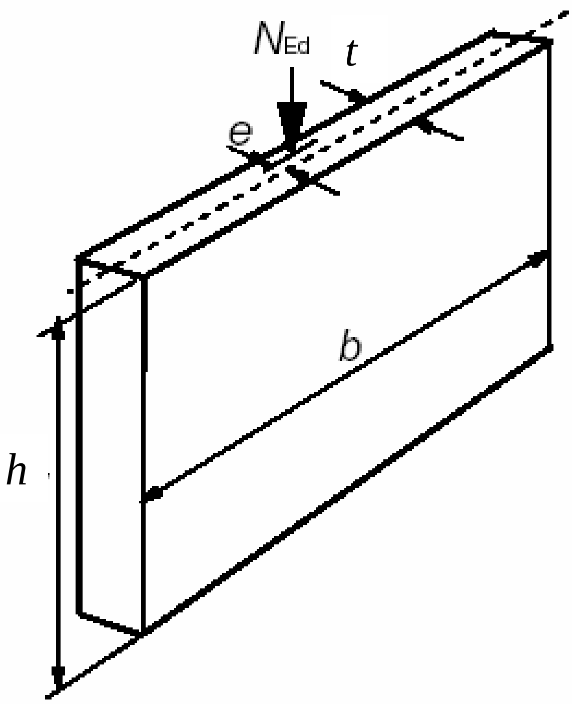
Partial factors in EN 1996

	Material	γ_M				
		Class				
		1	2	3	4	5
	Masonry made with:					
A	Units of Category I, designed mortar[1]	1,5	1,7	2,0	2,2	2,5
B	Units of Category I, prescribed mortar[2]	1,7	2,0	2,2	2,5	2,7
C	Units of Category II, any mortar[1,2,5]	2,0	2,2	2,5	2,7	3,0
D	Anchorage of reinforcing steel	1,7	2,0	2,2	2,5	2,7
E	Reinforcing steel and prestressing steel	1,15				
F	Ancillary components[3,4]	1,7	2,0	2,2	2,5	2,7
G	Lintels according to EN 845-2[3]	1,5 to 2,5				

Notes:

1. Requirements for designed mortars are given in EN 998-2 and EN 1996-2
2. Requirements for prescribed mortars are given in EN 998-2 and EN 1996-2
3. Declared values are mean values.
4. Damp proof courses are assumed to be covered by masonry γ_M.
5. When the coefficient of variation for Category II units is not greater than 25%.

Simple wall

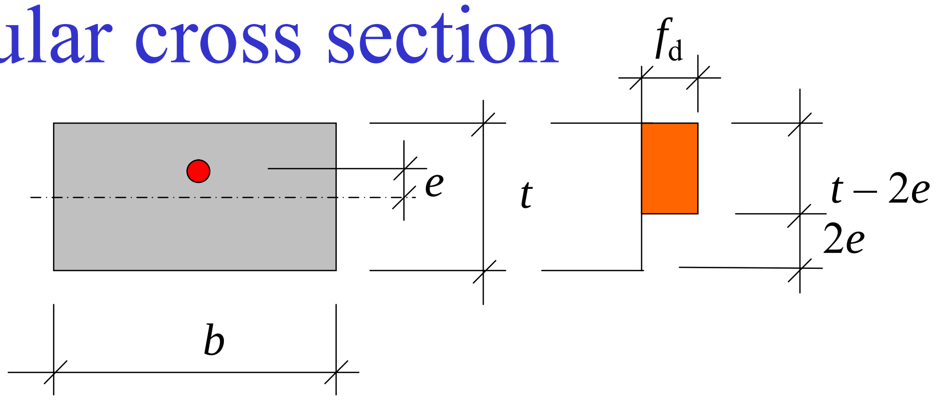


$h_{ef} = \rho_n h$

$\rho_n \leq 1$ reduction coefficient dependent on boundary conditions $\rightarrow$ n = 2, 3, 4.

For reinforced concrete slabs $\rho_n = 0{,}75$.

Rectangular cross section



$\boldsymbol{N_{Rd} = b\ t\ f_d\ \Phi_{i,m}}$

N_{Rd} is design resistance of cross section,

b width of wall,

t thickness of wall (without plaster),

$\Phi_{i,m}$ reduction coefficient.

Reduction coefficient for haed or foot of wall:

$\boldsymbol{\Phi_i = (1 - 2\ e_i / t)}$

$e_i = e_{fi} + e_a$, is the total eccentricity, $e_i \geq 0{,}05\ t$

$e_{fi} = M_{Edi}/N_{Edi}$ eccentricity due to load

$e_a = h_{ef}/450$ random eccentricity/ imperfections.

Middle cross section

Reduction coefficient Φ_m due to eccentricity and slenderness

$$\boldsymbol{\Phi_m = A_1 \exp(- u^2/2) < 1}$$

Coefficient A_1 due to eccentricity dependent on e_{mk} a t:

$$\boldsymbol{A_1 = 1 - 2\ e_{mk}/t,}$$

e_{mk} is the total eccentricity $0{,}33t \geq e_{mk} \geq 0{,}05\ t$

$$\boldsymbol{e_{mk} = e_{fm} + e_a + e_k,\quad e_m = e_{fm} + e_a}$$

load:	$\boldsymbol{e_{fm} = M_{Ed}/N_{Ed}}$
imperfections:	$\boldsymbol{e_a = h_{ef}/450,}$
creep:	$\boldsymbol{e_k = (0{,}002\ \Phi_\infty h_{ef}/t_{ef}) \sqrt{(t\ e_m)}}$

e_k depends on creep coefficient $\Phi_\infty = \varepsilon_{c,\infty}/\varepsilon_{e1}$, $\varepsilon_{e1} = \sigma/E$: $\Phi_\infty = 0$ to 2, for stones 0, fired bricks 0,5 až 1,5, concrete units 1,5 až 2.

Effect of slenderness

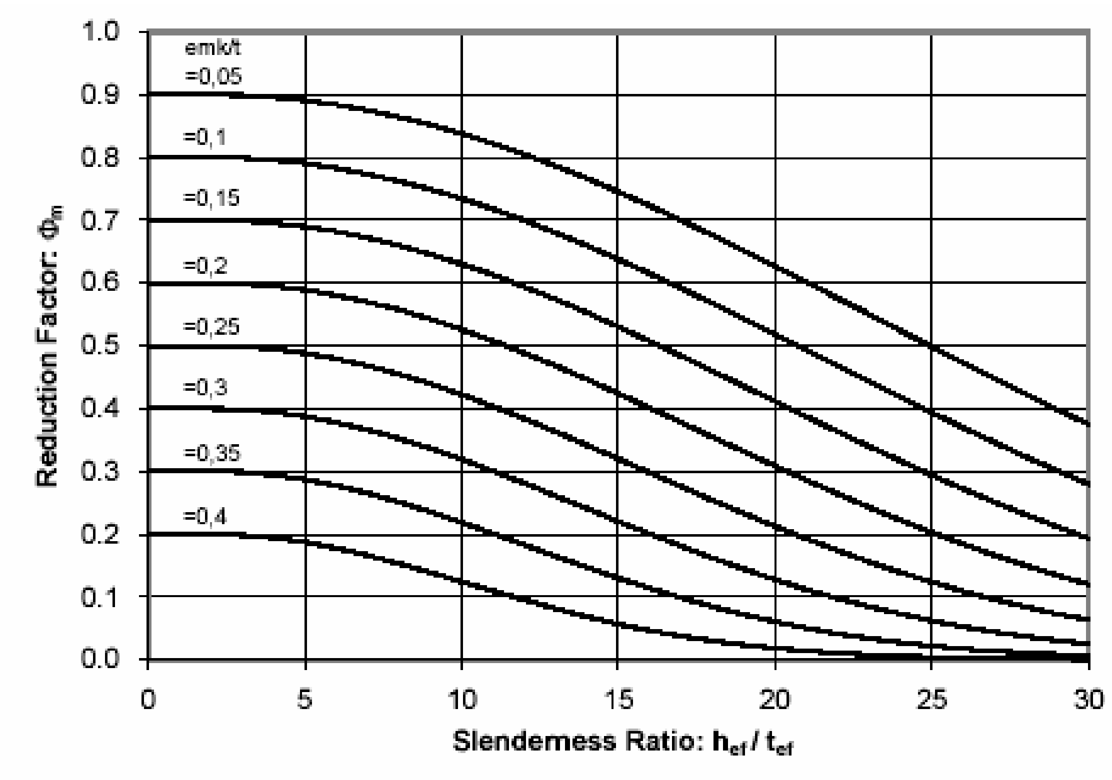
Coefficient **exp(– u^2/2)** depends on slenderness λ:

$$u = \frac{\lambda - 0,063}{0,73 - 1,17\frac{e_{mk}}{t}} \qquad \lambda = \frac{h_{ef}}{t_{ef}}\sqrt{\frac{f_k}{E}}$$

Effective thickness t_{ef} equals actual thickness t in case of one layer.

Graphs – tables for $\Phi_m = A_1 \exp(-u^2/2)$ given for the coefficient of masonry defocrmation $\alpha_{sec} = E / f_k$ (~ 1000), slenderness ratio $h_{ef} / t_{ef} < 27$ (commonly ~ 5 to 10), and eccentricity $e_{mk} / t \geq 0,05$.

Reduction coefficients Φ_m for α_{sec} =1000



An example

Fired bricks f_u =25 MPa, units I, production B, $\gamma_M = 2{,}2$

$K = 0{,}4$; $f_b = \delta f_u = 0{,}77 \times 25 = 19{,}25$ Mpa; M10: $f_m = 10$ Mpa

$f_k = 0{,}4 \times 19{,}25^{0{,}65} \times 10^{0{,}25} = 4{,}86$ MPa, $f_d = f_k / \gamma_M = 4{,}86/2{,}2 = 2{,}07$ MPa

$M = 0$, $e_{fi} = e_{fm} = 0$; $h_{ef} = 0{,}75 \times 3{,}3 = 2{,}5$ m, $b = 1$ m, $t = 0{,}44$ m

$$\mathbf{N_{Rd} = \Phi_{i,m} \times b \times t \times f_d = \Phi_{i,m} \times 0{,}911\ MN}$$

Foot and head of the wall:

$e_a = h_{ef}/450 = 2{,}5/450 = 0{,}0055$ m

$e_i = e_{fi} + e_a = 0 + 0{,}0055$ ($\geq 0{,}05\, t$); $0{,}05\, t = 0{,}05 \times 0{,}44 = 0{,}022$ m

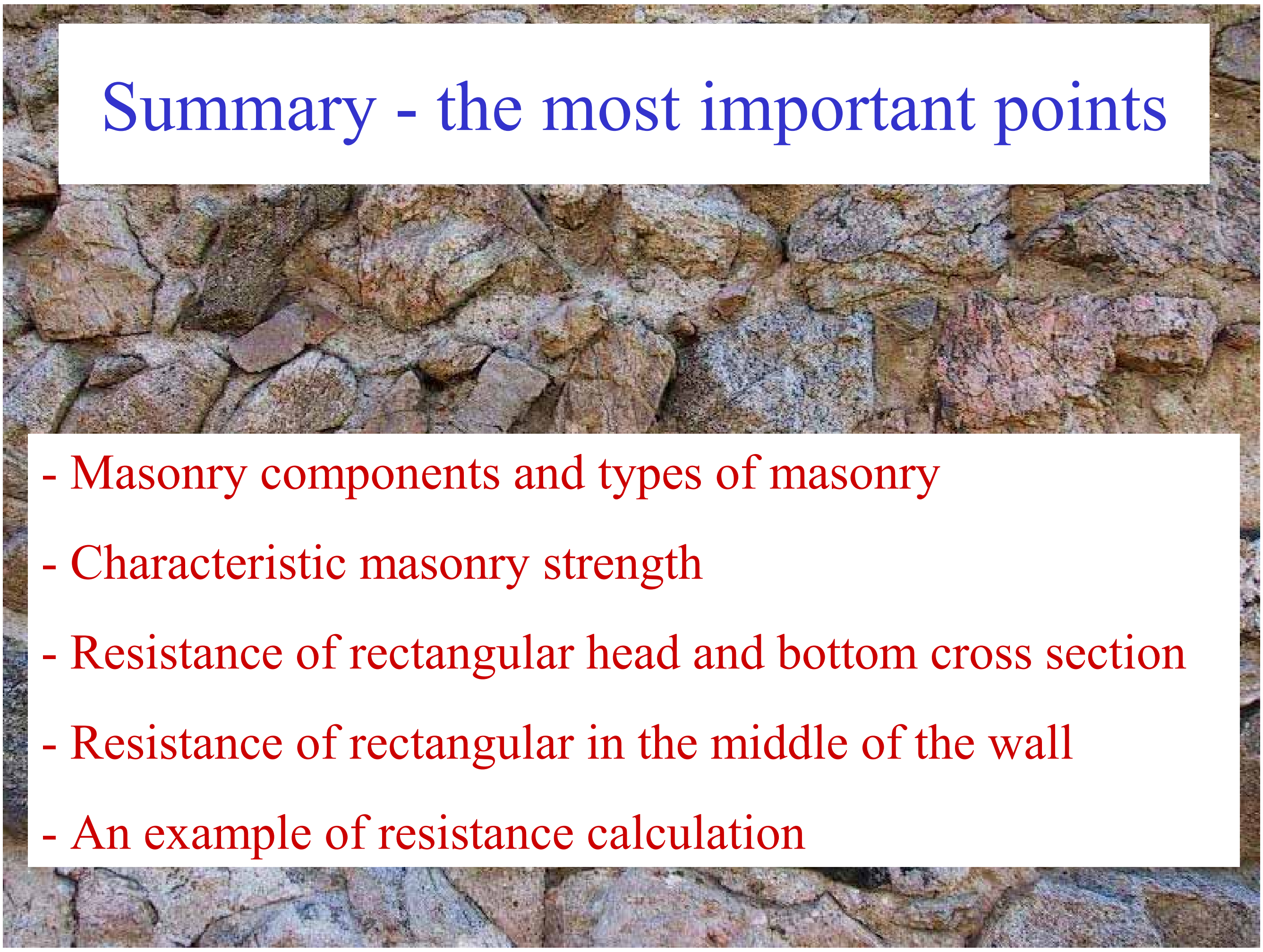
$e_i = 0{,}022$ m , $\Phi_i = 1 - 2\, e_i / t = 1 - 2 \times 0{,}022/0{,}44 = 0{,}9$

$$\mathbf{N_{Rd} = \Phi_i \times b \times t \times f_d = 0{,}9 \times 1 \times 0{,}44 \times 2{,}07 = 0{,}820\ MN}$$

Middle of the wall:

$e_k = 0$, for $\alpha_{sec} = 1000$, $h_{ef}/t_{ef} = 5{,}64$ and $e_{mk}/t = 0{,}05$ graph: $\Phi_m = 0{,}88$

$$\mathbf{N_{Rd} = \Phi_m \times b \times t \times f_d = 0{,}88 \times 1 \times 0{,}44 \times 2{,}07 = 0{,}802\ MN}$$



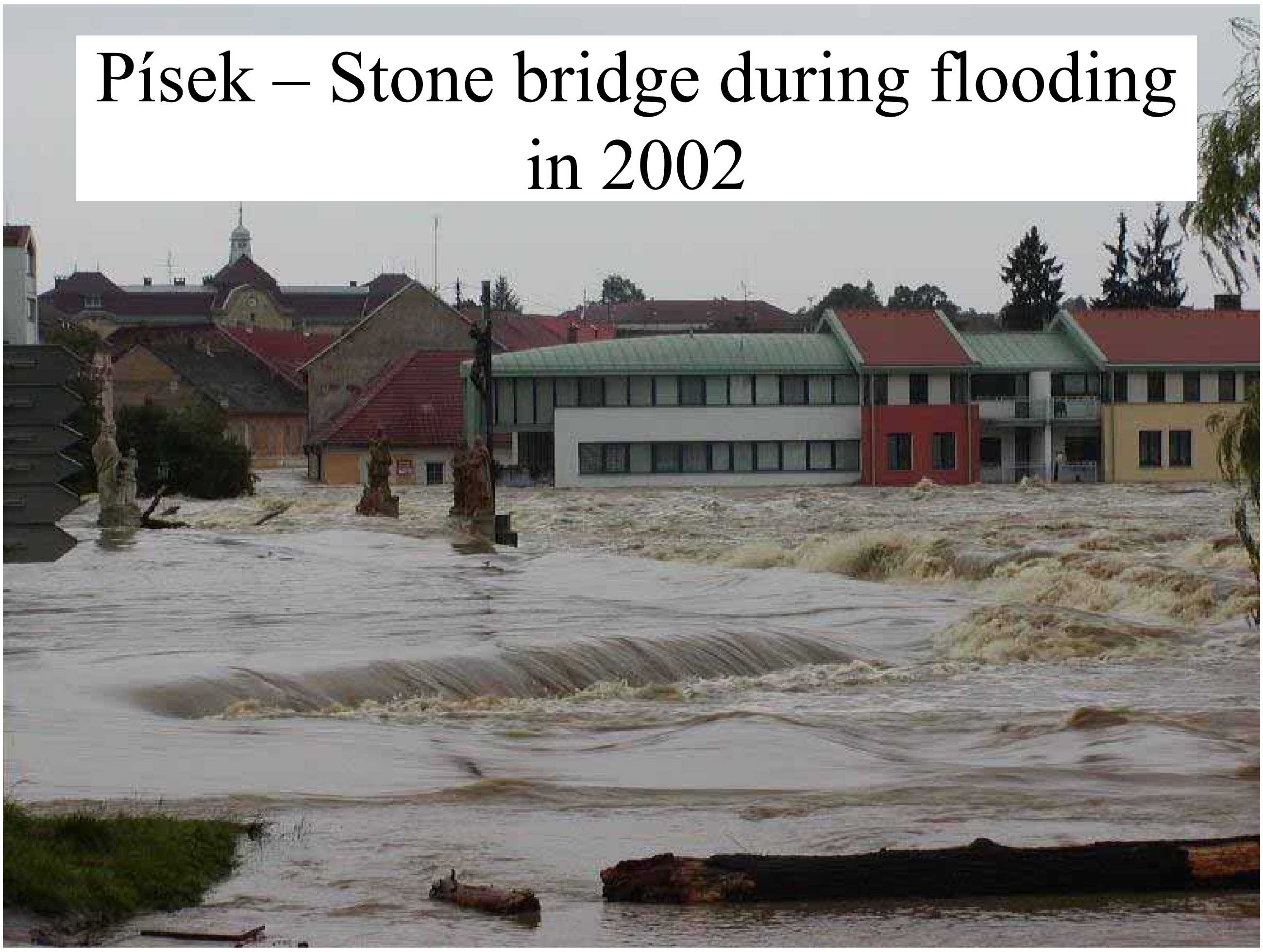
Masonry bridge in Switzerland

Alby Sweden


Nymburk - renaissance city hall


Nymburk – town walls

Písek – Stone bridge 13 century



Písek – Stone bridge during flooding in 2002

Písek – Stone bridge after flooding in 2002