Ispunsko ziđe POROHERM IZO PROFI – mehanička i toplinska svojstva

UNIVERSITY OF SPLIT,
FACULTY OF CIVIL ENGINEERING,
ARCHITECTURE AND GEODESY

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Doc. dr. sc. **Ivan Balić**, dipl.ing.građ
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Ivan Racetin, mag. ing. geod. et geoinf., Ph.D student

u suradnji s:

Wienerberger

Dipl.-Ing. **Alexander Lehmden**, Head of International Product Management Wall of Wienerberger AG
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Iulian Cuta, Civ. Eng. International Product Manager - Region East at Wienerberger AG

webinar, 02/06/2020.

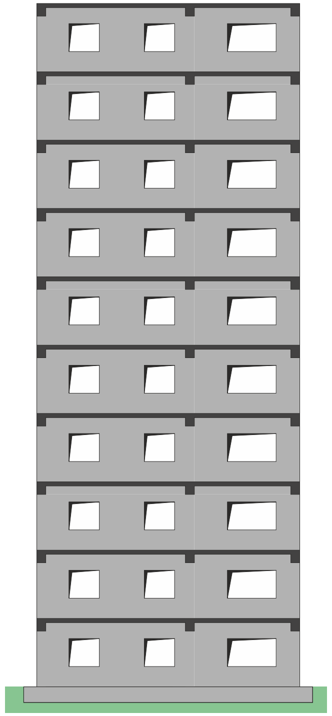
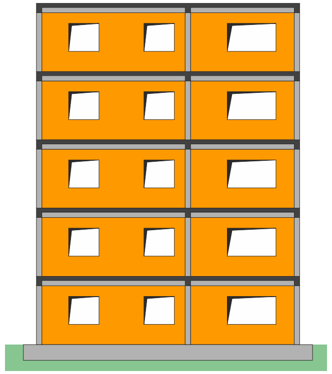
Ispunsko ziđe POROHERM IZO PROFI

A/
Mehanička svojstva - nosivost okomito na ravninu zida

B/
Nestacionarni toplinski tok

A/
Mehanička svojstva - nosivost okomito na ravninu zida

Ispunsko ziđe POROHERM IZO PROFI – Mehanička svojstva

A/B zgrada	Zgrada od omeđenog ziđa	A-b zgrada s ispunskim ziđem
		

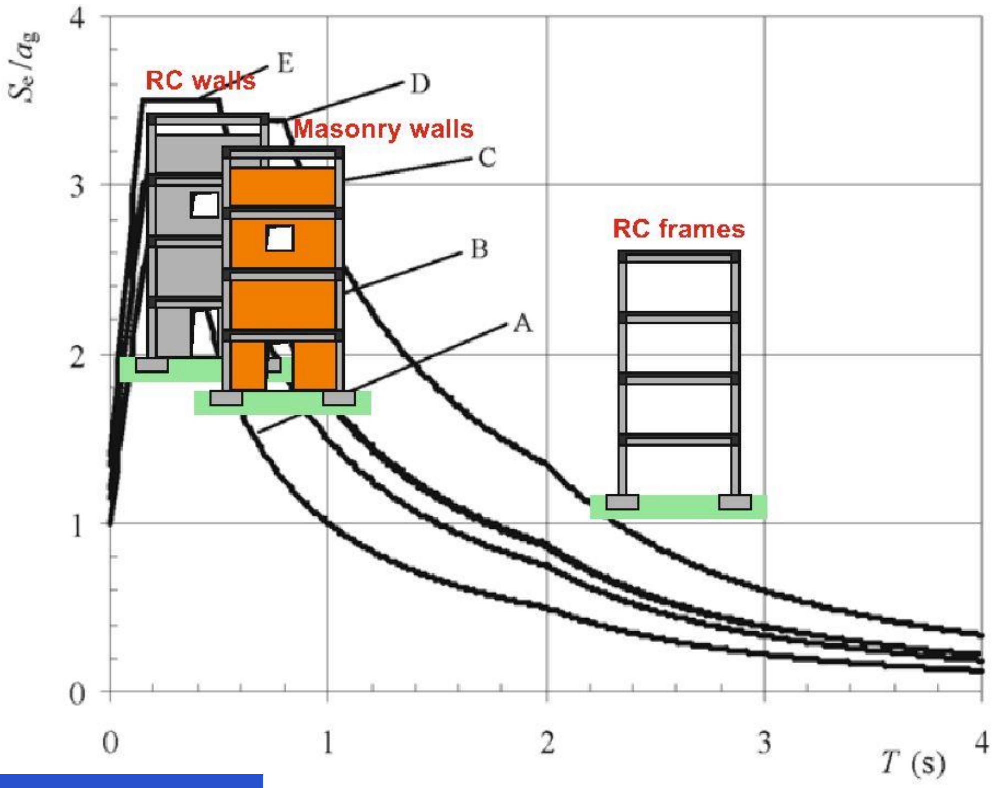
	A/B zgrada	Zgrada od omeđenog ziđa	A-b zgrada s ispunskim ziđem
Broj katova:	+	+/-	+
Toplinska svojstva:	-	+	+

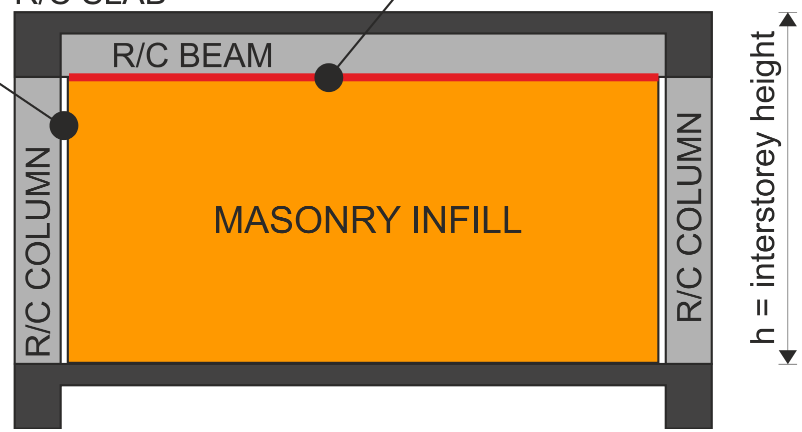
Potres

https://earthquaketrack.com/p/croatia/biggest

- 3 days ago 3.3 magnitude, 10 km depth
  Stolac, Federation of Bosnia and Herzegovina, Bosnia and Herzegovina
- 12 days ago 4.2 magnitude, 10 km depth
  Metković, Dubrovačko-Neretvanska, Croatia
- 13 days ago 3.0 magnitude, 10 km depth
  Kašina, Grad Zagreb, Croatia
- about a month ago 3.2 magnitude, 10 km depth
  Dubrava, Grad Zagreb, Croatia
- about a month ago 3.0 magnitude, 10 km depth
  Kašina, Grad Zagreb, Croatia
- 2 months ago 3.4 magnitude, 10 km depth
  Kašina, Grad Zagreb, Croatia
- 2 months ago 4.6 magnitude, 10 km depth
  Kašina, Grad Zagreb, Croatia
- 2 months ago 5.4 magnitude, 10 km depth
  Kašina, Grad Zagreb, Croatia
- 3 months ago 3.3 magnitude, 7 km depth
  Potoci, Federation of Bosnia and Herzegovina, Bosnia and Herzegovina
- 3 months ago 4.0 magnitude, 15 km depth
  Gračac, Zadarska, Croatia

Ispunsko ziđe POROHERM IZO PROFI – Mehanička svojstva





EUROCODES BUILDING THE FUTURE

EN 1998-1:2004

4 PRORAČUN ZGRADA

4.3 Proračun konstrukcije

4.3.6 Dodatne mjere za okvire s ispunskim ziđem

4.3.6.1 Općenito

(4) U betonskim zidnim sustavima ili dvojnim sustavima istovrijednim zidnim kao i u ukrućenim čeličnim ili spregnutim čelično-betonskim sustavima ***međudjelovanje s ispunskim ziđem smije se zanemariti.***

S ograničenjem međukatnog pomaka na 5 ‰ [prema EN 1998-1:2004, 4.4.3.2 (1)]:

- ispunsko ziđe nema značajan doprinos u ukupnoj krutosti na horizontalna djelovanja
- oštećenja zgrada uslijed potresa su minimalna jer ziđe može podnijeti takve međukatne pomake bez značajnih oštećenja

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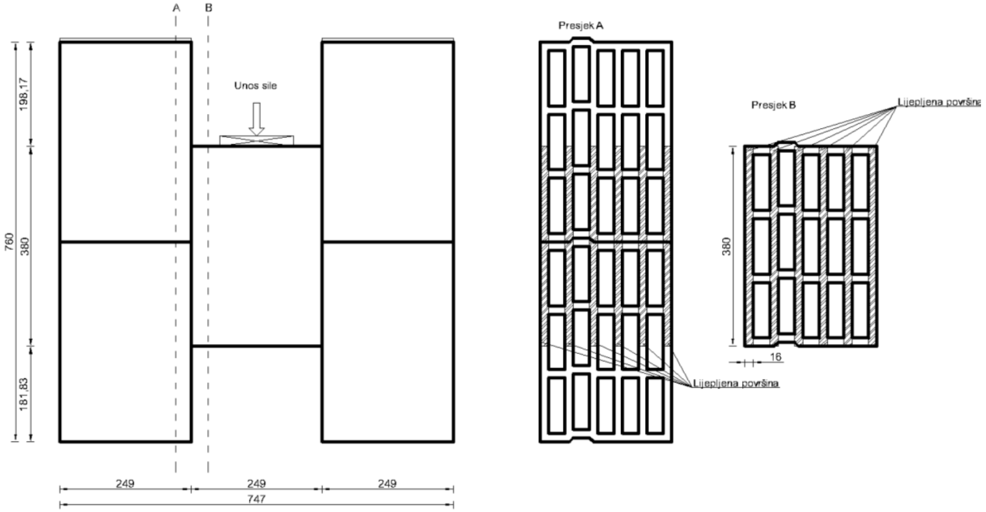
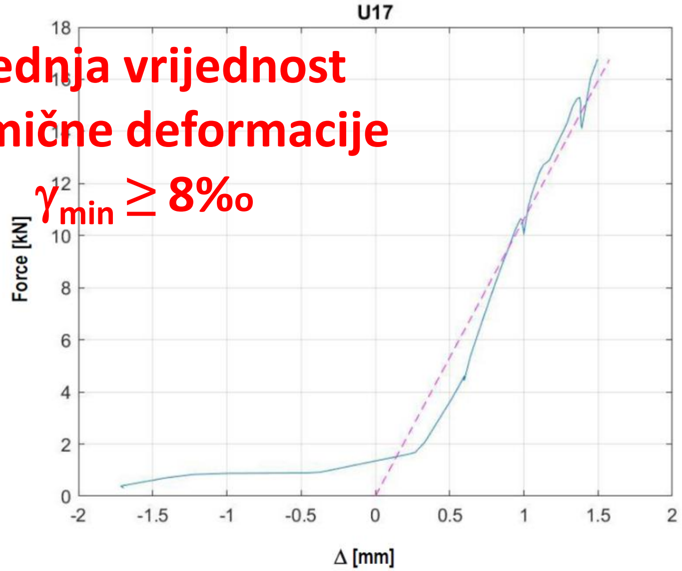
Određivanje posmične čvrstoće na kontaktu između blokova lijepljenih ljepilo Dryfix.Extra (poliuretanski adheziv)





Srednja vrijednost posmične deformacije

$\gamma_{min} \geq 8‰$

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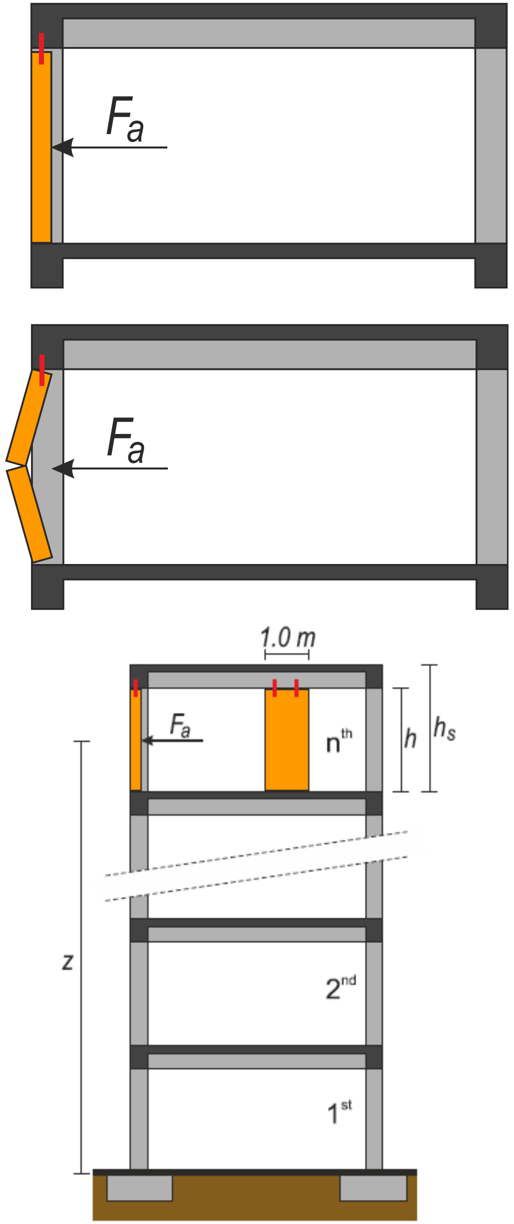

Fig 2.4 Masonry infill wall – non-structural elements

According to EN 1998-1, non-structural elements may be verified on seismic load as shown below.

The effects of the seismic action may be determined by applying to the non-structural element a horizontal force F_a which is defined as follows

$$F_a = (S_a * W_a * \gamma_a) / q_a \qquad \text{[EN 1998-1:2004; (4.24)]}$$

where:

F_a — is the horizontal seismic force, acting at the centre of mass of the non-structural element in the most unfavourable direction

W_a — is the weight of the element

S_a — is the seismic coefficient applicable to non-structural elements

The seismic coefficient S_a may be calculated using the following expression:

$$S_a = \alpha * S * [3 * (1 + z/H) / (1 + (1 - T_a/T_1)^2) - 0.5] \qquad \text{[EN 1998-1:2004; Eq. (4.25)]}$$

where:

- α - the ratio of the design ground acceleration on type A ground, a_g, to the acceleration of gravity g
- S - the soil factor
- T_a - the fundamental vibration period of the non-structural element
- T_1 - the fundamental vibration period of the building in the relevant direction
- z - the height of the non-structural element above the level of application of the seismic action (foundation or top of a rigid basement)
- H - the building height measured from the foundation or from the top of a rigid basement

The value of the seismic coefficient S_a may not be taken less than $\alpha * S$.

γ_a — is the importance factor of the element, see EN 1998-1:2004; 4.3.5.3

For the following non-structural elements the importance factor γ_a shall not be less than 1.5:

- anchorage elements of machinery and equipment required for life safety systems
- tanks and vessels containing toxic or explosive substances considered to be hazardous to the safety of the general public.

In all other cases (as exterior wall) the importance factor γ_a of non-structural elements may be assumed to be

$$\gamma_a = 1.0$$

q_a — is the behaviour factor of the element

Upper limit values of the behaviour factor q_a for non-structural elements "Exterior and interior walls" [EN 1998-1:2004; Table 4.4] is $q_a = 2.0$

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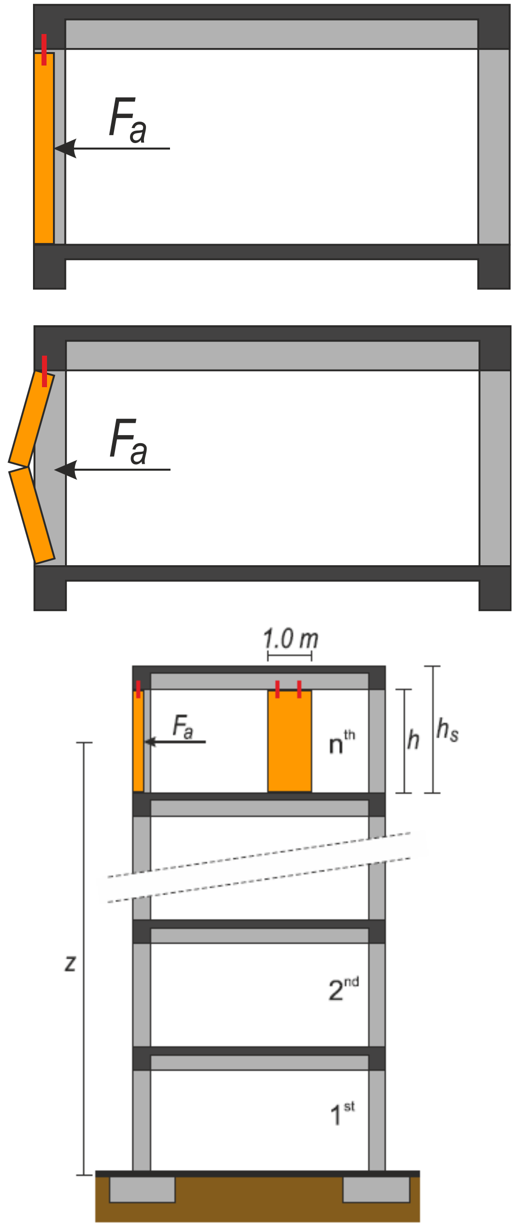

Fig 2.4 Masonry infill wall – non-structural elements

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MASONRY INFILL WALL - Porotherm IZO Profi with Porotherm Dryfix.extra adhesive bonding system
Verification according to EN 1998-1 (4.3.5 Non-structural elements) and EN 1996-1

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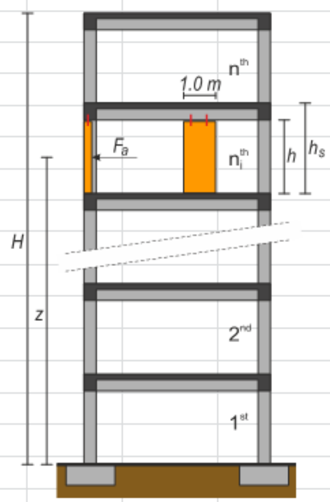
Use this table "as is" - without warranty. Use it at your own risk.

This is an approximate calculation with the following assumptions:

- infill wall is fixed at the bottom (mortar) and at the top (by PU or by two stell 2 dowels/m+mortar)
- plane of failure is parallel to the bed joints
- calculation is carried out on a wall L=1 m long
- specific weight of masonry: γ = 7.5 kN/m3
- additional permanent load on infill wall (blaster, insulation, other permanent load): W_{add} = 0.10 kN/m2
- characteristic compressive strength of masonry: f_k = 6.35 MPa [experimental testing, ZAG Ljubljana/Slovenia, št. P 0550/08-650-3]
- modulus of elasticity: E = 7.48 GPa [experimental testing, ZAG Ljubljana/Slovenia, št. P 0550/08-650-3]
- importance factor of the element: γ_a = 1.0 [EC8; 4.3.5.3 (2)]
- behaviour factor of the element: q=2.0 [EC8; Table 4.4.]
- flexural strength of masonry with the plane of failure parallel to the bed joints: f_{xk1} = 0.15 MPa [EC6; 3.6.3]

Note: Fullfill only yellow cells

Input data:					
thickness of infill wall	*t =*	*0.25*	*m*		
number of storeys of RC building	*n =*	*8*	*storeys*		
storey on which the infill wall is located	n_i =	*7*			
height of infill wall (clear storey height)	*h =*	*2.7*	*m*		
storey height	h_s =	*2.9*	*m*		
the ratio of the design ground acceleration on type A ground	α =	*0.22*	*g*		
ground type [EC8; Table 3.1]		A			
partial factor for material [HRN EN 1996-1-1:2011/NA]	γ_M =	2			
Results:					
the weight of the infill wall (L=1.0 m)	W_a =	5.3	kN		
fundamental vibration period of the infill wall in the relevant direction	T_a =	0.0209	s		
fundamental vibration period of the building in the relevant direction [EC8; Eq. 4.6]	T_1 =	0.53	s		
soil factor	S =	1.00			
seismic coefficient applicable to non-structural elements	S_a =	0.51			
horizontal seismic force, acting at the centre of mass of the non-structural element	F_a =	1.36	kN		
design bending moment due to horizontal seismic force F_a: $M_{Ed,fxk1}=F_a*h/8$	$M_{Ed,fxk1}$ =	0.46	kNm/m		
design load-bearing moment with the plane of failure parallel to the bed joints	$M_{Rd,fxk1}$ =	**0.78**	**kNm/m**	>	$M_{Ed,fxk1}$



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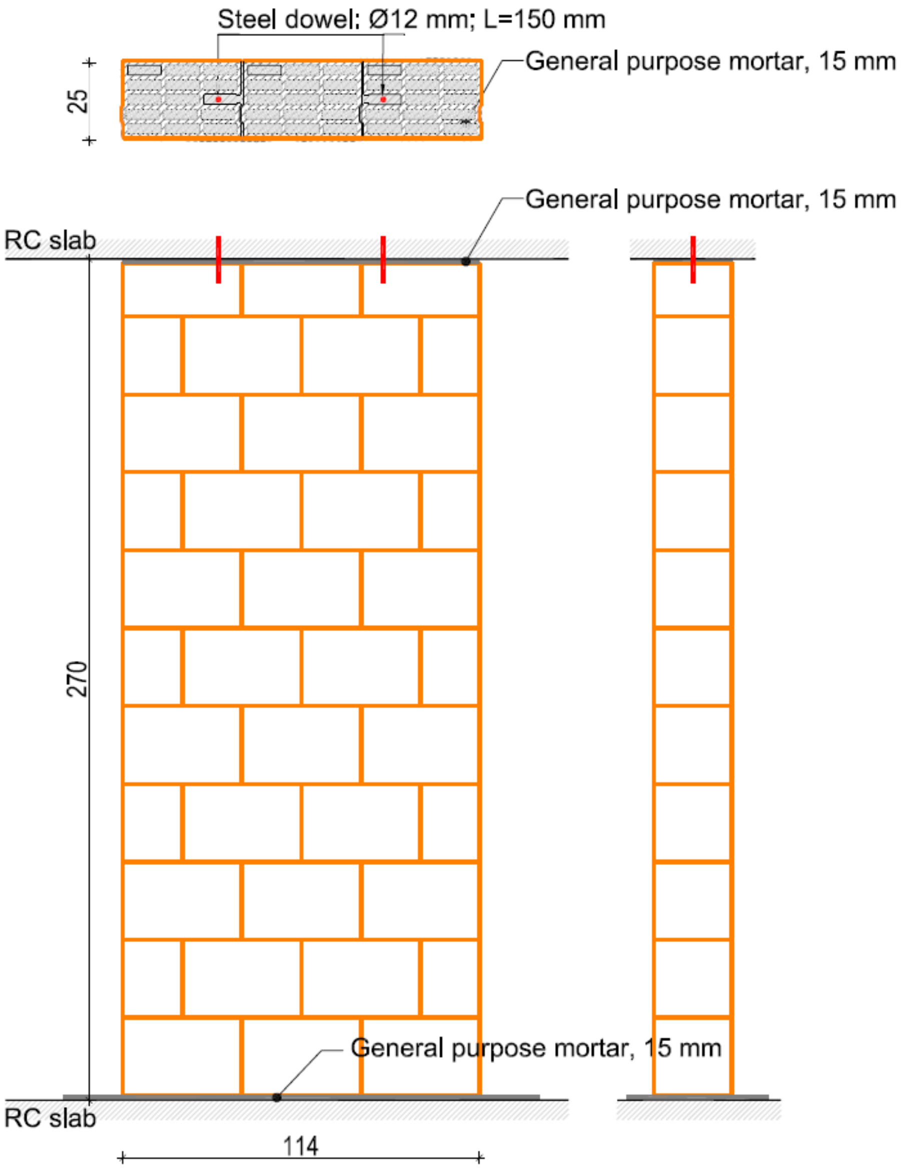

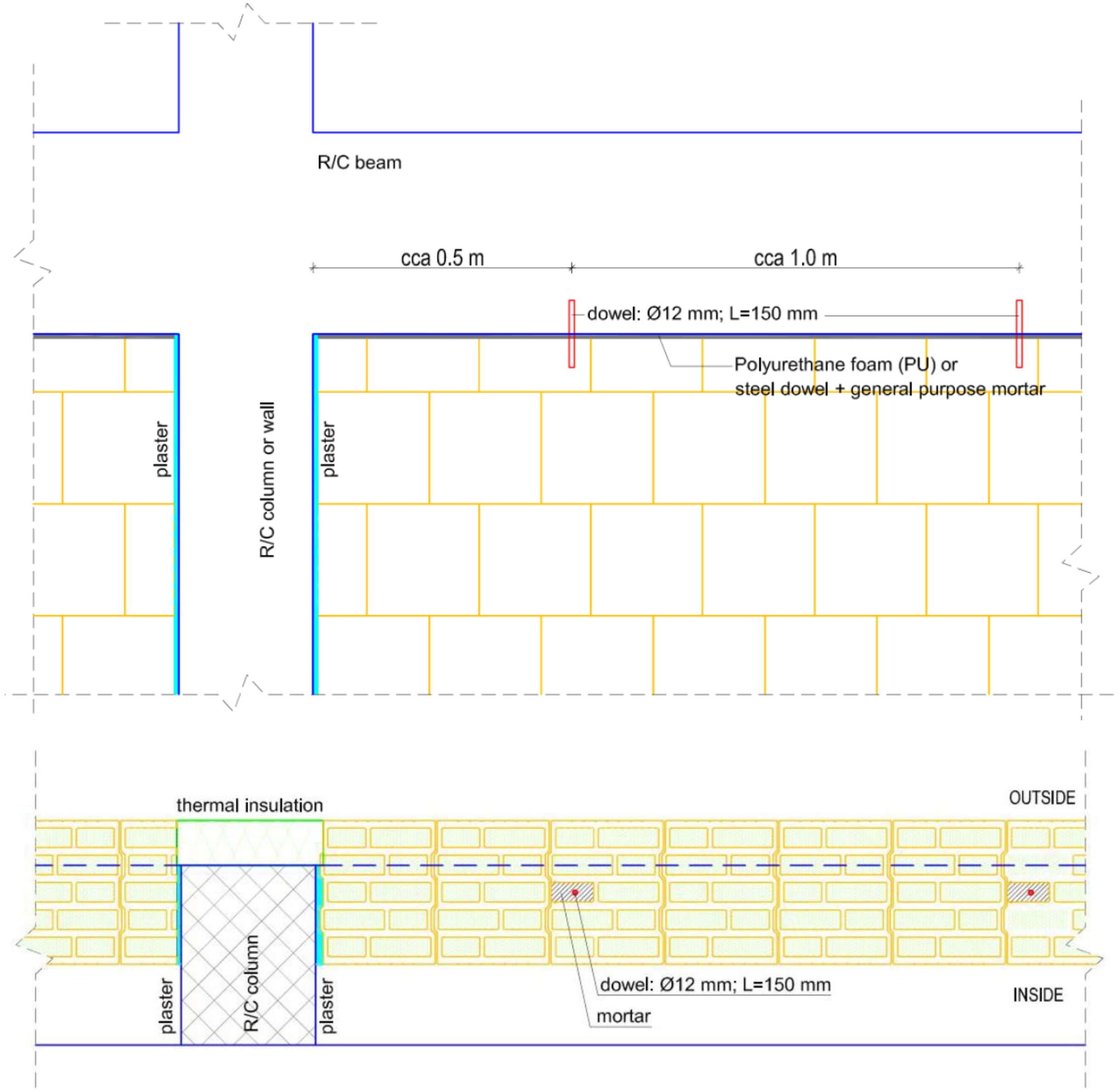

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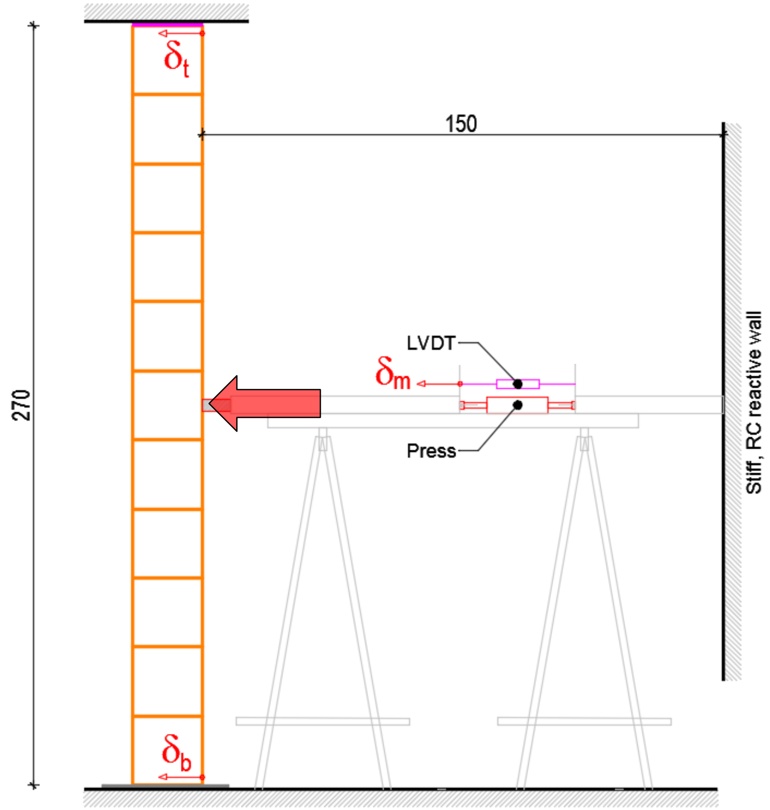

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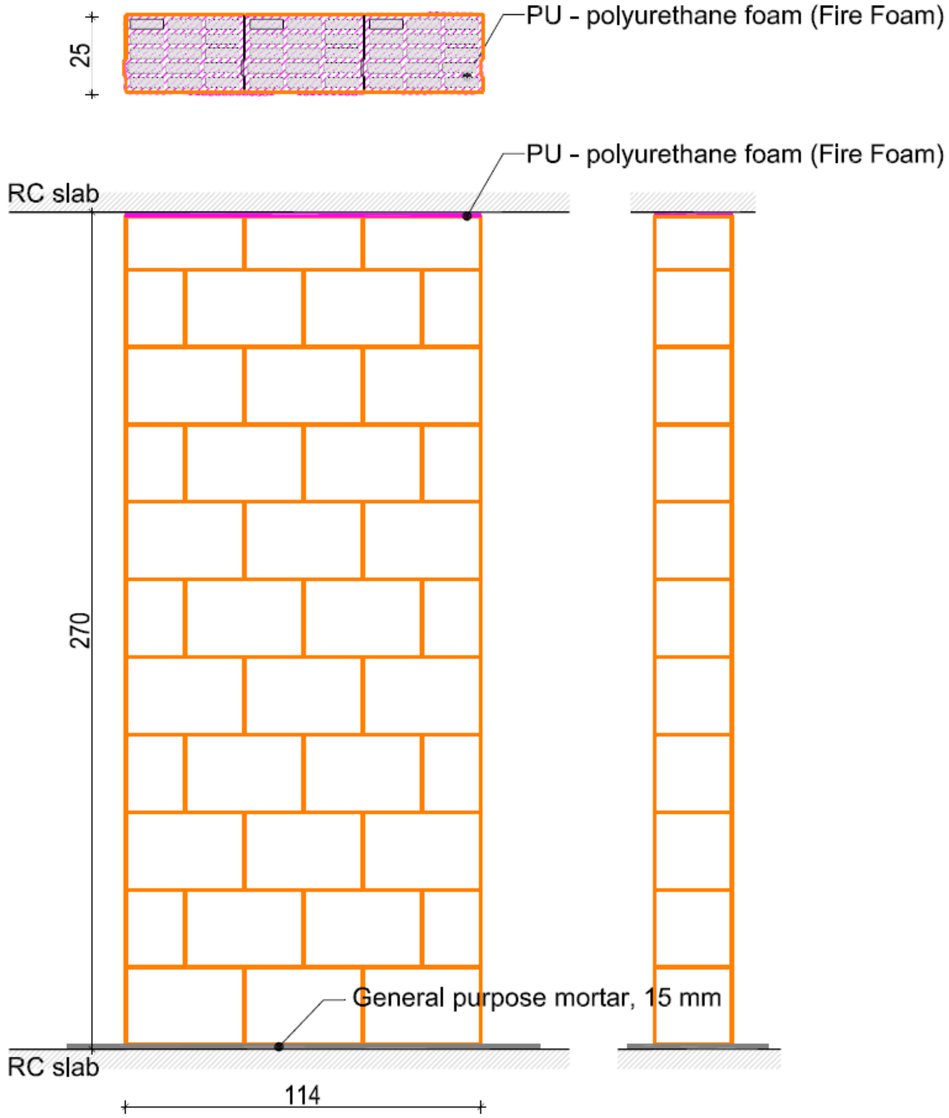

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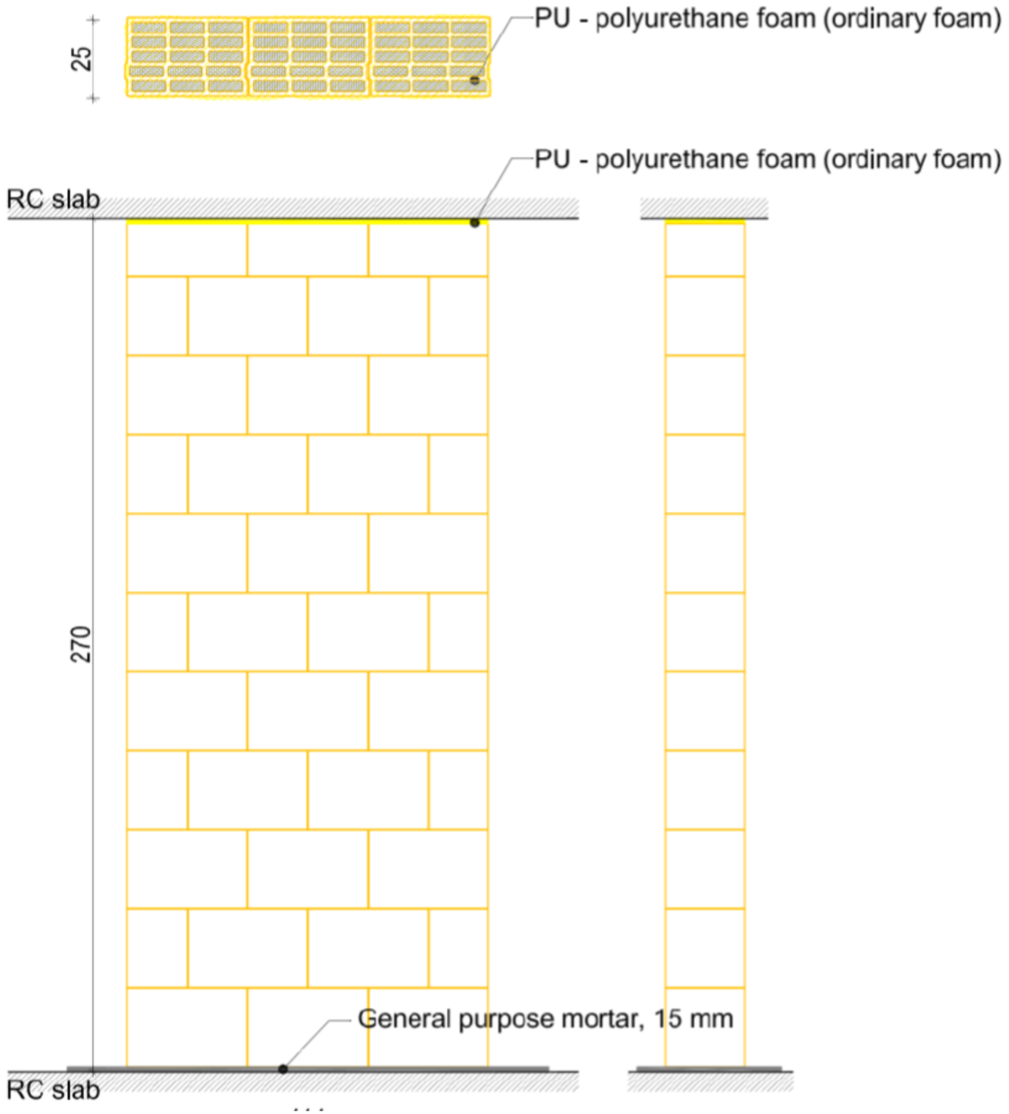
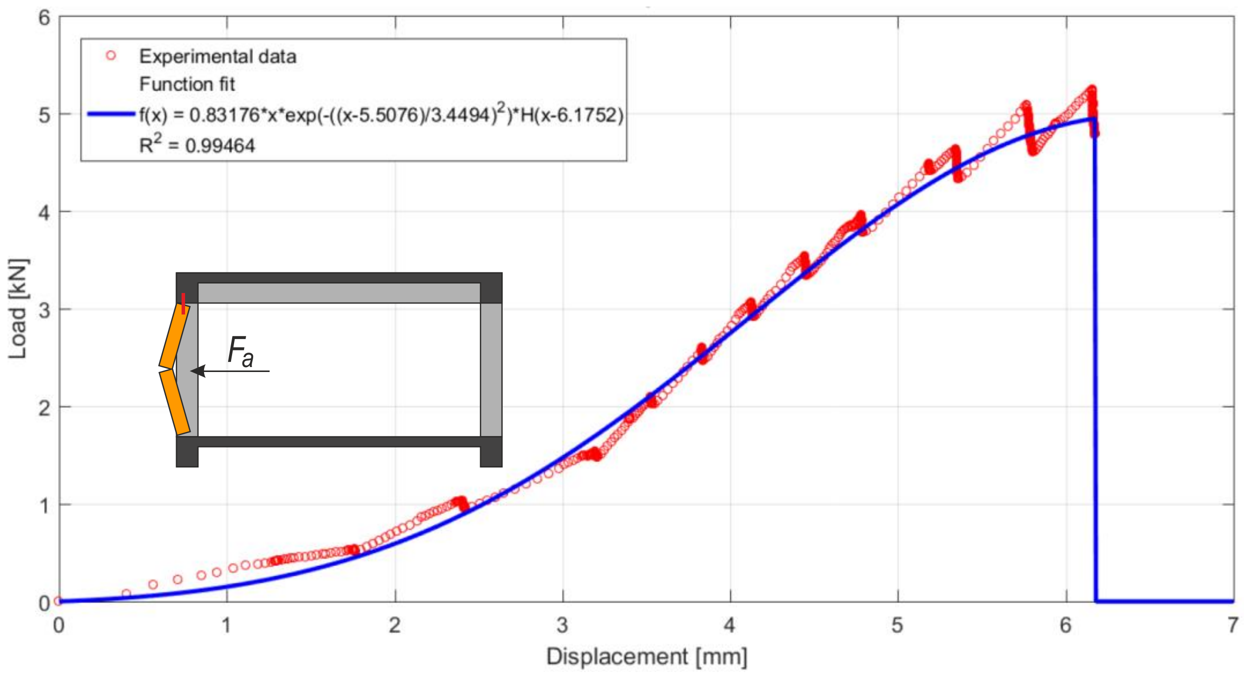
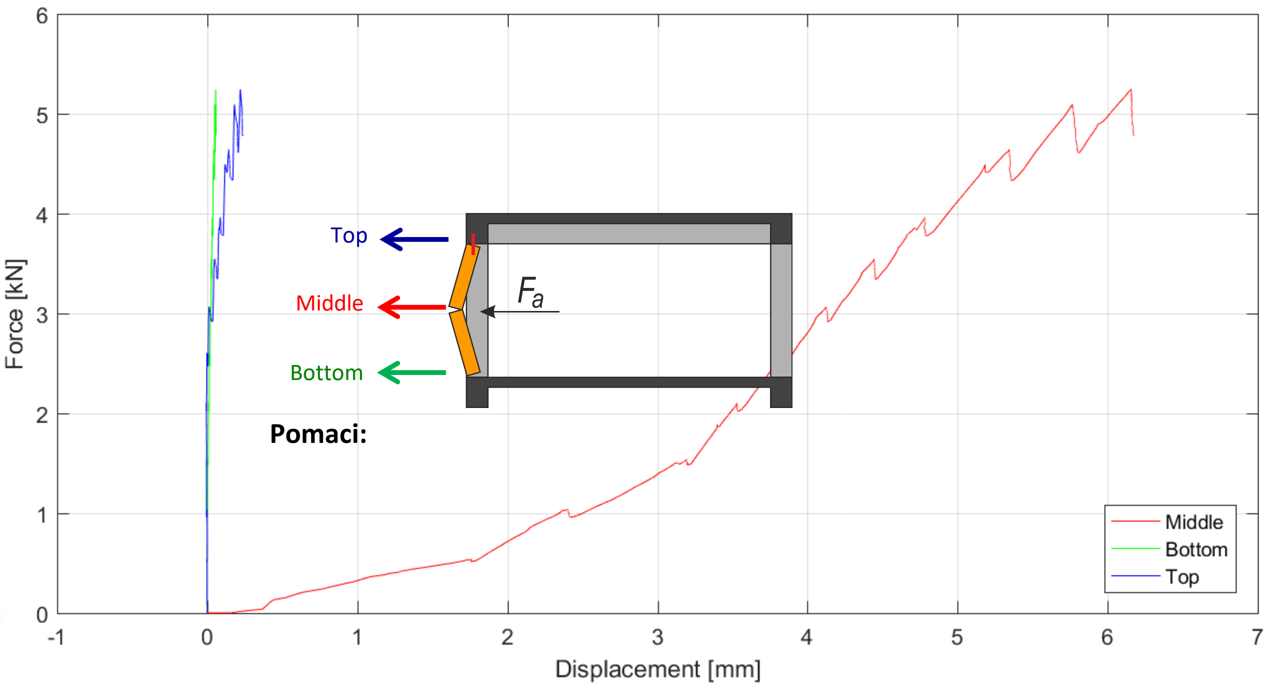


Ispunsko ziđe POROHERM IZO PROFI – Mehanička svojstva

Ispunsko ziđe POROHERM IZO PROFI – Mehanička svojstva





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Viewing results for type SD

Intensity of force in midspan [kN]	Horizontal deflection in midspan [mm]	Horizontal deflection at the bottom [mm]	Horizontal deflection at the top [mm]
$F_{SD/1} = 4.6$	$\delta_m = 3.5$	$\delta_b = 0.0$	$\delta_t = 0.2$
$F_{SD/2} = 5.2$	$\delta_m = 2.7$	$\delta_b = 0.0$	$\delta_t = 0.0$
$F_{SD/3} = 5.2$	$\delta_m = 4.8$	$\delta_b = 0.0$	$\delta_t = 0.9$
$F_{SD,mean} = 5.0$	$\delta_{m,mean} = 3.7$	$\delta_{b,mean} = 0.0$	$\delta_{t,mean} = 0.4$

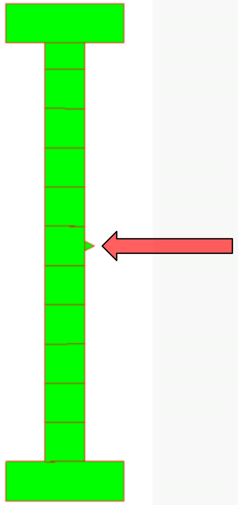
Viewing results for type PU

Intensity of force in midspan [kN]	Horizontal deflection in midspan [mm]	Horizontal deflection at the bottom [mm]	Horizontal deflection at the top [mm]
$F_{PU/1} = 5.1$	$\delta_m = 6.1$	$\delta_b = 0.05$	$\delta_t = 0.2$
$F_{PU/2} = 5.0$	$\delta_m = 4.8$	$\delta_b = 0.02$	$\delta_t = 0.2$
$F_{PU/3} = 4.7$	$\delta_m = 4.8$	$\delta_b = 0.03$	$\delta_t = 0.2$
$F_{PU,mean} = 4.9$	$\delta_{m,mean} = 5.2$	$\delta_{b,mean} = 0.03$	$\delta_{t,mean} = 0.2$

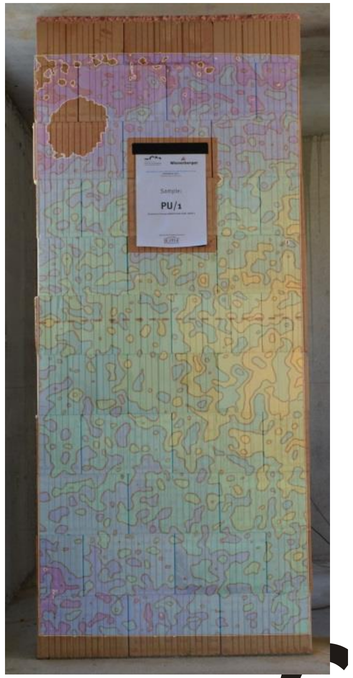
Viewing results for type PU-o

Intensity of force in midspan [kN]	Horizontal deflection in midspan [mm]	Horizontal deflection at the bottom [mm]	Horizontal deflection at the top [mm]
$F_{PU-o/1} = 4.25$	$\delta_m = 3.8$	$\delta_b = 0.10$	$\delta_t = 0.8$
$F_{PU-o/2} = 2.9$	$\delta_m = 2.4$	$\delta_b = 0.02$	$\delta_t = 0.2$
$F_{PU-o,mean} = 3.6$	$\delta_{m,mean} = 3.1$	$\delta_{b,mean} = 0.06$	$\delta_{t,mean} = 0.5$

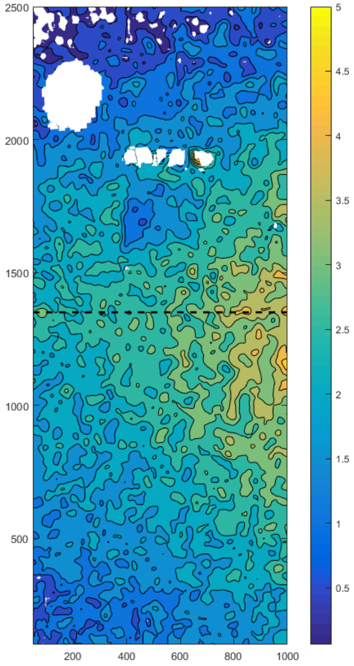
Ispunsko ziđe POROHERM IZO PROFI – Mehanička svojstva

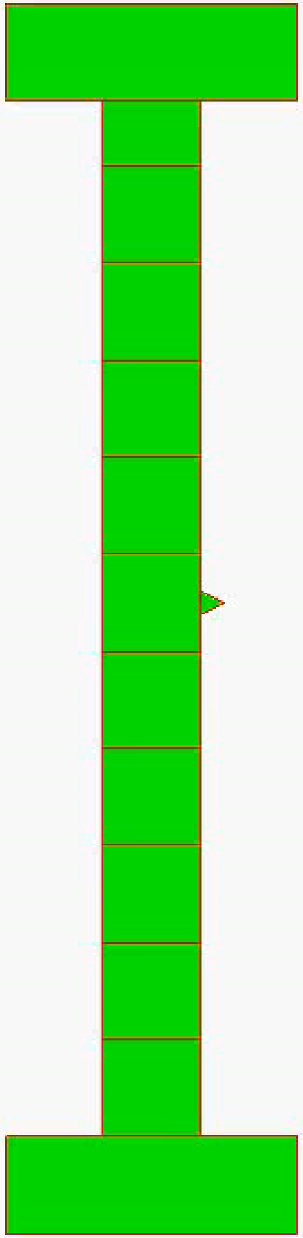


Displacement field overlay on the photo of wall

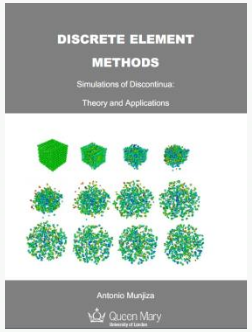


Calculated displacement field



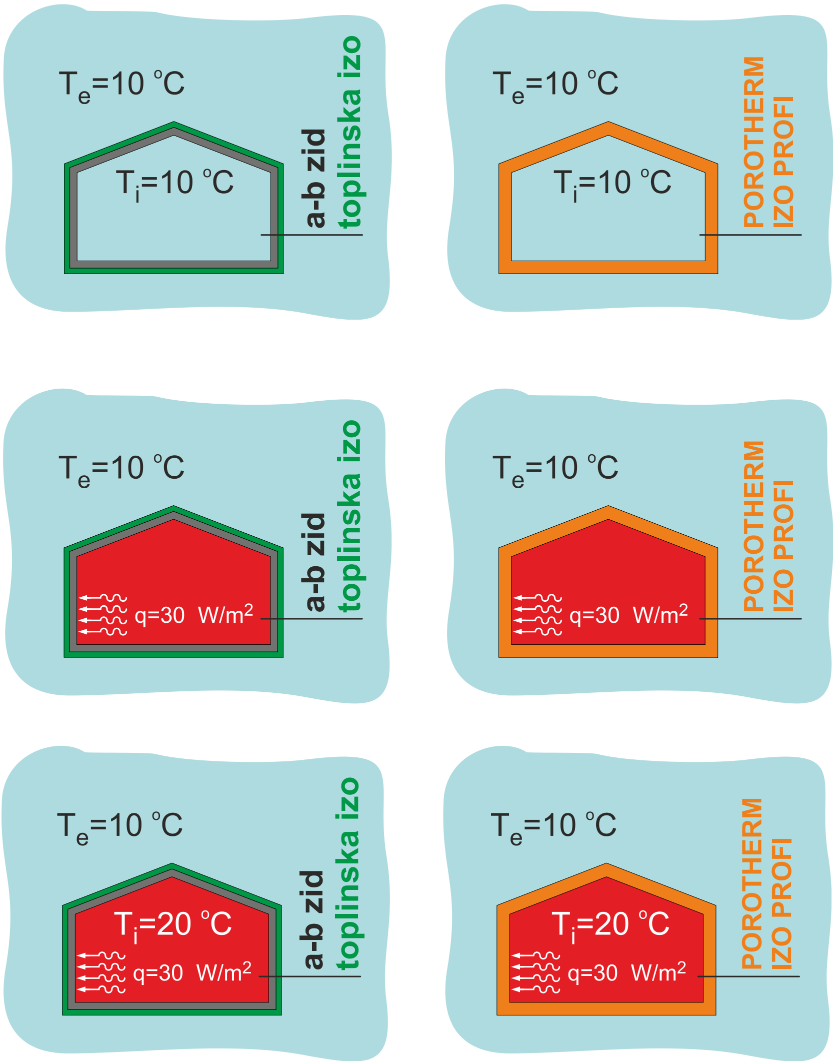


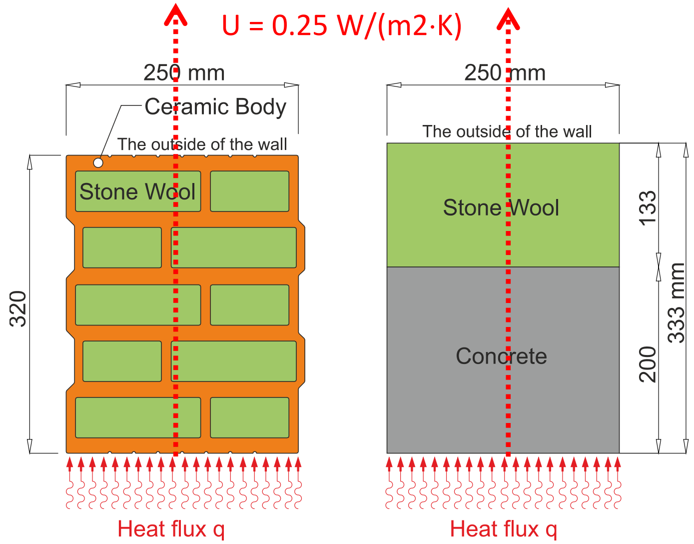
Prof.
Antonio Munjiza



B/
Nestacionarni toplinski tok

B/ Nestacionarni toplinski tok





POROTHERM IZO PROFI 32 wall:

Ceramic body:

Thermal conductivities in the direction of X, Y KXX=KYY= 0.18 W/(m·K)

Densityr = 1450 kg/m3; Specific heat c = 900 J/(kg·K)

Thermal isolation (stone wool):

Thermal conductivities in the direction of X, Y KXX=KYY=0.034 W/(m·K)

Density r = 50 kg/m3; Specific heat c = 1030 J/(kg·K)

Convective heat transfer coefficient: **U = 0.25 W/(m2·K)**

R/C wall with thermal insulation (+ stone wool outside):

Concrete:

Thickness of concrete wall: t = 0.20 m

Thermal conductivities in the direction of X, Y: KXX=KYY= 2.6 W/(m·K)

Density ρ = 2400 kg/m3; Specific heat c = 1000 J/(kg·K)

Thermal isolation (mineral wool) - ETICS:

Thickness of mineral wool: t = 0.133 m*

(*thickness chosen to obtain equal value of U for both walls)

Thermal conductivities in the direction of X, Y KXX=KYY=0.034 W/(m·K)

Density ρ = 50 kg/m3; Specific heat c = 1030 J/(kg·K)

Convective heat transfer coefficient (R/C wall with thermal insulation):

$U = 1/(\Sigma t_i/KXX_i) = 1/(0.20/2.6+0.133/0.034)$ **U = 0.25 W/(m2·K)**

Transientna analiza provođenja topline – ravninski problem:

3. Governing equation

The material obeys Fourier's law of heat conduction:

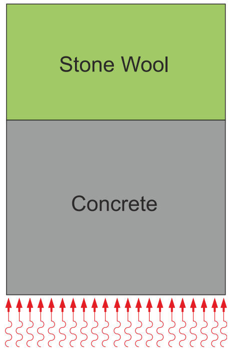
$$q = -K\frac{\partial T}{\partial x}$$

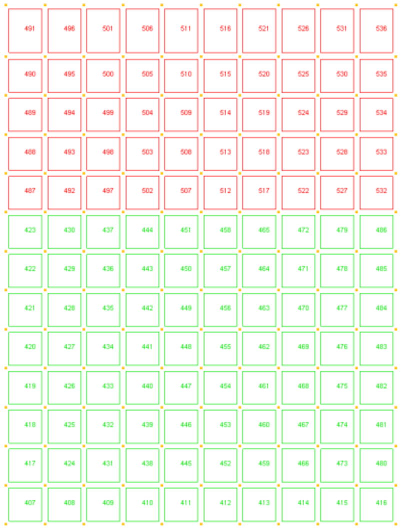
where:

q ...... the rate of heat flow conducted per unit area

K ..... the thermal conductivity tensor for the material

$\frac{\partial T}{\partial x}$ ..... the temperature gradient vector in Cartesian coordinates.





The general equation for heat conduction in solids is

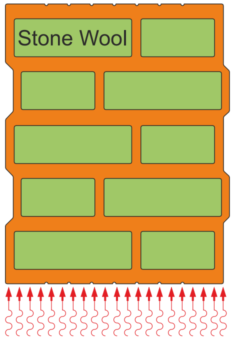
$$\left[\frac{\partial}{\partial x}\left(k_x\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial x}\left(k_y\frac{\partial T}{\partial y}\right)\right]+q=\rho c\frac{\partial T}{\partial t}$$

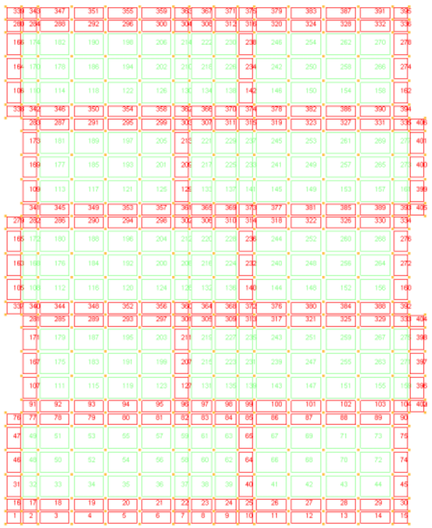
where:

ρ ...... the mass density of the material

c ...... the specific heat

t ...... the time

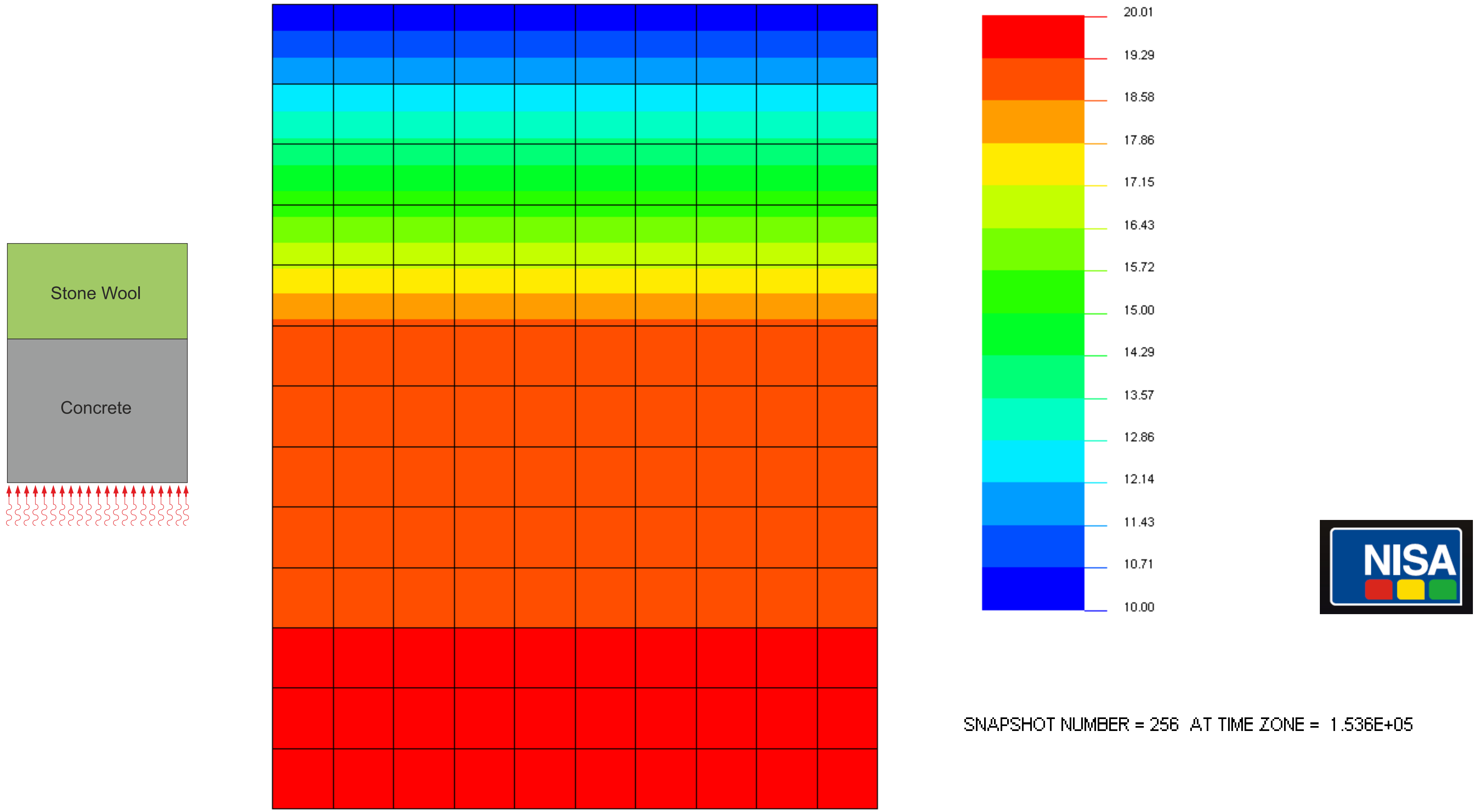




and may be generally subjected to one or more of the following boundary conditions.

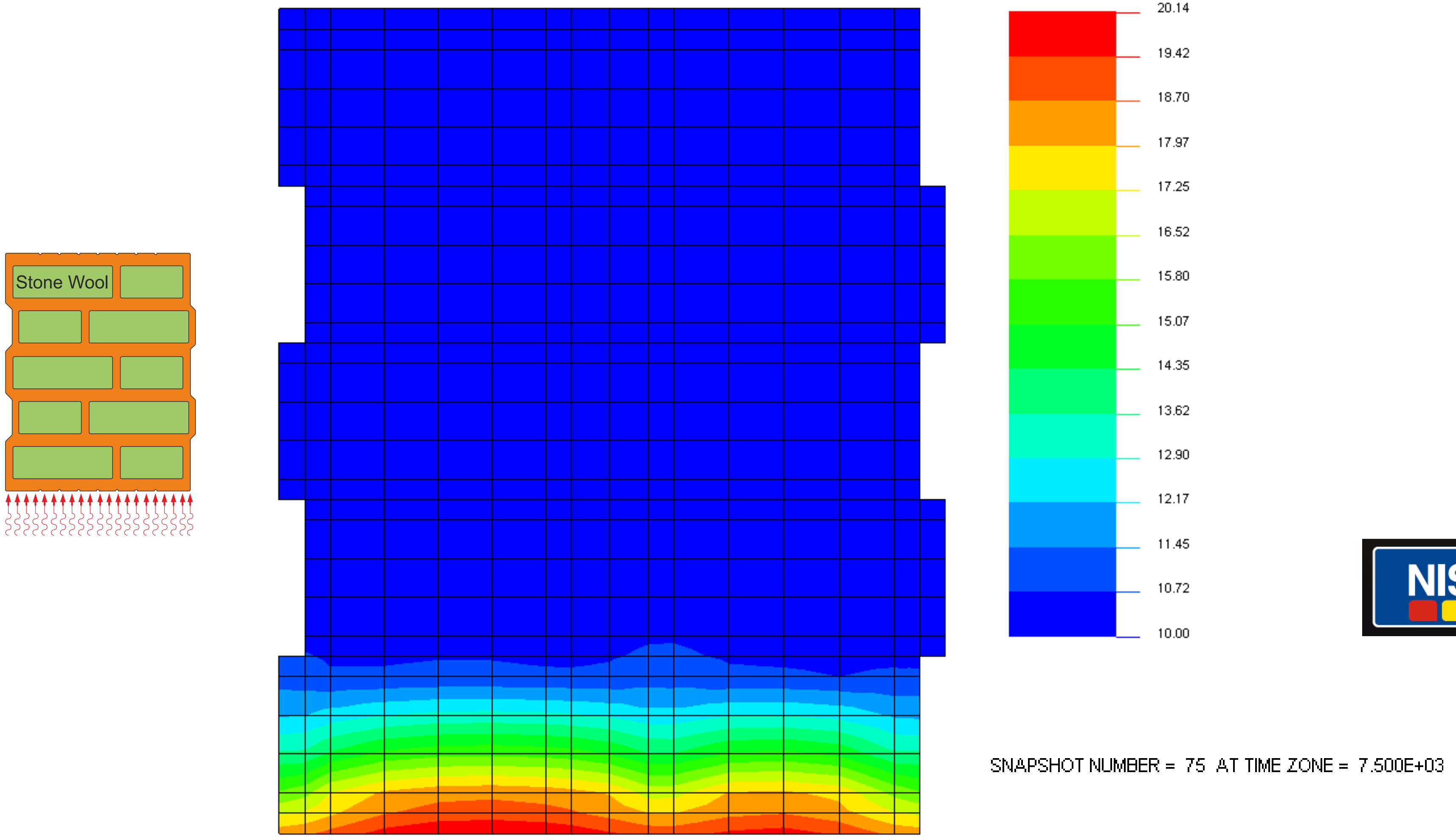
Equation is solved by Finite Element Method (2D problem).

B/ Nestacionarni toplinski tok



Temperature field after t = 153600 sec = 2560 min = 42 hours 40 min

B/ Nestacionarni toplinski tok



Temperature field after t = 7500 sec = 125 min = 2 hours 5 min

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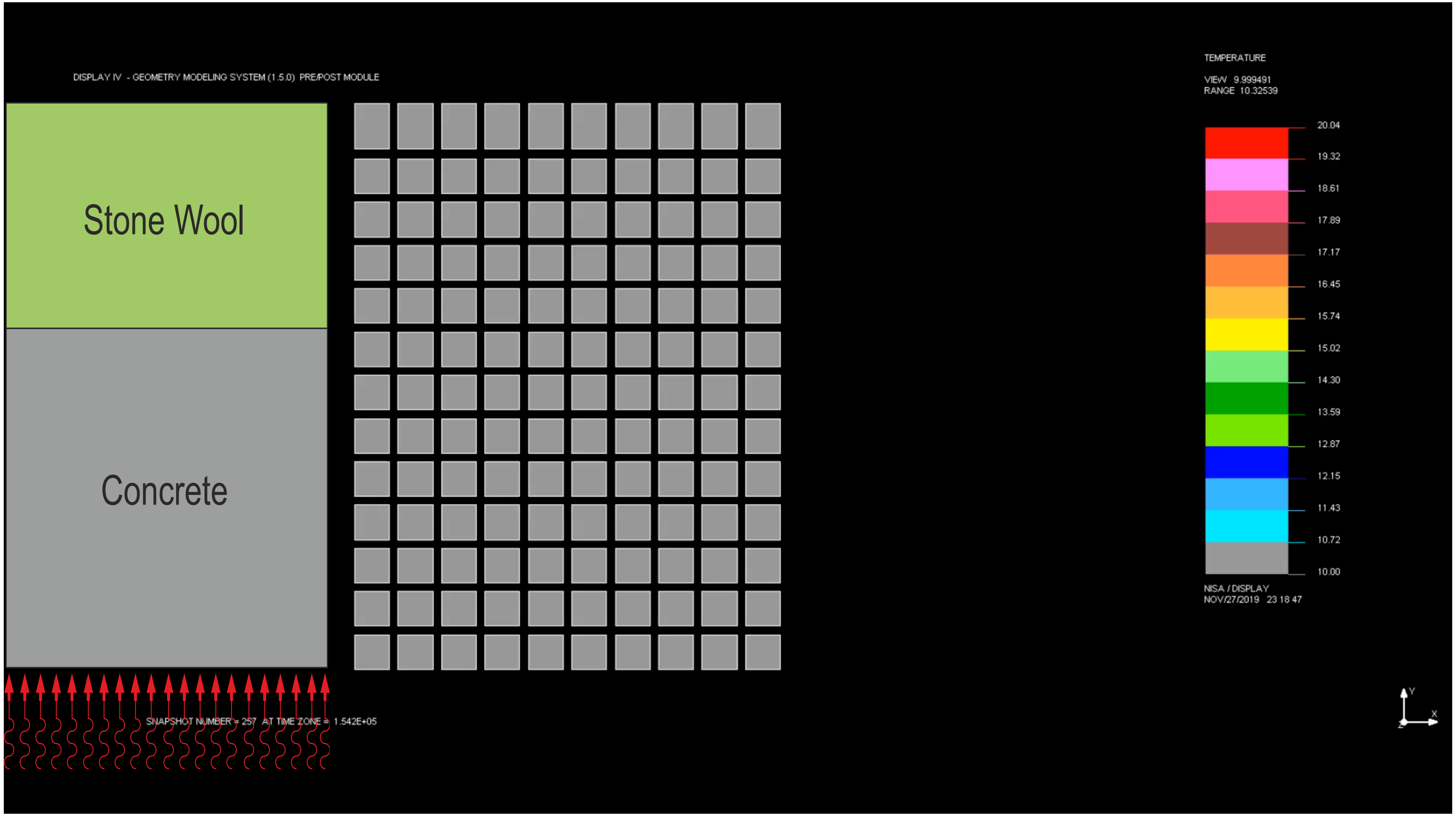

video

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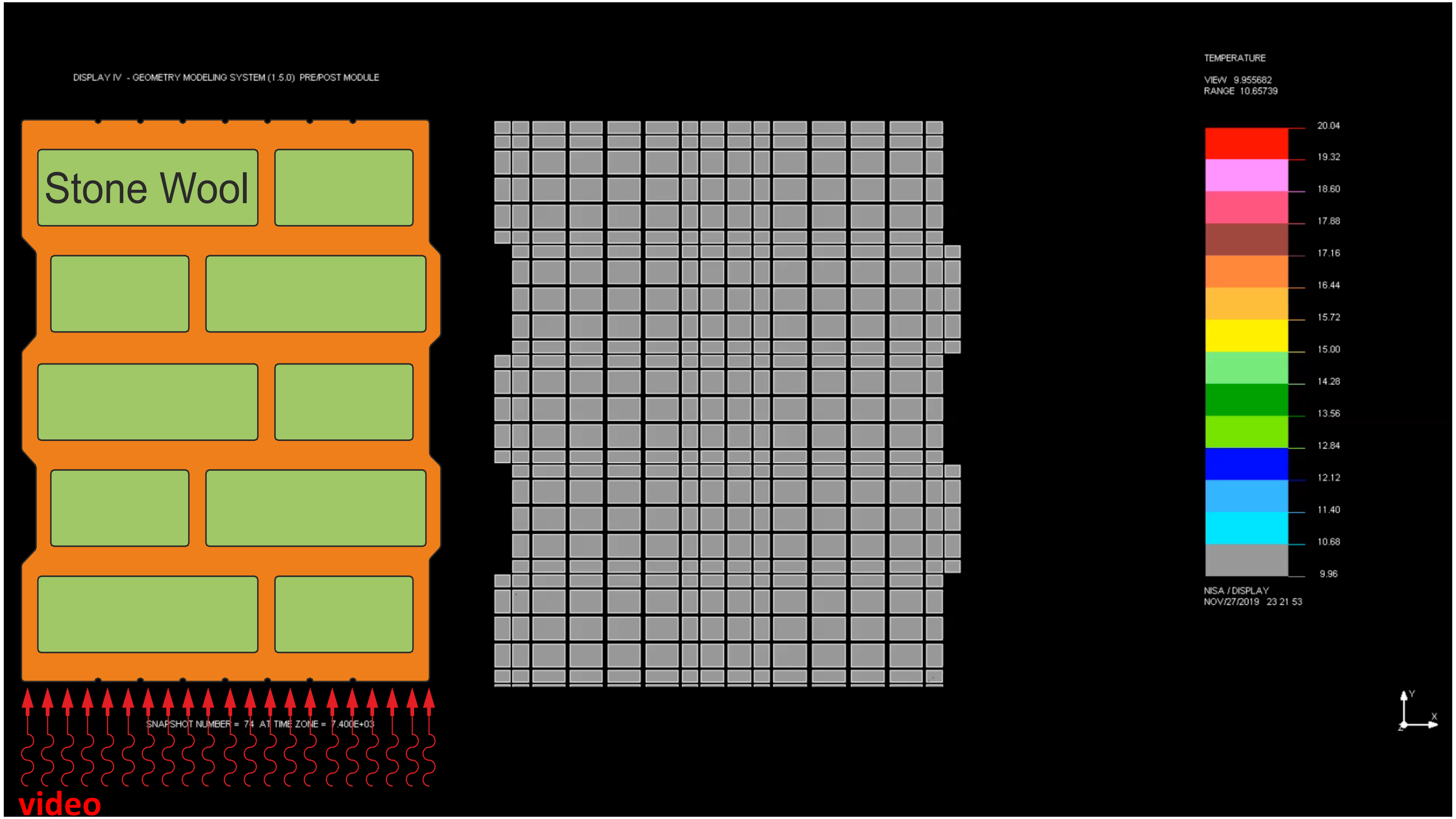
Ispunsko ziđe: Toplinska svojstva



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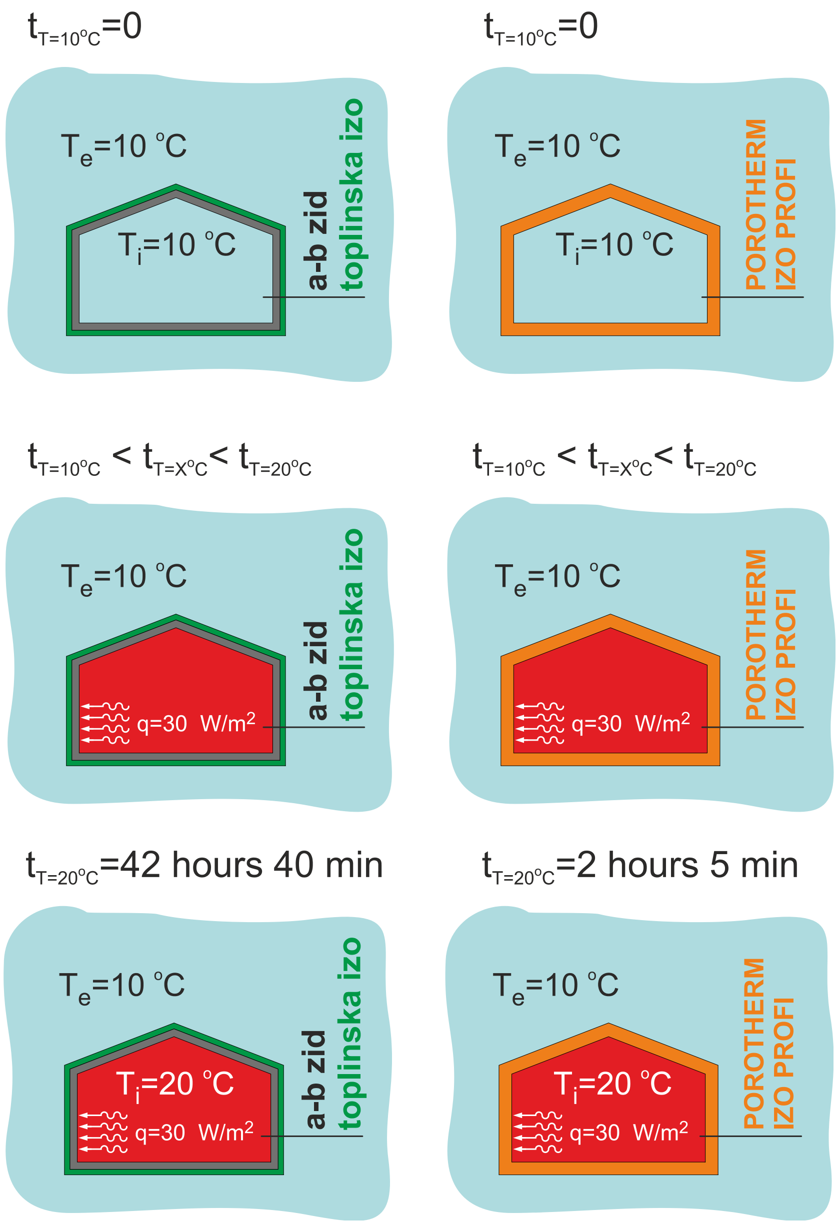
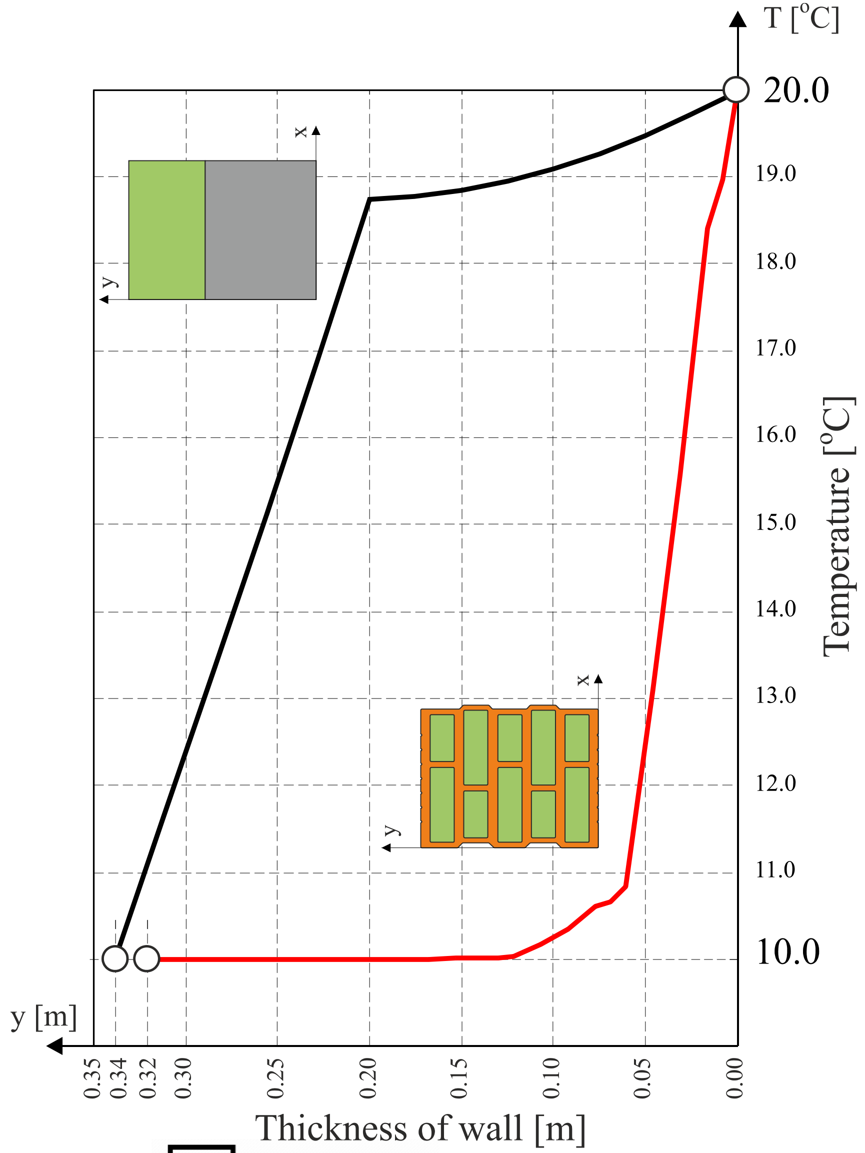
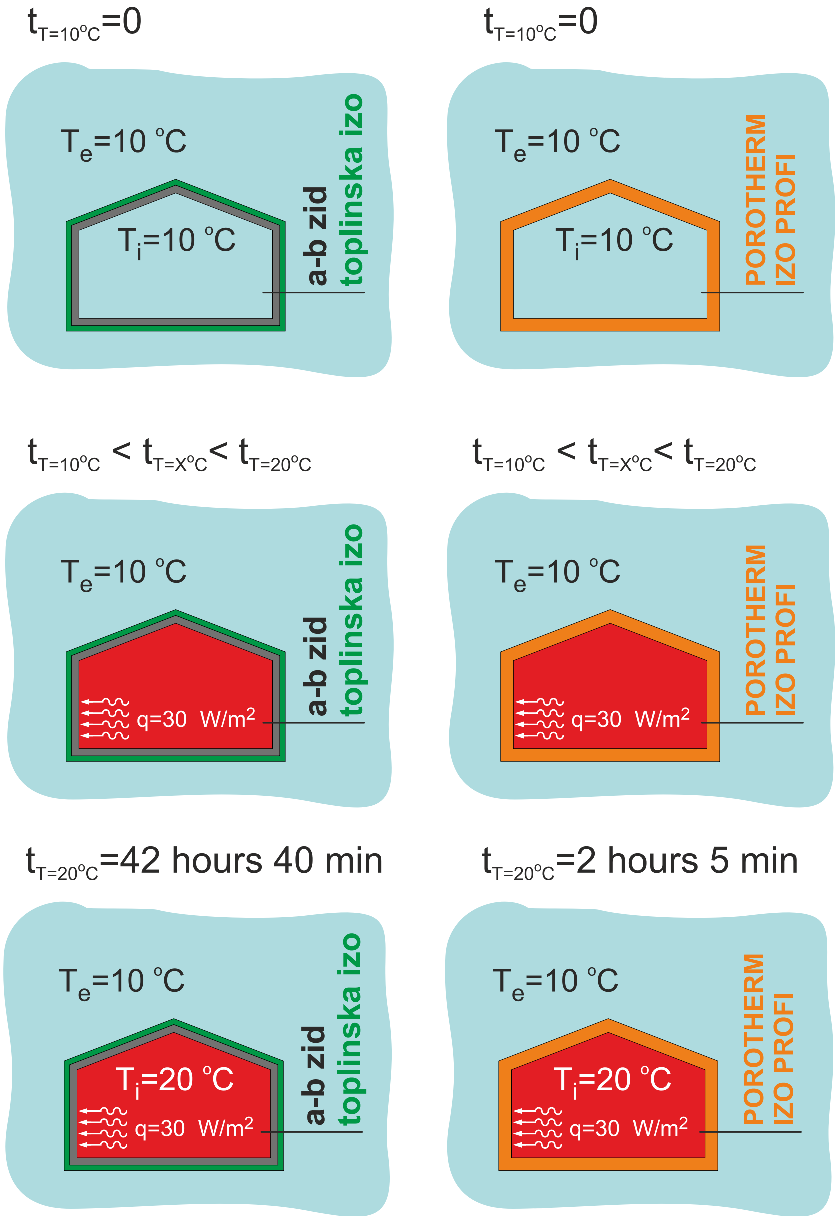
B/ Nestacionarni toplinski tok





B/ Nestacionarni toplinski tok



Ciljanu temperaturu na unutarnjoj strani zida od T_i = 20.0 ^{O}C konstrukcija postiže za:

- **2 sata 5 min - POROTHERM IZO PROFI 32 zid**
- **42 sata 40 min – a/b zid s toplinskom izolacijom izvana (kamena vuna)**

U zgradi od POROTHERM IZO PROFI 32 blokova potrebno je 40 sati i 35 minuta manje (uz toplinski tok q=30 W/m2), za postizanje temperature na unutarnjoj strani zida T_i = 20.0 ^{O}C te je ušteda energije:

Q_{save} = 40.6 sati * 30 W/m2 = 1.217 kWh/m2

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Zahvaljujemo:

ĆITIĆ GRADNJA d.o.o. SPLIT

MAPEI

Sika

ERING,
DESY

Wienerberger

Hrvatsk

Ispunsko ziđe POROHERM IZO PROFI – mehanička i toplinska svojstva

HVALA NA PAŽNJI

Literatura:
[1] Development of infill masonry solution for Adriatic region, University of Split - Faculty of Civil engineering, Architecture and Geodesy, REPORT, 2019.
[2] Tomažević, Miha: EARTHQUAKE-RESISTANT DESIGN OF MASONRY BUILDINGS, Imperial College Press, London, 1999.
[3] NISA/HEAT, User manual, Cranes Software, Inc., USA

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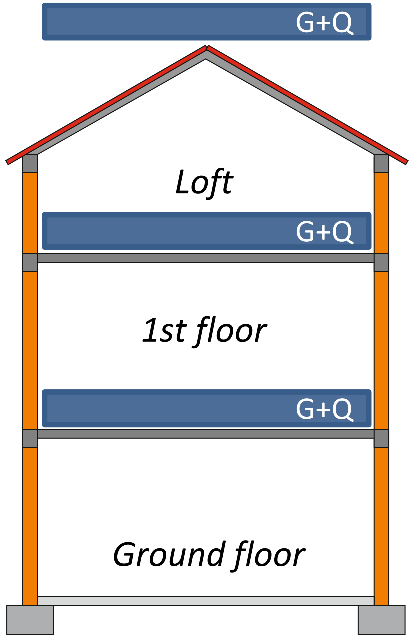
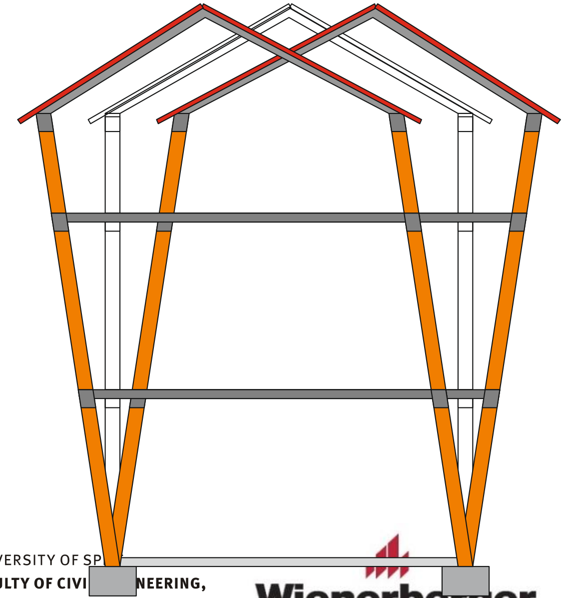
Porotherm Profi System / Masonary - Family house (up to 3 storeys)

Dominant loads

Gravity loads

Seismic (earthquake) load





Specific GRAVITY load [G+Q]:

- up to 10 kN/m2 per storey
- total: up to 30 kN/m2

Seismic (earthquake) load

- According to EUROCODE 8 (Rules for “simple masonry buildings”
- Minimum strength of masonry units: 5 MPa

Porotherm Profi System / Masonary - Family house (up to 3 storeys)

Rules for "simple masonry buildings" - EC8

EUROCODES BUILDING THE FUTURE

Earthquake force VS Wall area ($p_{A,min.}$) VS Number of floors allowed

Tablica 9.3(HR) – Dopušteni broj katova n iznad temeljnog tla i najmanje ploštine poprečnih presjeka nosivih zidova $p_{A,min}$ u svakom smjeru izražene kao postotak bruto tlocrtne ploštine kata za „jednostavne zidane zgrade"

Broj katova n	Vrsta zida					
	nearmirano		nearmirano	omeđeno	nearmirano	omeđeno
	a_g = 0,05	a_g = 0,10	a_g = 0,20		a_g = 0,30	
$S_d(T)$	0,075	0,15	0,30	0,24	0,45	0,36
1	2,0	2,0	2,0	2,0	3,0	3,0
2	2,0	2,0	2,5	2,0	6,5	3,0
3	2,0	2,0	3,0	2,5	–	6,5
4	2,0	2,0	5,0	3,0	–	–
5	2,0	2,0	6,5	5,0	–	–

Zagreb 6.5%

Napomena 1: Prizemlje se broji kao kat. Ne broji se prostor ispod krova, a iznad punog kata.

Napomena 2: $S_d(T) = a_g\,S\ (2{,}5/q)$

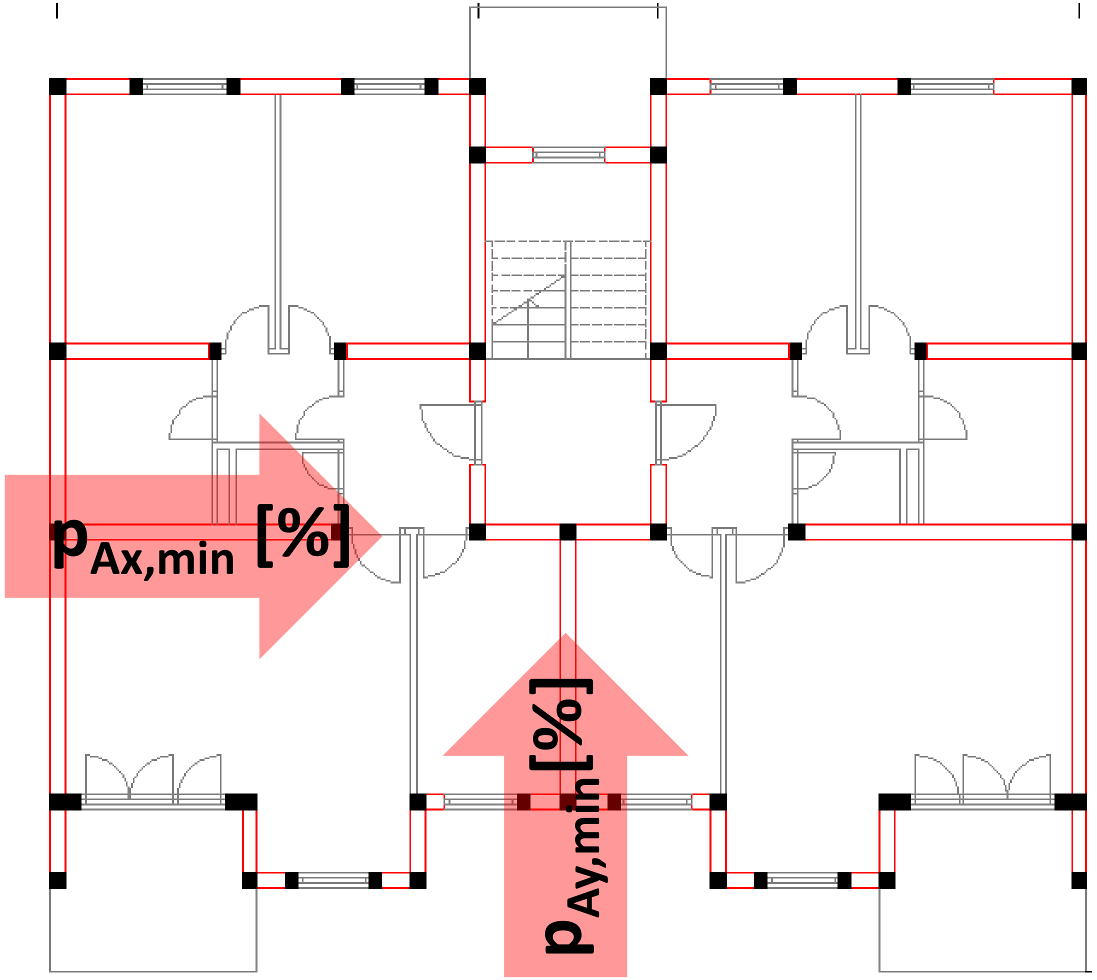
Napomena 3: Za spektar tipa 1 i tip B temeljnog tla S = 1,2.
Za nearmirano ziđe q = 2,0 pa je $S_d(T) = 1{,}5\ a_g$.
Za omeđeno ziđe q = 2,5 pa je $S_d(T) = 1{,}2\ a_g$.

Napomena 4: Faktor važnosti zgrade $\gamma_I = 1{,}0$.

Napomena 5: Parcijalni koeficijent sigurnosti za materijal $\gamma_M = 2{,}0$ za stalno i promjenjivo opterećenje, a $\gamma_M = 1{,}5$ za izvanredno (potresno) opterećenje (vidjeti točku 9.6(3) norme HRN EN 1998-1:2011 i točku 2.51 ovog dokumenta).

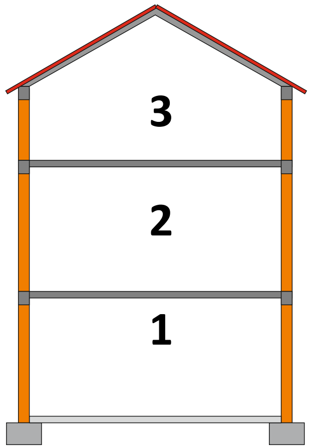
Napomena 6: Karakteristična vlačna čvrstoća ziđa određena ispitivanjem f_{tk} = 0,3 N/mm^2.
Karakteristična posmična čvrstoća ziđa f_{vk} u skladu s normom HRN EN 1996-1-1:201Y: $f_{vk} = f_{vko} + 0{,}4\sigma_d = 0{,}3 + 0{,}4\sigma_d$ za mortove M10 i TM10 i opečne zidne elemente skupine 2, tlačne čvrstoće f_b=10 N/mm^2.

Napomena 7: Omeđeno ziđe primjenjivo je i za a_g = 0,05 i a_g = 0,10.

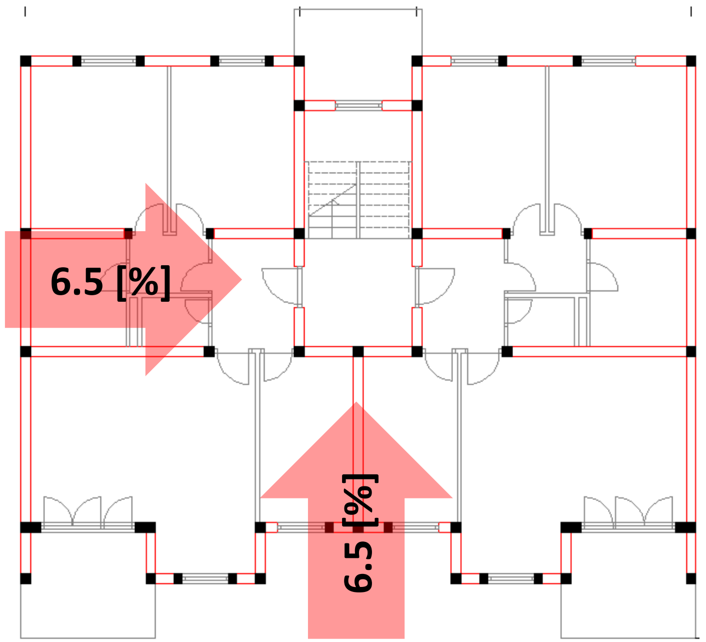


Porotherm Profi System / Masonary - Family house (up to 3 storeys)

Family house in Zagreb
3 storeys

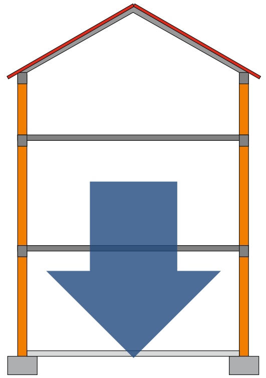


Minimum area of shear walls for
„simple masonry buildings":
$p_{A,total}$ = 2 x 6.5% = 13%



POROTHERM PROFI +
Dryfix.extra +
R/C confining elements

Total gravity load
G+Q = 30 kN/m2



Porotherm Profi System / Masonary - Family house (up to 3 storeys)

Total specific gravity load	$G+Q = 30\ kN/m^2$
Specific area of masonry wall (6.5%):	$0.065\ m^2/m$
Specific normal stress in masonry (for ideal position of the walls):	$f_{k,spec,id.} = 0.030\ [MN] / 0.065\ [m2/m] = 0.46\ MPa$
Increase of stresses due to unfavourable (accidental and nonsymmetrical) position of the walls:	2X
Specific normal stress in wall:	$f_{k,spec.} = 0.46*2 = 0.92\ MPa$
The partial factor for materials (mean value):	$\gamma_M = 2.2$
The reduction factor for slenderness and eccentricity:	$\Phi \cong 0.75$
Constant K (according to group of masonry units, Group 2):	$K = 0.70$
Minimum required compression strength of masonry:	$f_{k,req,min.} = f_{k,spec.} * \gamma_M / \Phi = 0.92*2.2/0.75 = 2.7\ MPa$
Minimum required compression strength of block:	$f_{b,req,min.} = (f_{k,spec.} / K)^{(1/0.85)} = (2.7 / 0.70)^{(1/0.85)} = 4.9\ MPa$

Minimum required compression strength of block:

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