Potresna odpornost zidanih stavb z opeko nove generacije – strokovno izobraževanje za arhitekte in projektante

Zidovje kot polnilo POROTHERM IZO PROFI – mehanske in toplotne lastnosti

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

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Wienerberger

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webinar, 23/06/2020.

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IZS INŽENIRSKA ZBORNICA SLOVENIJE

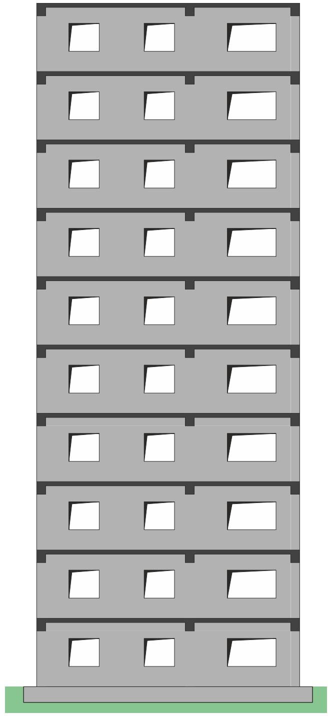
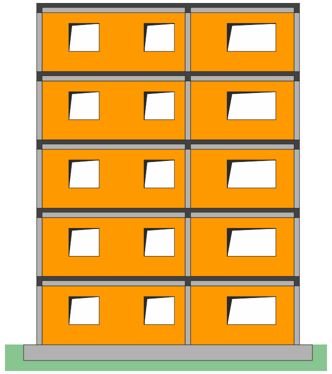
Zidovje kot polnilo POROTHERM IZO Profi

A/
Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

B/
Nestacionarni toplotni tok

A/
Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

	A/B zgradba	Zgradba iz povezanega zidovja	A-b zgradba z zidovjem kot polnilo
			
Število nadstropij:	+	+/-	
Toplotne lastnosti:	-	+	

Potres

- 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

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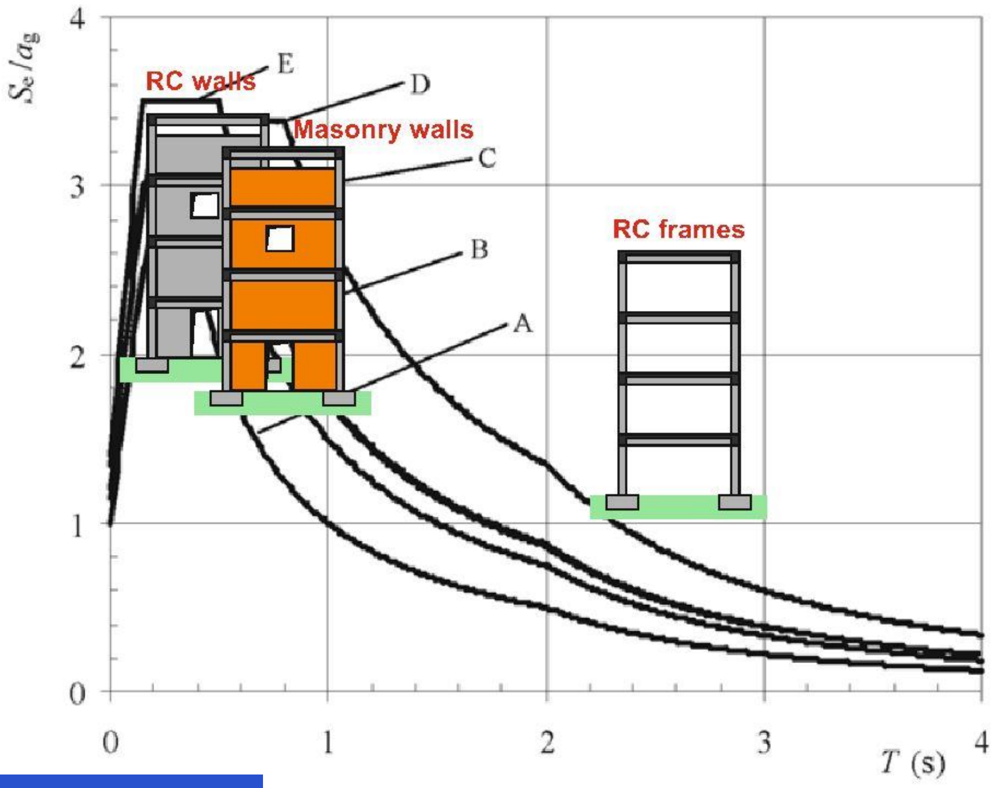
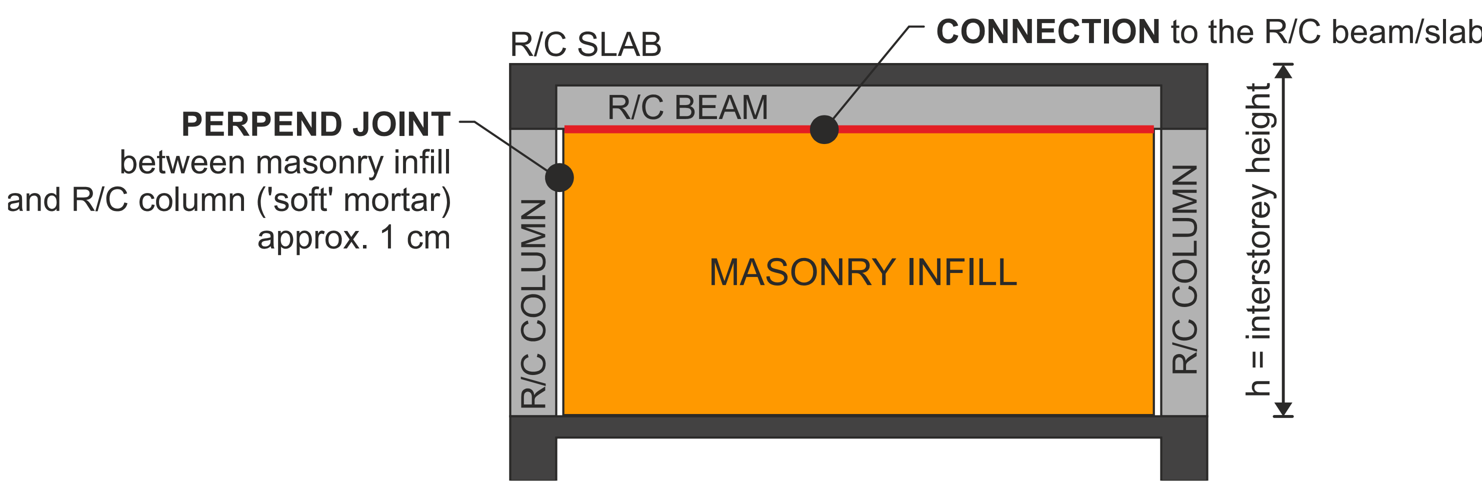
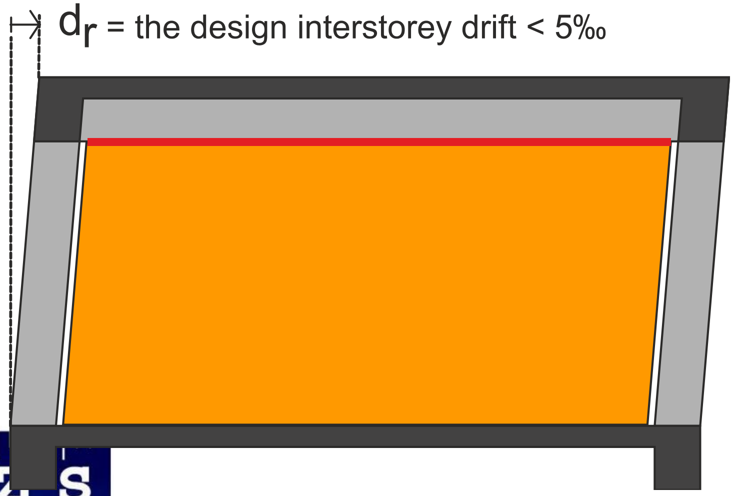
A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu





Z omejitvijo mednadstropnega pomika 5 **‰** [skladno z EN 1998-1:2004, 4.4.3.2 (1)]:

- zidovje kot polnilo nima znatnega doprinosa v skupni togosti na horizontalna delovanja
- poškodbe stavb zaradi delovanja potresa so minimalne, ker zidovje lahko prenese takšne mednadstropne pomike brez znatnih poškodb



EUROCODES BUILDING THE FUTURE

EN 1998-1:2004

4 IZRAČUN STAVB

4.3 Izračun konstrukcije

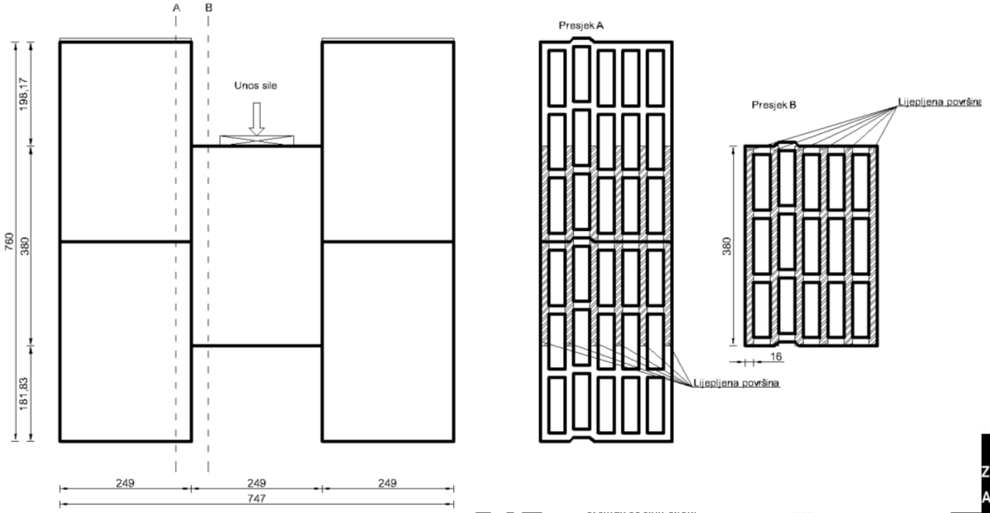
4.3.6 Dodatni ukrepi za okvirje s polnilnim zidovjem

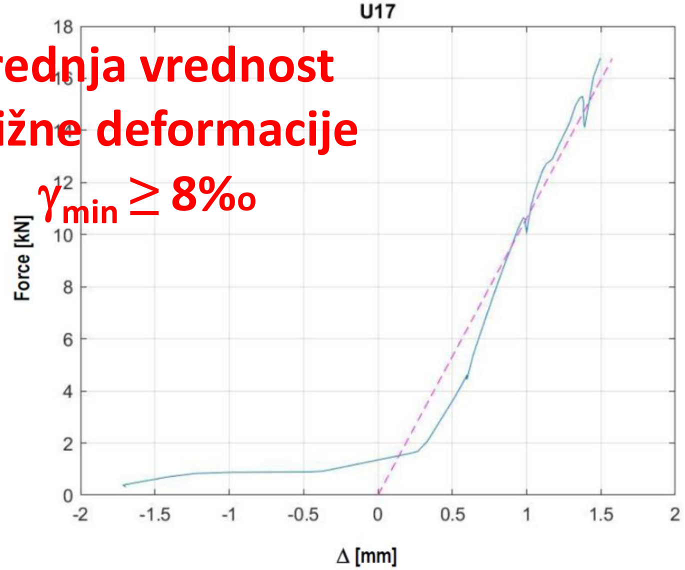
4.3.6.1 Splošno

(4) »Pri stenastih (betonskih) ali mešanih konstrukcijskih sistemih, ekvivalentnih stenastim, kakor tudi pri jeklenih ali sovprežnih jekleno-betonskih (okvirnih) sistemih s povezji, ***lahko sodelovanje zidanih polnil zanemarimo.****«*

A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

Določanje strižne trdnosti na spoju med zidaki, lepljenimi z lepilom Dryfix.Extra (poliuretansko lepilo)





Srednja vrednost strižne deformacije

$\gamma_{min} \geq 8‰$

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A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

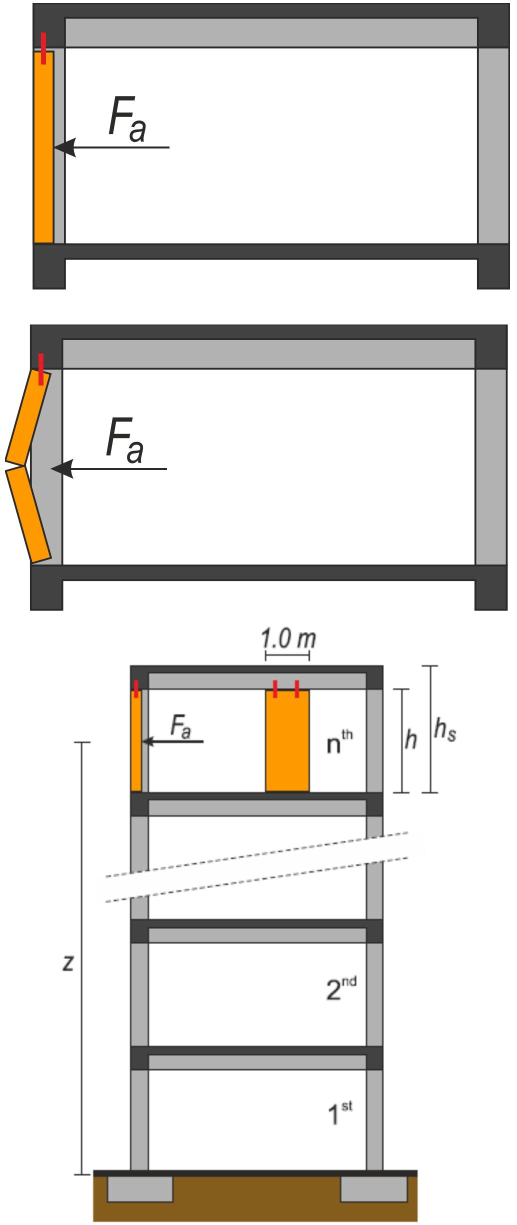

Fig 2.4 Masonry infill wall – non-structural elements

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:

$S_a = \alpha * S * [3 * (1 + z/H) / (1 + (1 – T_a/T_1)^2)-0.5]$ [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 $q_a = 2.0$

A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

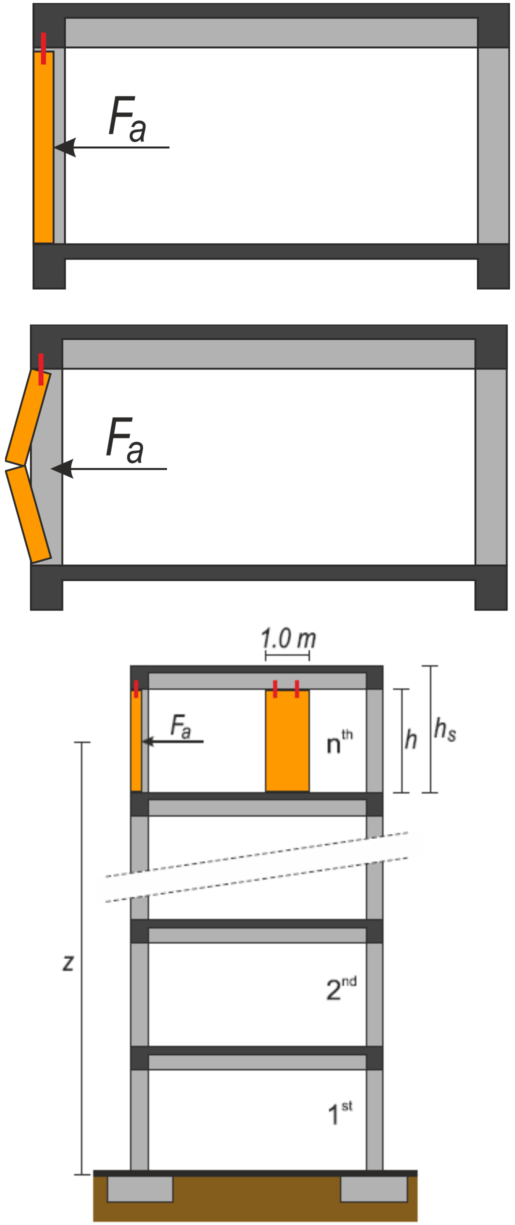

Fig 2.4 Masonry infill wall – non-structural elements

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

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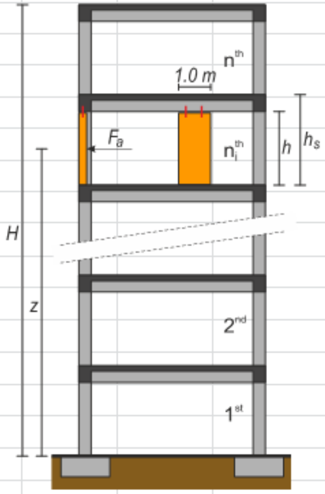
Use this table "as is" - without warranty. Use it at your own risk.

This is an approximate calculation with the following assumptions:

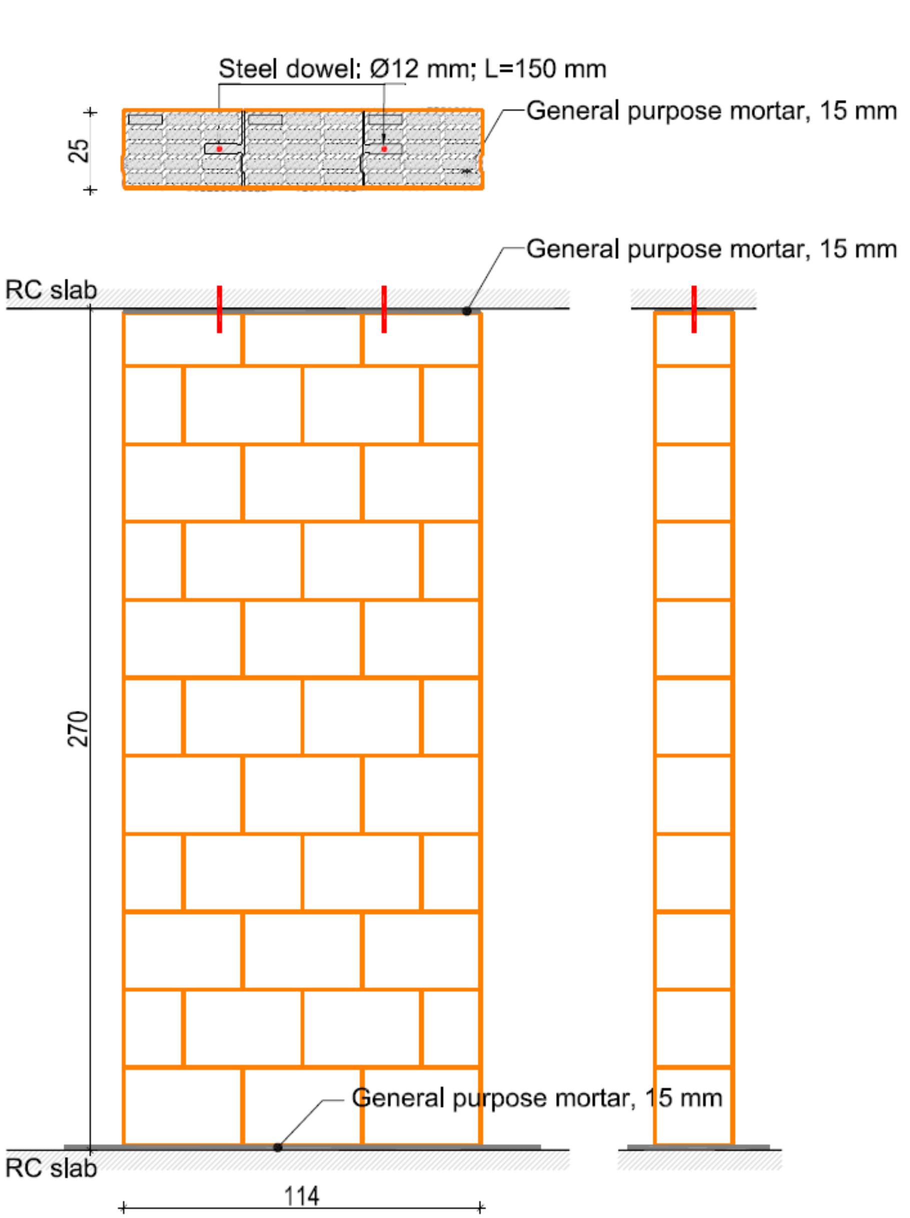
- infill wall is fixed at the bottom (mortar) and at the top (by PU or by two stell 2 dowels/m+mortar)
- plane of failure is parallel to the bed joints
- calculation is carried out on a wall L=1 m long
- specific weight of masonry: γ = 7.5 kN/m3
- additional permanent load on infill wall (blaster, insulation, 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]

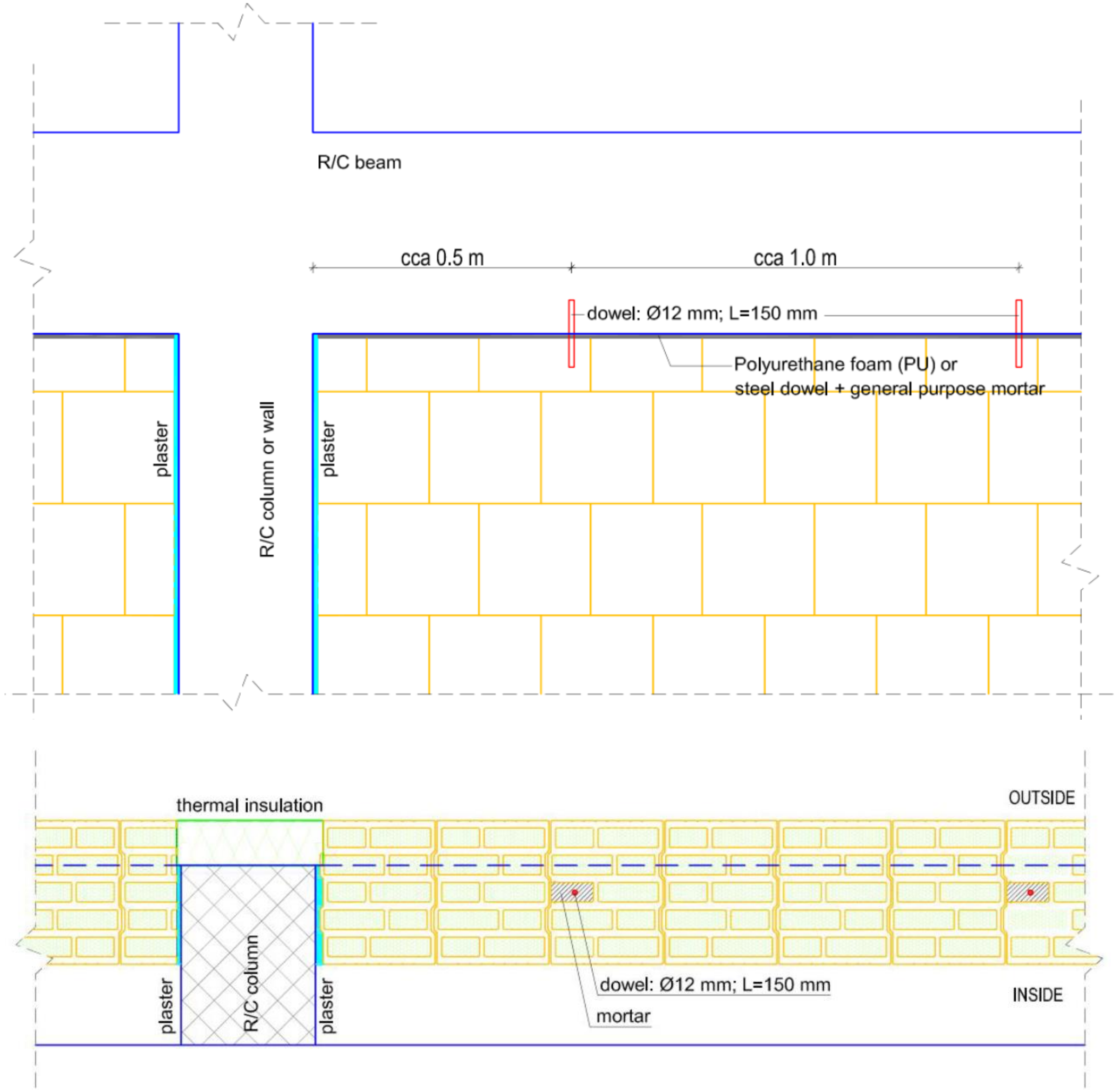
Note: Fullfill only yellow cells

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** > $M_{Ed,fxk1}$

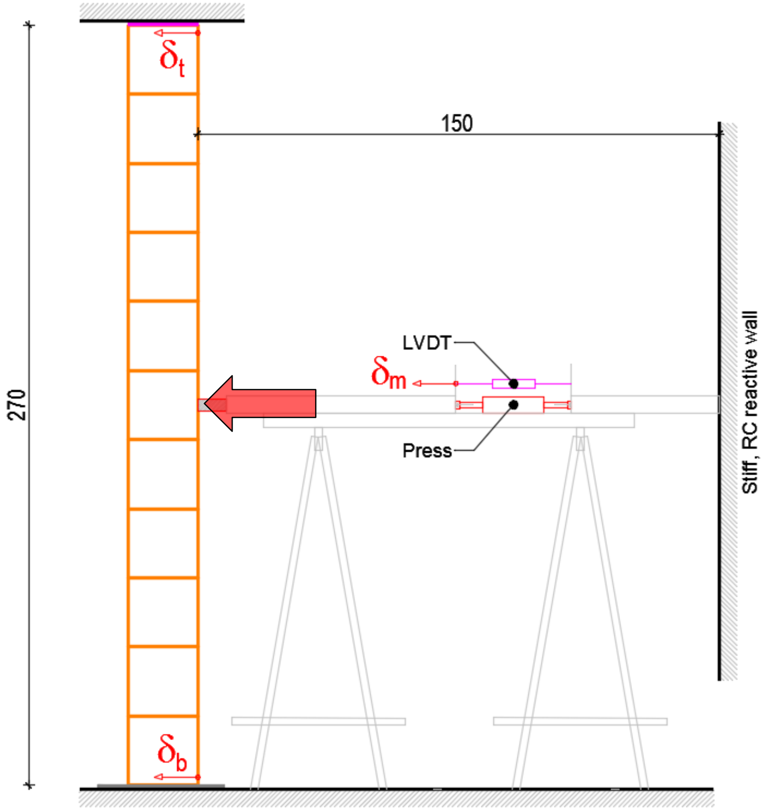


A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

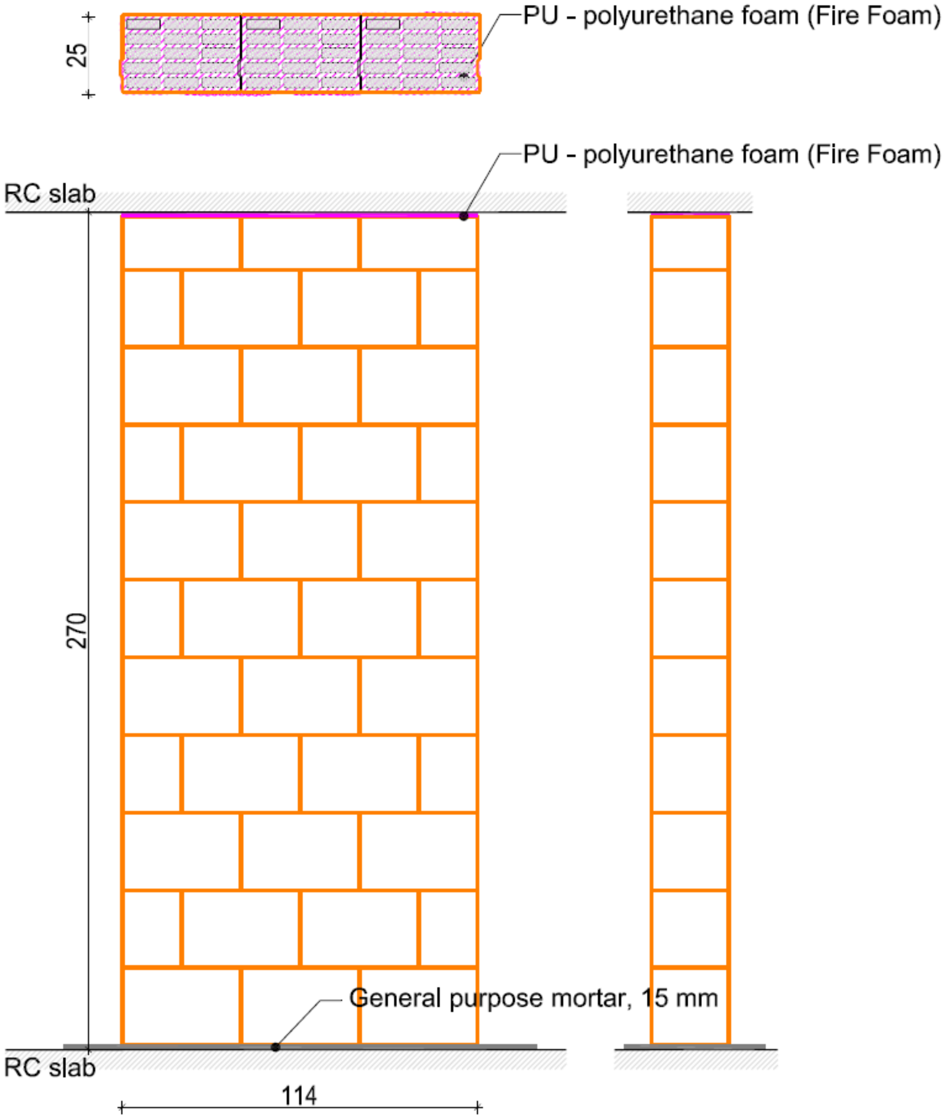




A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu



A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu



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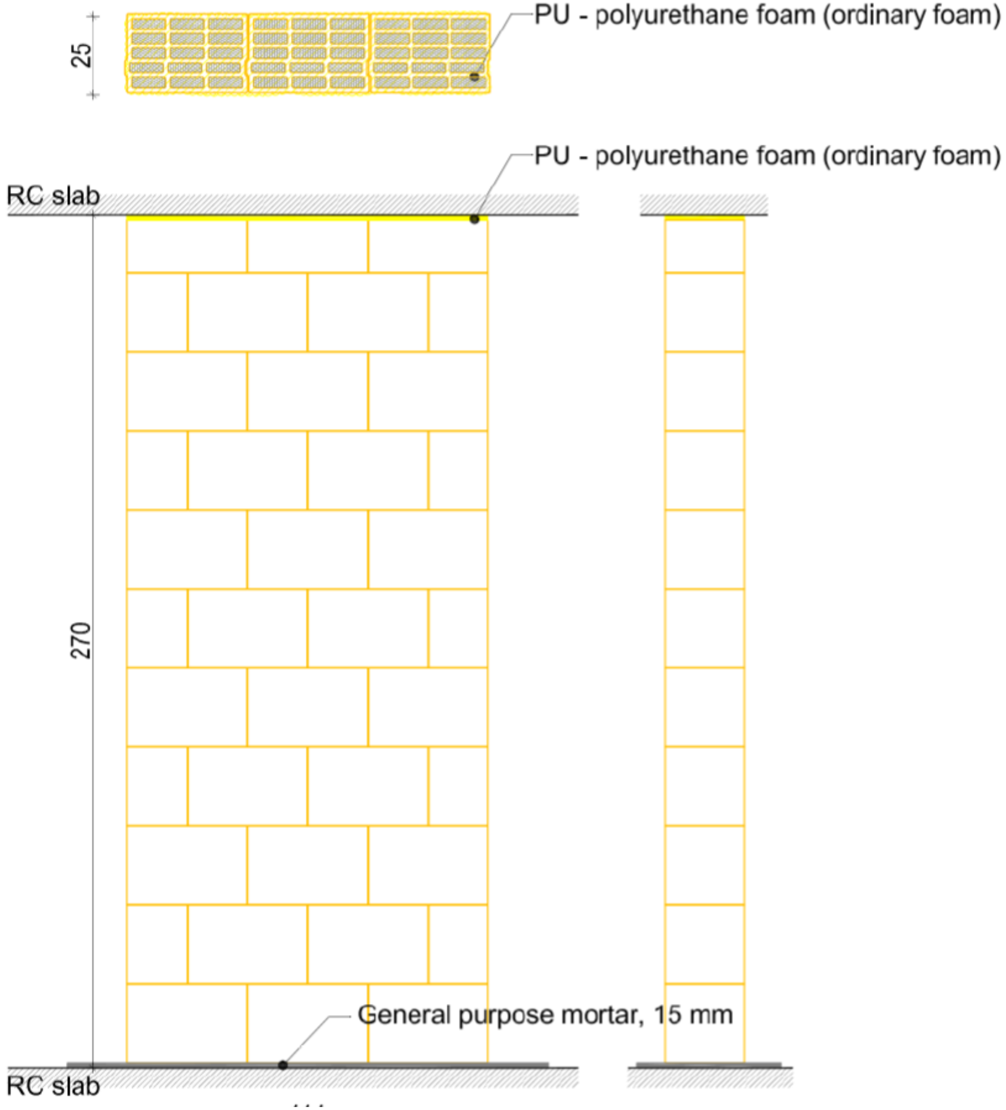
A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu



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A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

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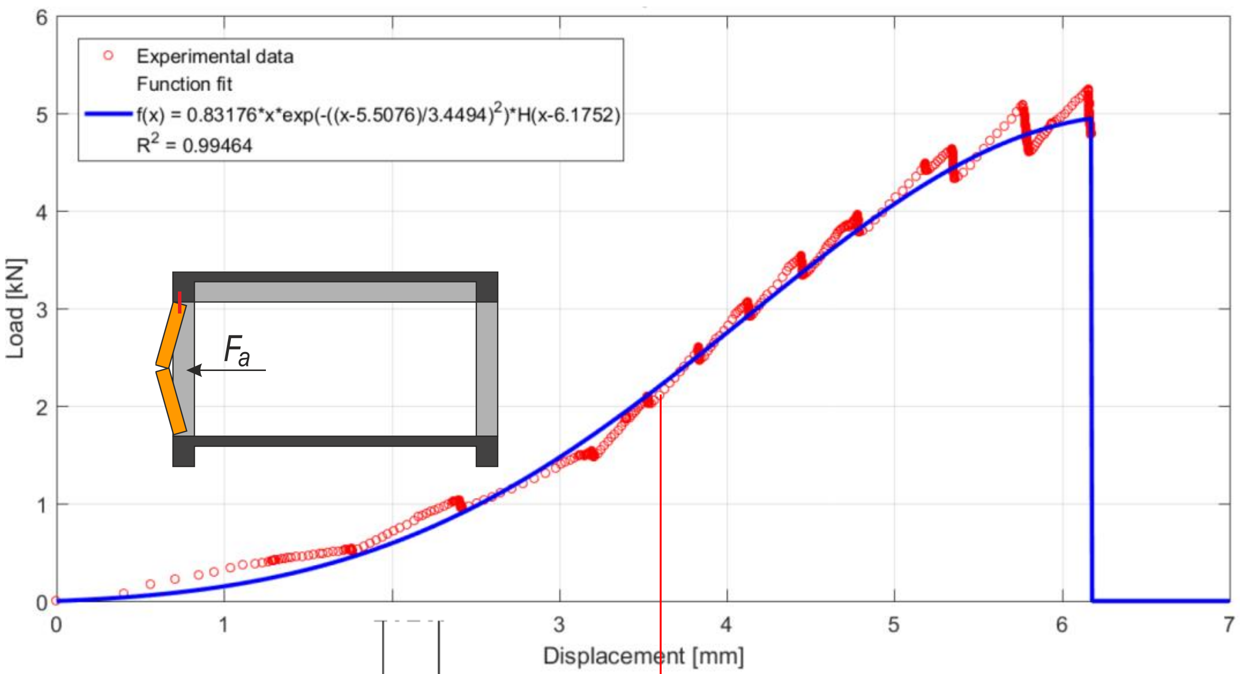
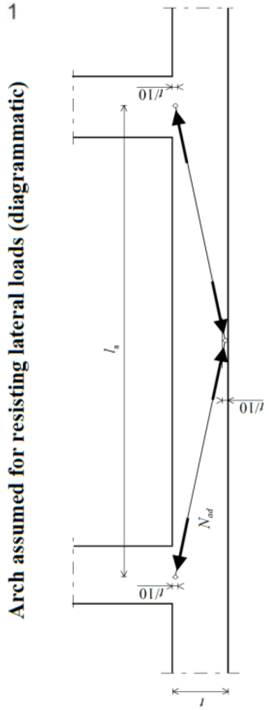
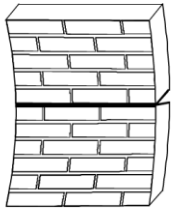
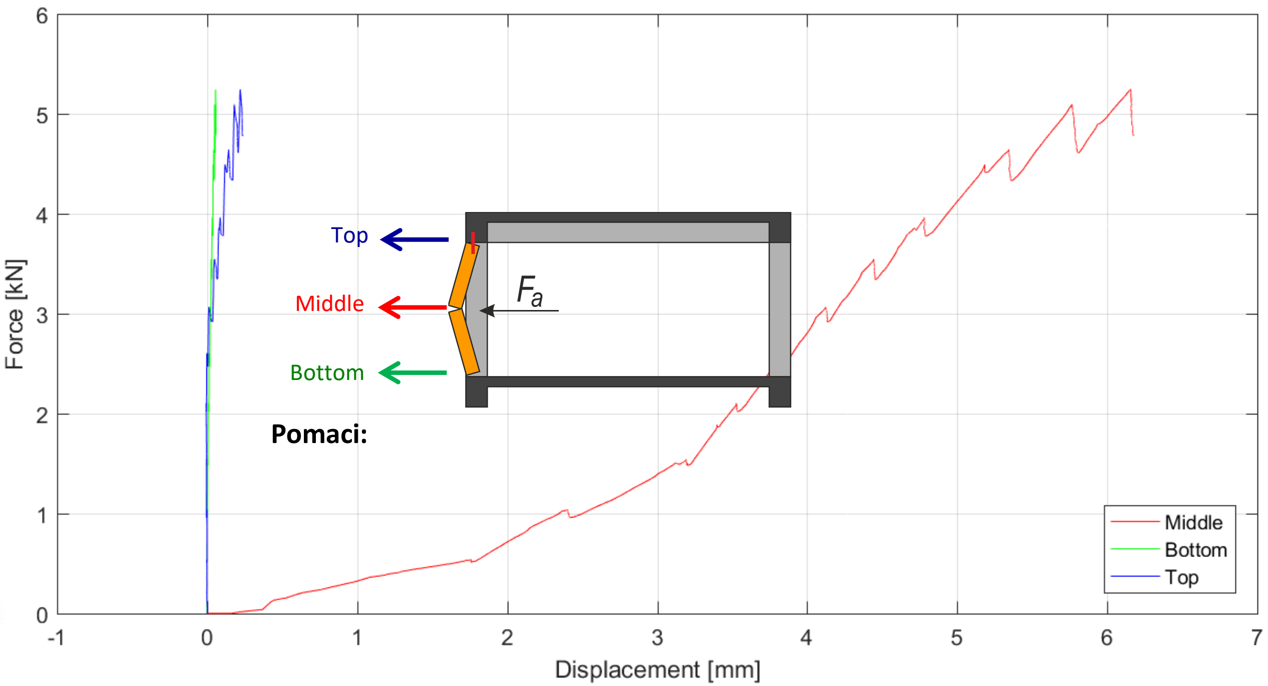






plane of failure parallel to bed joints, f_{xk1}



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A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

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]
$F_{SD/1} = 4.6$	$\delta_m = 3.5$	$\delta_b = 0.0$	$\delta_t = 0.2$
$F_{SD/2} = 5.2$	$\delta_m = 2.7$	$\delta_b = 0.0$	$\delta_t = 0.0$
$F_{SD/3} = 5.2$	$\delta_m = 4.8$	$\delta_b = 0.0$	$\delta_t = 0.9$
$F_{SD,mean} = 5.0$	$\delta_{m,mean} = 3.7$	$\delta_{b,mean} = 0.0$	$\delta_{t,mean} = 0.4$

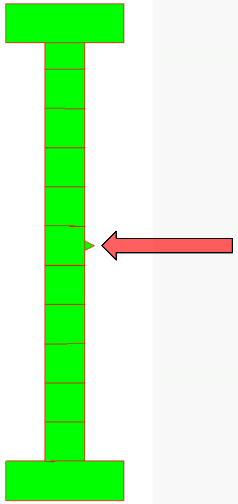
Viewing results for type PU

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

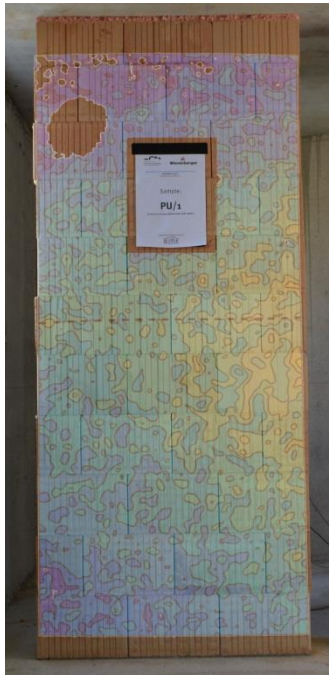
Viewing results for type PU-o

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

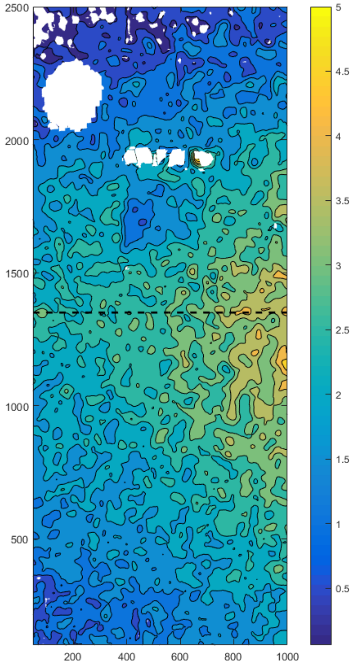
A/ Mehanske lastnosti – nosilnost pravokotna na ravnino zidu

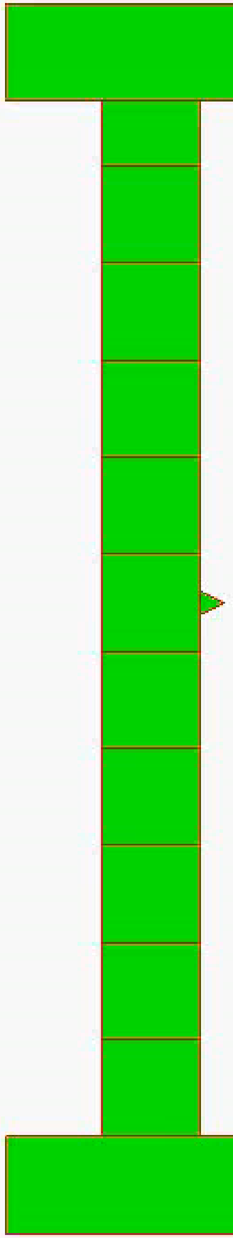


Displacement field overlay on the photo of wall

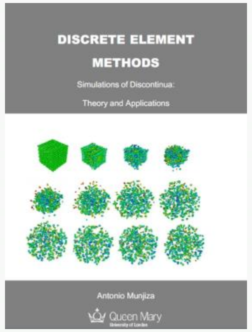


Calculated displacement field





Prof.
Antonio Munjiza



B/
Nestacionarni toplotni tok

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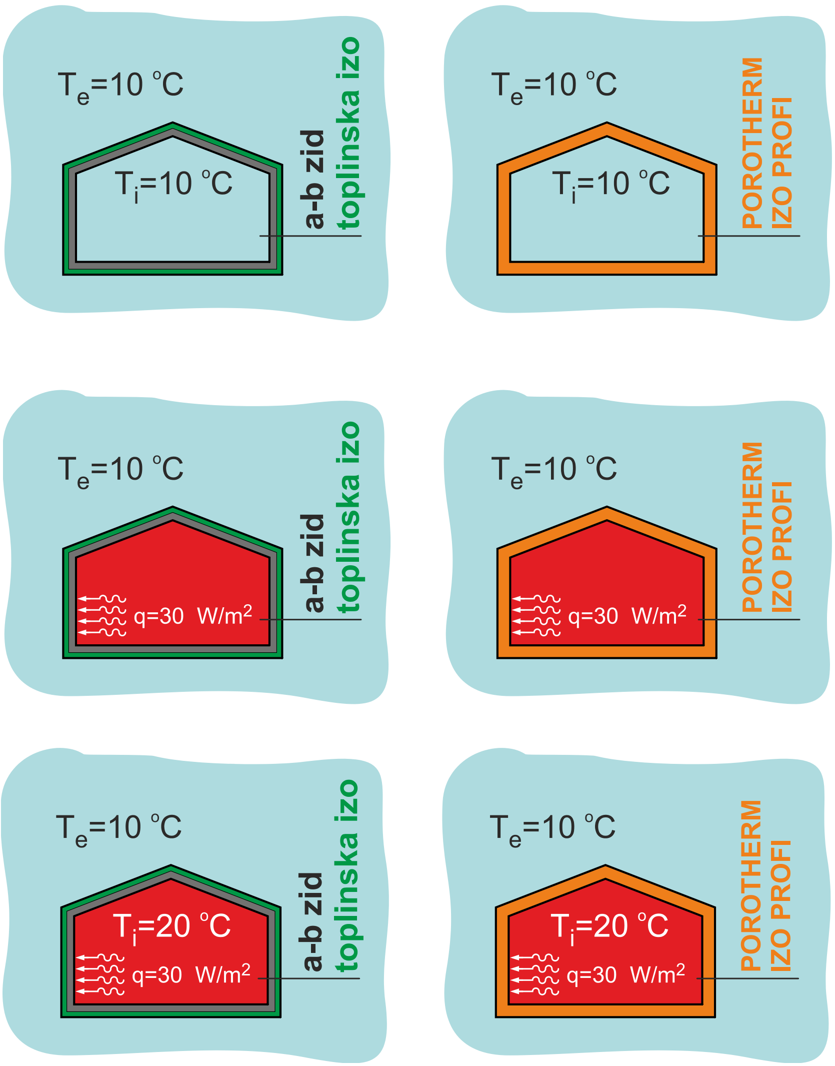
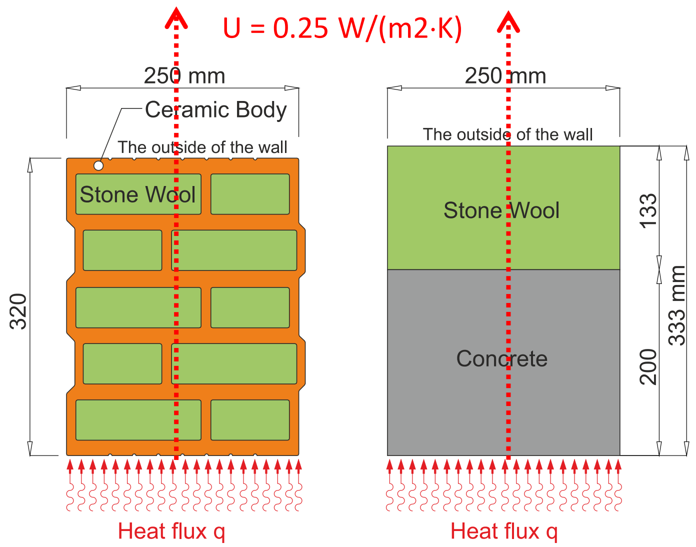




POROTHERM IZO PROFI 32 wall:

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/ (Σ t_i/KXX_i) … 0.133/0.034) **U = 0.25 W/(m2·K)**

B/ Nestacionarni toplotni tok

Transientna analiza toplotne prevodnosti – ravninski problem:

3. Governing equation

The material obeys Fourier's law of heat conduction:

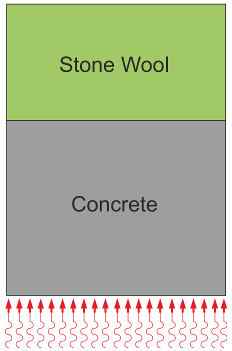
$$\boldsymbol{q} = -\boldsymbol{K}\frac{\partial \boldsymbol{T}}{\partial \boldsymbol{x}}$$

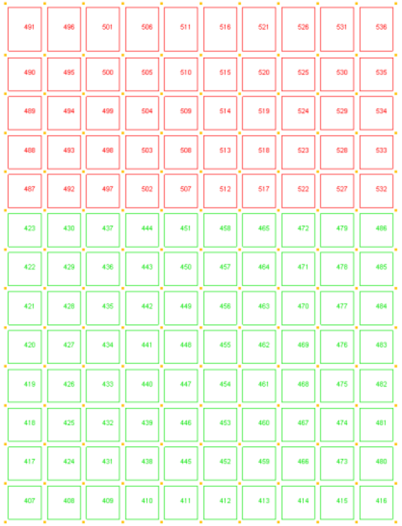
where:

$\boldsymbol{q}$ ...... the rate of heat flow conducted per unit area

$\boldsymbol{K}$ ..... the thermal conductivity tensor for the material

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





The general equation for heat conduction in solids is

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

where:

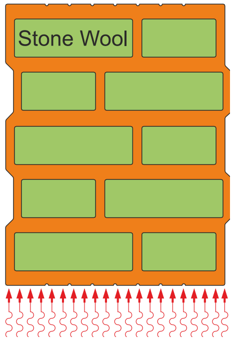
ρ ...... the mass density of the material

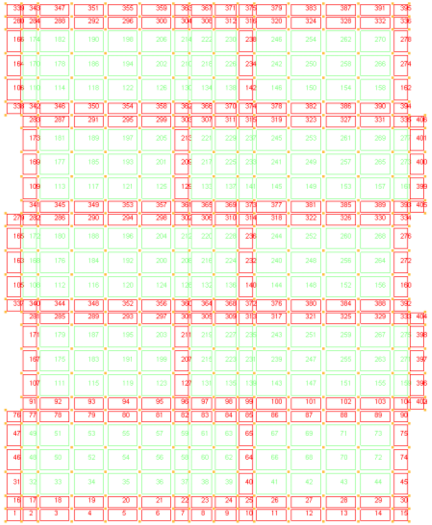
c ...... the specific heat

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).





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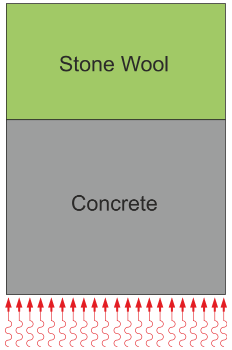
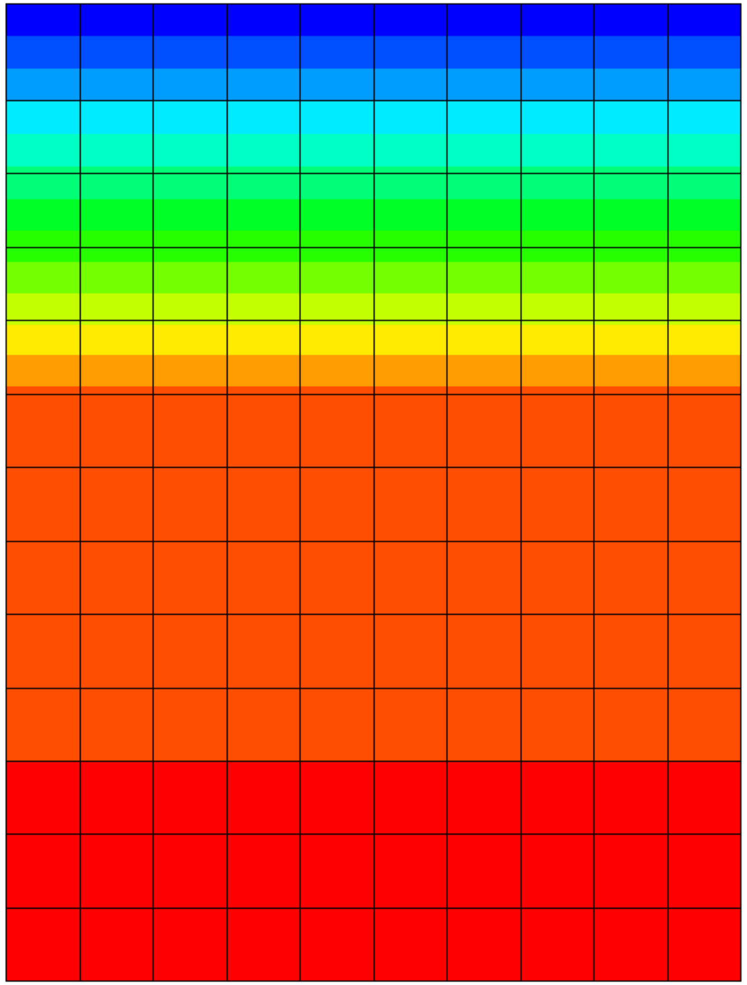
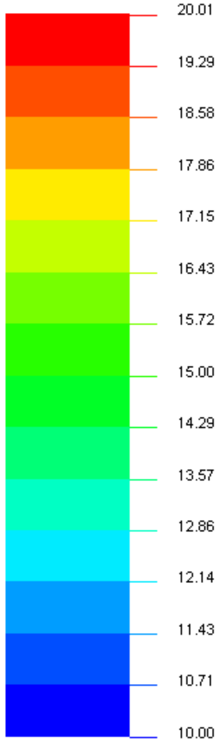
ZBORNICA ZA ARHITEKTURO IN PROSTOR SLOVENIJE

IZS INŽENIRSKA ZBORNICA SLOVENIJE

B/ Nestacionarni toplotni tok







SNAPSHOT NUMBER = 256 AT TIME ZONE = 1.536E+05

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

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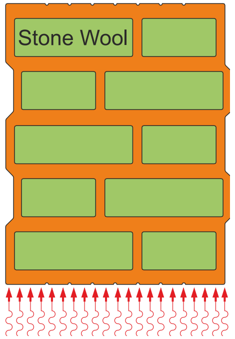

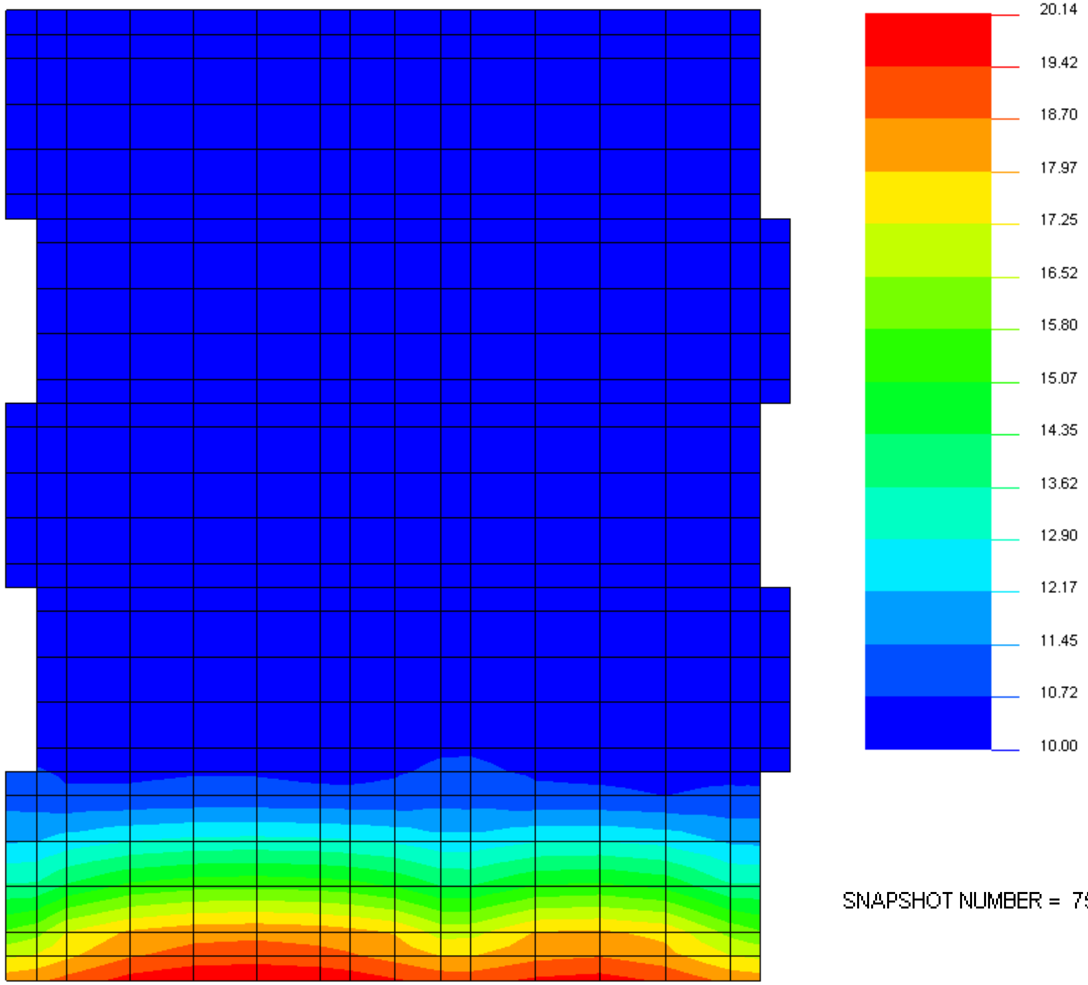

SNAPSHOT NUMBER = 75 AT TIME ZONE = 7.500E+03

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

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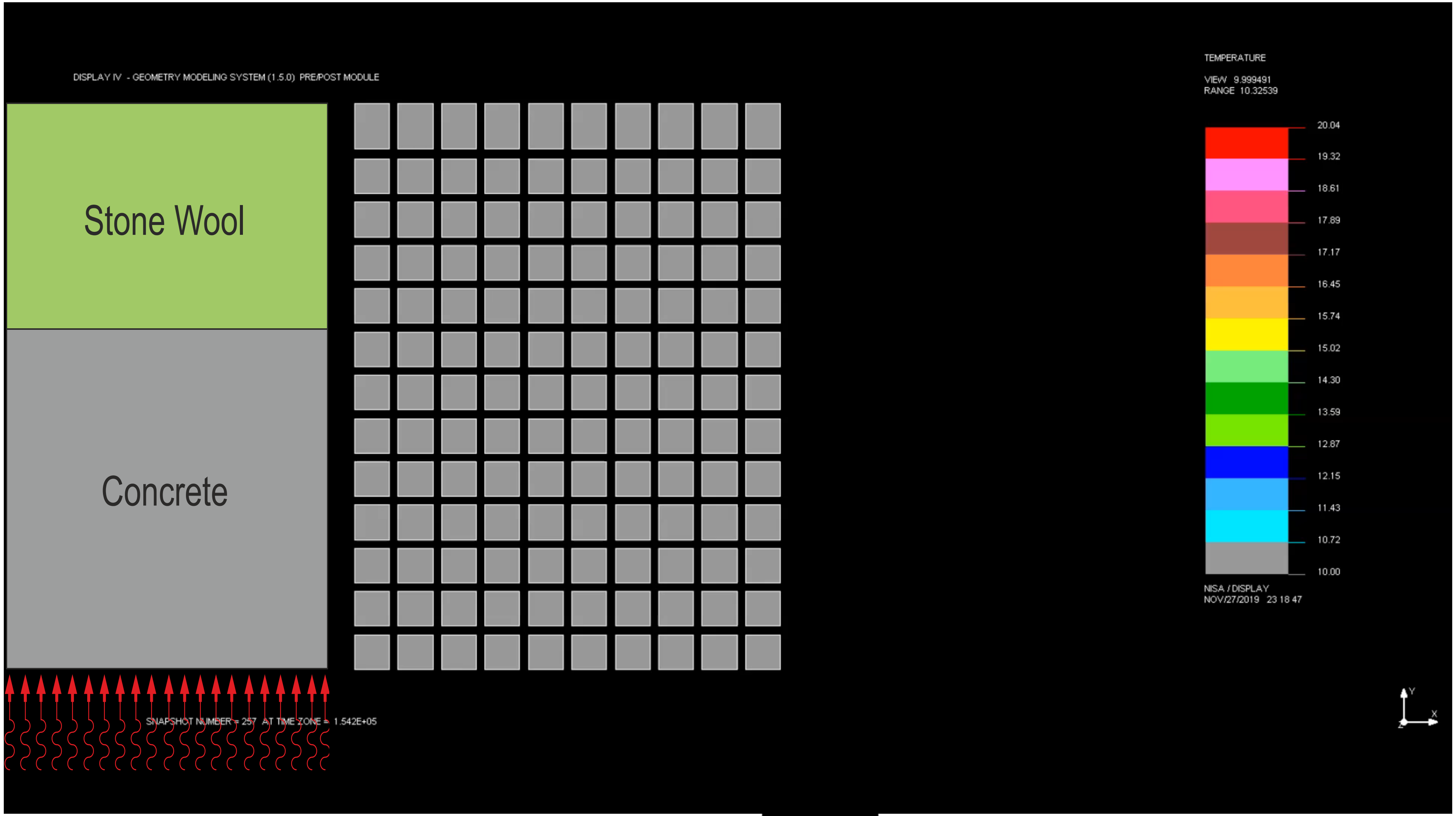

video

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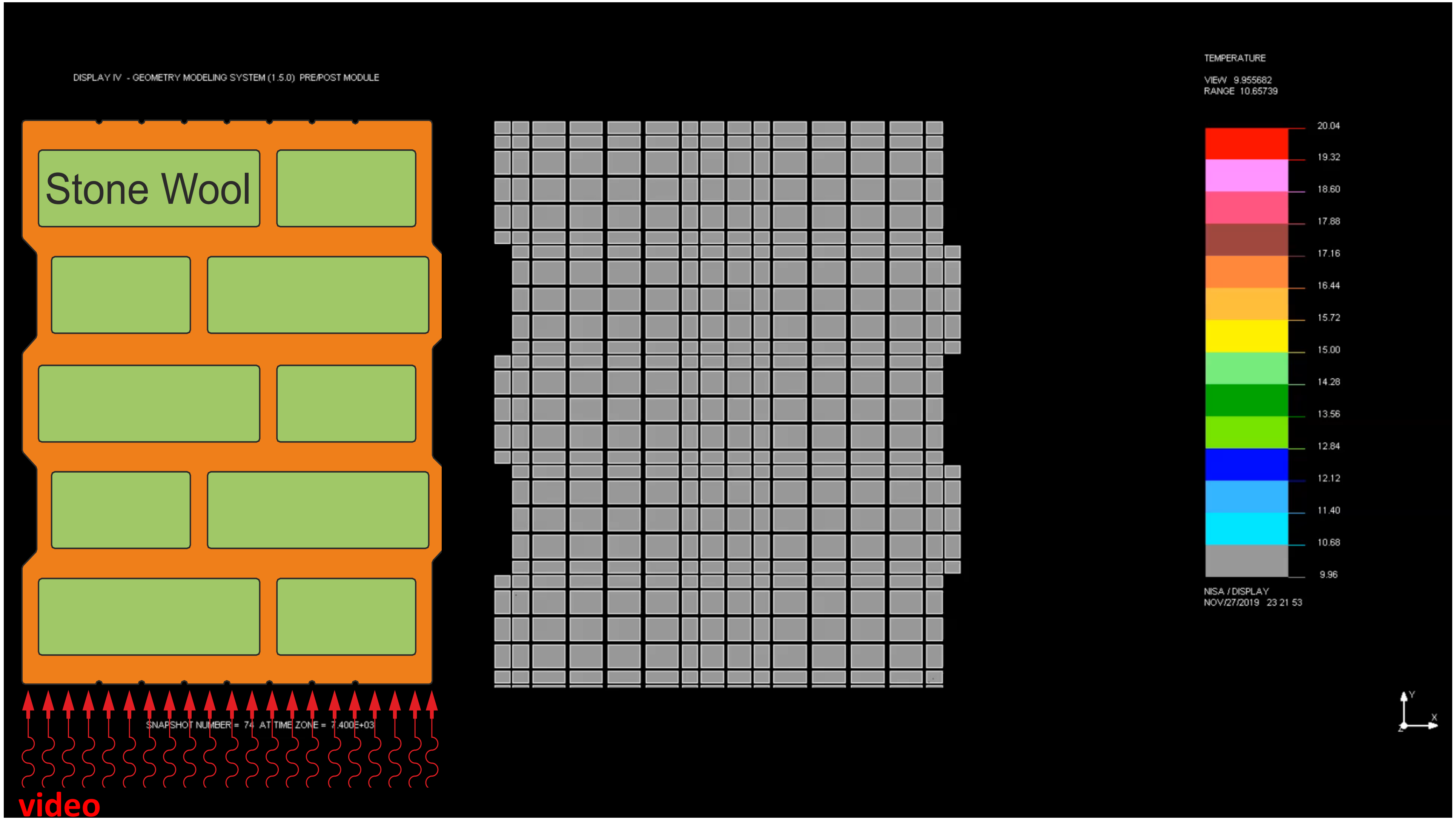

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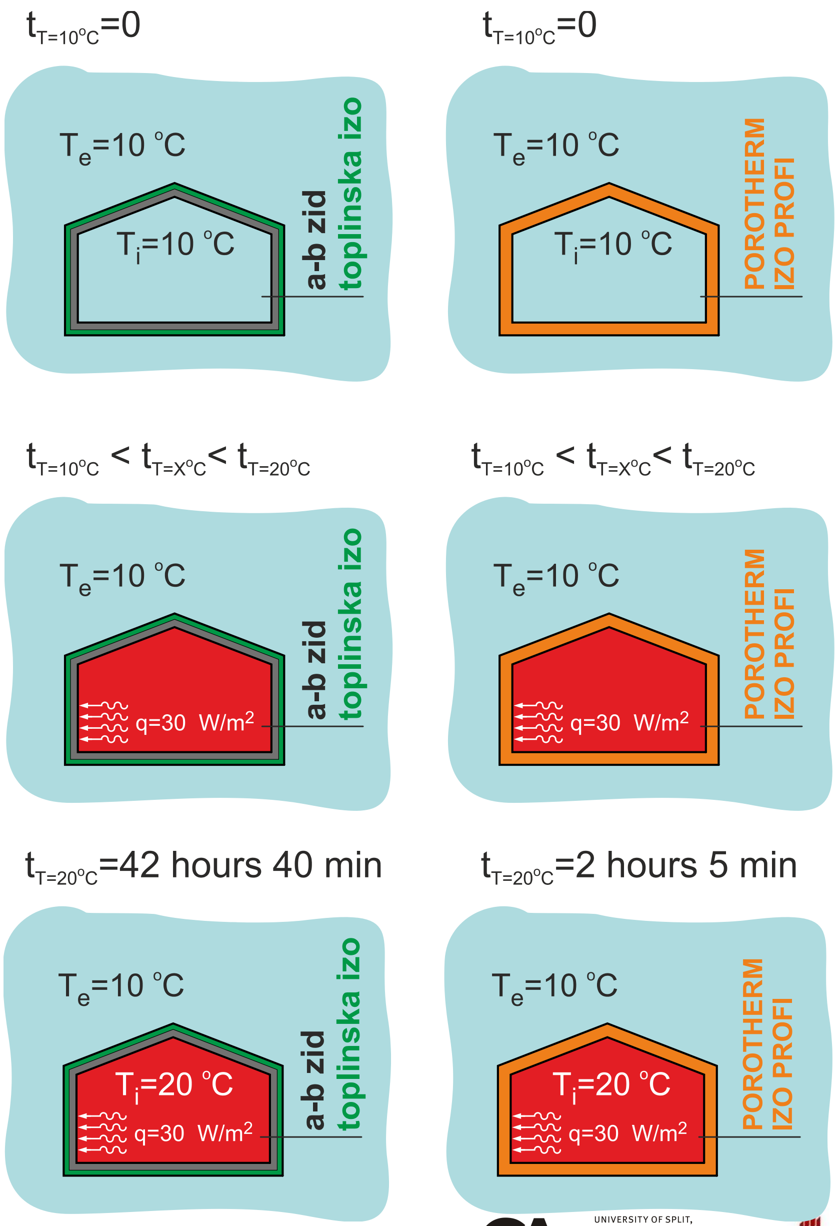
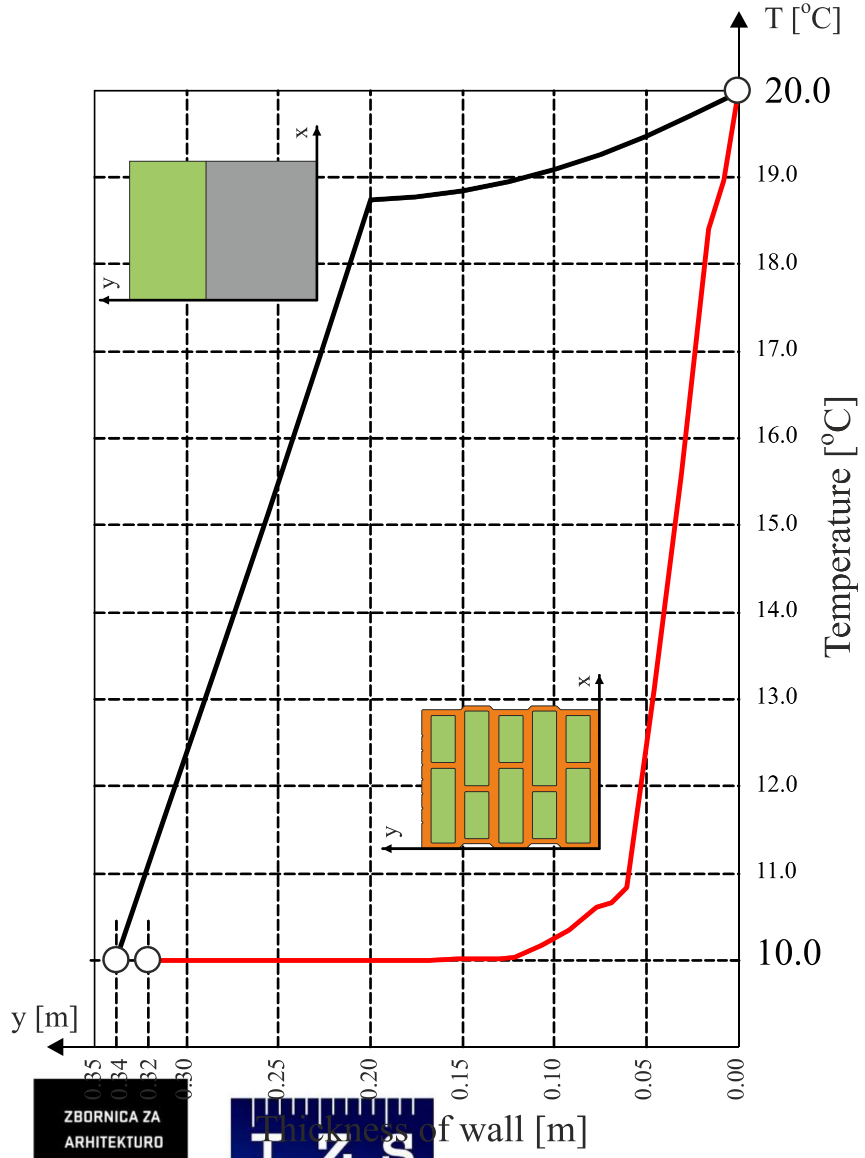
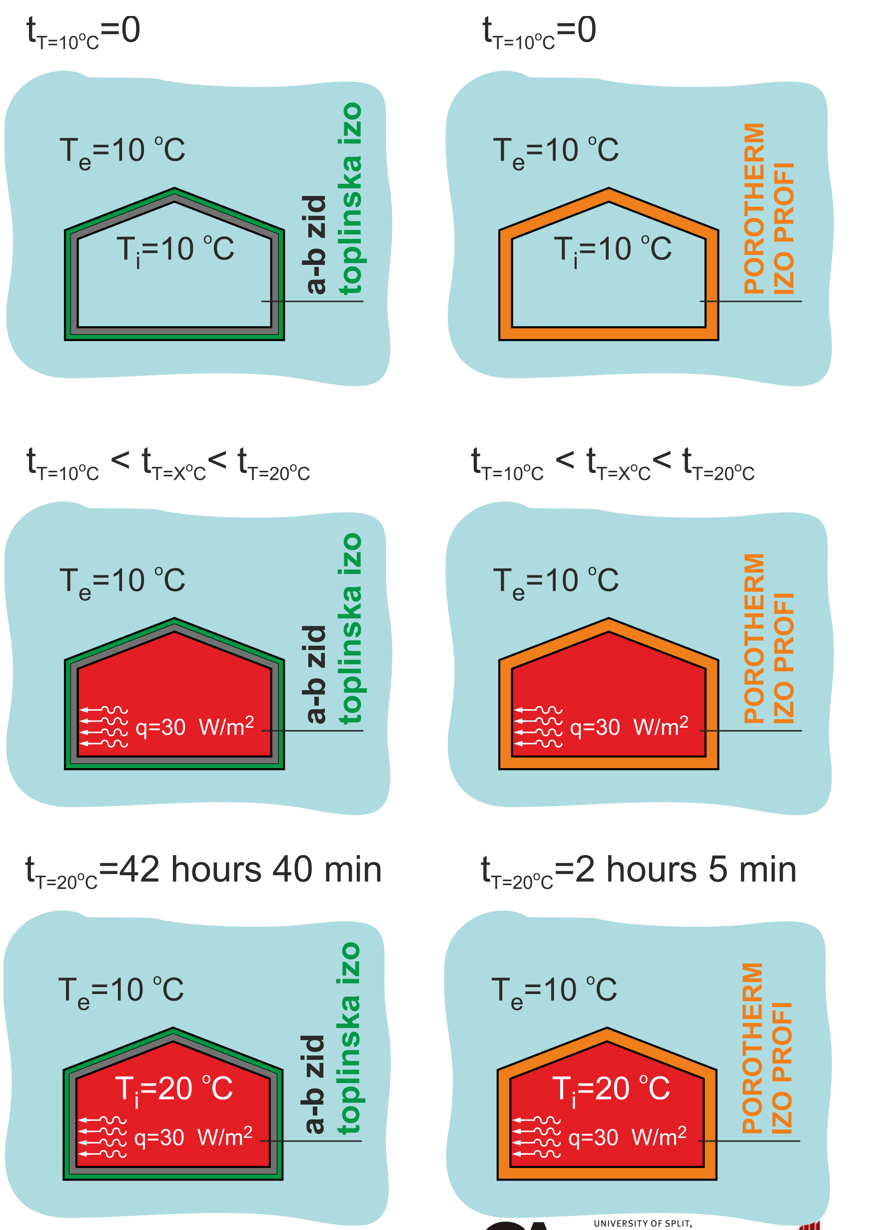
B/ Nestacionarni toplotni tok





B/ Nestacionarni toplotni tok



Ciljano temperaturo na notranji strani zidu T_i = 20.0 ^{O}C konstrukcija doseže za:

- **2 uri 5 min - POROTHERM IZO Profi 32 zid**
- **42 ur 40 min – a/b zid s toplotno izolacijo na zunanji strani (kamena volna)**

V zgradbi iz opeke POROTHERM IZO Profi 32 je potrebno 40 ur in 35 minut manj časa (ob toplotnem toku q=30 W/m^2), za doseganje temperature na notranji strani zidu T_i = 20.0 ^{O}C in je prihranek energije:

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

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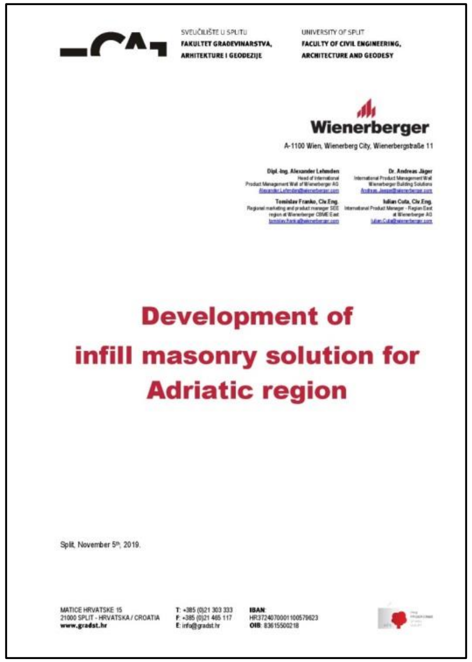
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FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

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FACULTY OF CIVIL ENGINEERING, ARCHITECTURE AND GEODESY

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Iulian Cuta, Civ.Eng.
International Product Manager - Region East at Wienerberger AG

Development of infill masonry solution for Adriatic region

Split, November 5th, 2019.

Hrvoje Smoljanović

Ivan Balić

Vladimir Divić, Boris Trogrlić, Srđan Kovač,

Josip Peroš, Mirela Galić, Irena Hospel, Ante Mihanović

Tomislav Franko

Iulian Cuta

Andreas Jäger

Boris Trogrlić

Alexander Lehmden

Hvala:

ĆITIĆ GRADNJA d.o.o. SPLIT

MAPEI

Sika

ZBORNICA ZA ARHITEKTURO IN PROSTOR SLOVENIJE

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Zidovje kot polnilo POROTHERM IZO PROFI – mehanske in toplotne lastnosti

HVALA ZA POZORNOST

Literatura:

[1] Development of infill masonry solution for Adriatic region, University of Split - Faculty of Civil Engineering, Architecture and Geodesy, REPORT, 2019.

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[3] Tomažević, Miha: Potresno odporne zidane stavbe, TEHNIS d.o.o. Ljubljana, 2009.

[4] NISA/HEAT, User manual, Cranes Software, Inc., USA

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