# INFLUENCE OF USING CLAY BLOCK WITH INCREASED MASS ON ENERGY PERFORMANCE OF AN OFFICE BUILDING IN NIŠ

by

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*The objective of the research was to compare various types of clay blocks in terms of construction thermal inertia parameters and the influence they would have on the energy performance of an office building located in Niš. For this, a new type of clay block with increased mass is proposed, and a custom approach for determining all relevant indicators is described, intensively relying on building energy performance simulations. Fourteen configurations of external walls made of clay blocks, including the newly proposed block with increased mass, were investigated using EnergyPlus with a custom weather file to obtain construction thermal storage indicators, i.e., time lag and decrement factor. The results show the average decrement factor of less than 1% and the average time lag of approximately 9 hours for the newly proposed clay block, which is very similar to the values obtained for commercially available clay blocks. In addition, the same model of the building was used to check the influence that this increased mass has on the energy performance of the building served by a low temperature radiant and fan coil system. The results indicate the possibility of reducing heating energy consumption by 3.65% by using the increased mass clay block, while maintaining similar wall U-values, when compared with regularly used clay blocks, with a negligible change in cooling energy consumption.*

Key words*: thermal inertia, opaque envelope, clay block, EnergyPlus low temperature radiant*

## Introduction

Buildings are the central place of most human activities since the majority of the time is spent indoors at home or at work, at one's leisure, and so on. Buildings require vast amounts of energy to fulfil their main requirement in separating people from outside conditions. All buildings are responsible for 40% of energy consumption and 36% of GHG emissions at the EU level, considering all phases of the building lifecycle (construction, operation, refurbishment, and demolition) [1]. The largest part of this share is used during the operational phase of the building lifecycle, most of which is spent in HVAC systems (space heating and cooling and sanitary water heating) [2]. The building stock across Europe varies, but the general conclusion is that 75% of all buildings are energy inefficient, and only 1% on average is being renovated yearly, with less than 1% of the annual turnover rate [3]. Although these figures illustrate that in existing buildings most savings could be achieved through refurbishment, construction and implementation of various energy efficiency measures in new buildings will have a long-term im-

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pact. Improving the energy performance of a building envelope by lowering heat transmittance of envelope parts (both opaque and transparent), *i.e.*, by defining maximum allowed *U*-values, is still a highly used practice in most national regulations, such as in Serbia [4, 5]. Adding more thermal insulation satisfy the defined values is the general practice, and numerous studies have been performed to find the optimal insulation thickness [6].

Unfortunately, the described approach does not consider the external wall configuration and its associated building thermal mass with all the benefits and potential drawbacks, although its importance is recognized in both the scientific and engineering community as the passive design strategy (the passive Trombe wall being the most known example), mostly in conjunction with low temperature radiant systems [7-9] or with thermally activated building systems [10].

Thermal mass of a building represents a time-dependent property of the building materials used in construction store and release heat energy. In this regard we can classify buildings as high thermal mass buildings or low thermal mass buildings [11]. The influence this thermal mass has on building energy performance and occupant thermal comfort largely depends on the building location, *i.e.*, the location climate conditions. In hot climates, thermal mass is used to regulate temperature variations and shifting peak inside temperatures thus improving thermal comfort [12] and generally reducing cooling loads [13]. In cold climates, thermal mass lowers the building energy demand for heating [14], but Reilly *et al.* [15] showed that using high thermal mass (concrete) can increase energy consumption for heating, especially if the building has intermittent heating operation, due to the increased energy demand at the system start and a longer time needed to reach the thermostat setpoint. In the Serbian climate (Belgrade), Andjelkovic *et al.* [16] reported that increasing mass in a large concrete office building can lead to reduced heating energy consumption in all analyzed cases (83% of analyzed cases had reduced peak heating demand) and reduced cooling energy consumption in 67% of analyzed cases (50% of analyzed cases showed reduced peak cooling demand). Traditionally in Serbia, as well as in Southeast Europe, the masonry wall (made from clay bricks or clay blocks) is the most common wall type found [17], and the influence that selecting different clay blocks has on building energy performance needs to be addressed, especially with regard to building thermal mass.

This paper presents the possibility of reducing building energy consumption by implementing a new type of clay block/wall system with increased mass. The block was applied to a new office building in Niš, Serbia. Its thermal performance was compared with commercially available clay blocks for various wall configurations and respective influence on the energy performance of the building served by low temperature radiant and fan-coil systems.

Using simulations in the early design stage can lead to significant energy savings, especially if the influence of a new material on building thermal mass is to be considered. Consequently, a straightforward and customized approach, applicable to every building model, is presented for the commercial building located in Niš, Serbia, by using EnergyPlus v.22.1.0 [18]. Fourteen configurations of external walls with clay blocks were examined for the modeled building under ideal load conditions. Among these fourteen external wall configurations, a new type of clay block (generic, multi-layered) was introduced, made from 6 cm thick solid brick and 19 cm thick clay block with holes filled with mineral wool.

Afterwards, for six wall compositions, including the one with increased mass, with similar *U*-values, which fulfil the minimum energy requirements of [4], the same office building was equipped with identical HVAC systems and operaTed in the same manner. Full-year simulations were performed to see how different wall thermal mass indicators impact heating and cooling energy demand/consumption.

### Structural thermal storage

Construction materials such as brick, clay block and concrete have such physical properties that allow them to store thermal energy, *i.e.*, they can absorb heat and release it, thus significantly impacting the overall building energy performance. Understanding how this affects both building energy demand and building energy performance can be particularly useful in selecting construction materials and proper HVAC systems.

Opaque building envelope parts (walls, floors, ceilings, and roofs) are constructed as a multi-layered sequence of homogenous materials with all their different thermo-physical (thermal conductivity, specific heat, density, thermal absorptance) and geometric properties (thickness). Under steady-state conditions, thermal performance is defined by thermal transmittance (*U*-value), independent of layer sequence (for the same individual layer thickness). On the other hand, layer sequence strongly impacts the overall construction thermal inertia (a structure's heat storage capacity), mostly expressed by two parameters: time lag and decrement factor [19]. Time lag (dephasing) is the time needed to propagate the heat flow from the outer surface to the inner surface. The decrement factor is defined as the ratio between amplitudes of the heat flow in internal and external surfaces (the ratio of differences between maximum and minimum inside and outside surface temperatures) during its propagation for 24 hours. Time lag and decrement factor are the primary metrics for existing material wall configurations [20-23] and for comparing new construction materials/wall systems [24-27], although with some variations in the definition for time lag. Belhadj *et al.* [25] defined time lag including a period of investigation of 24 hours (if the time of occurrence of inner surface maximum temperature is lower than the time of occurrence of outside surface maximum temperature, then the time lag is the sum of the difference of occurrences of the temperatures and the period of 24 hours. If the two temperatures are identical, then the time lag equals the period of 24 hours. In all other cases it is the difference between the time of occurrence of the two surface temperatures). A similar definition was implemented in [27] but with the addition of a 24 hours period to the difference of time of occurrence of the maximum inside and outside surface temperatures in all cases. In [26] the average time lag is introduced as the average between the maximum time lag (the difference between the time of occurrence of the maximum inside and outside surface temperatures) and the minimum time lag (the difference between the time of occurrence of the minimum inside and outside surface temperatures) for a structure over the same time period. Zhang *et al*. [21] introduced the time of occurrence of maximum and minimum outside outdoor air temperatures instead of outside surface temperatures in both time lag and decrement factor definitions.

Gasparella *et al.* [28] assessed the deviation stemming from using different approaches to calculate the dynamic thermal properties of fifteen types of opaque walls under periodic non-sinusoidal boundary conditions. These approaches were: the standardized procedure [19], the transfer function and finite difference method approach incorporated as the Direct Root Finding method in TRNSYS [29], the State-Space state method in EnergyPlus [30], and the Fast-Fourier transform approach selected as the reference case. The analysis was performed for three different summer design days. The results show that deviations between the approaches are negligible for selected locations.

Aste *et al.* [20] compared twenty-four external wall configurations with similar *U*-values. The first step was to calculate dynamic thermal properties with a standardized procedure, after which simulations for six selected test cell walls and a complex building in the Milan climate were performed under varying modelling assumptions. They reported an increase of 10% for heating and 20% for cooling demand for low inertia walls compared to high inertia walls.

Test cell simulation with EnergyPlus was also used in [25] to calculate the dynamic properties of the external wall with barley straw sand concrete. The EnergyPlus has been mostly used to evaluate building energy performance with different wall configurations, including new construction materials. Ascione *et al.* [24] used EnergyPlus to find the optimal building envelope design for nZEBs in the Mediterranean climate. It is interesting that the use of the then innovative materials (interlocking brick with holes filled with mineral wool and brick with holes filled with expanded polystyrene) in external walls was investigated among different possibilities. A similar procedure with EnergyPlus was adopted to check the thermal transmittance effect in Mediterranean residential buildings with different thermal mass [23]. The EnergyPlus simulations of a commercial building for various locations in China were used in [21] to find and evaluate the optimal insulation thickness and insulation position within the wall.

As it can be seen previously, EnergyPlus is frequently used to assess the influence of thermal mass on building energy performance when new materials or wall compositions are proposed for construction. All the reported metrics can be derived from regularly available outputs of simulation. In addition, every important parameter can be examined considering a particular building lay-out, surroundings, climate and indoor conditions throughout a year, or for particular conditions (heating and cooling design days, extreme climate conditions*, etc.*).

## Case study building

The building under investigation is a newly designed office building located in Niš, Serbia, fig. 1. Niš is the third largest city in Serbia and the largest in South-east Serbia. Niš has a humid subtropical climate with the continental influence (according to Koppen classification subtype Cfb – marine west coast climate). Average annual temperature in Niš is 11.9 °C, but with recorded exteremes of +44.2 °C and –23.4 °C. Outside design temperatures for Niš are: winter design temperature of –14.5 °C and summer design temperature of +35 °C. Heating degree-days for Niš have value of 2613 [4].

The building consists of the underground garage, ground floor (office, kitchen, dining room, toilet, and corridor), two identical floors (each with four offices, corridor and toilet as depicted in fig. 2) and top floor (two rooms for chill-out activities, corridor, and toilet). The staircase and elevator shaft run through the building from the ground floor to the top floor. Each space of the building was modeled as a separate thermal zone. The only unconditioned zones of the building are the elevator shaft, staircases, and underground garage, while all other zones of the building are conditioned, with a conditioned area of around 750 m$^2$.

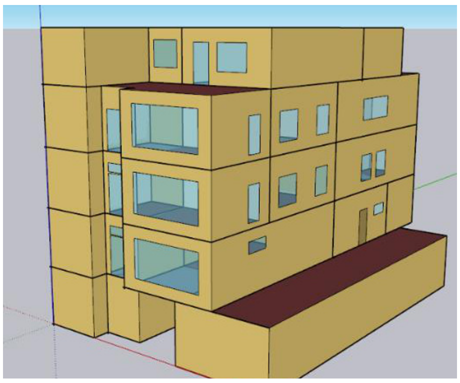

**Figure 1. Isometric view of the office building from the north-east direction**

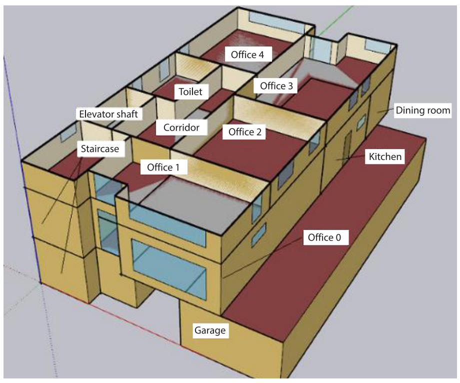


**Figure 2. Cross-section of a typical floor**

All simulation cases included the same internal walls separating heated from unheated spaces, internal walls separating heated spaces, the floor on the ground, the floor towards the basement, the floor of the other building stories and the roof. Their configuration and *U*-values are given in tab. 1. The transparent part of the envelope (windows and balcony doors) was simulated with a *U*-value of 0.8 W/m$^2$K and SHGC of 0.5, and remained constant for all simulations. The same was done for infiltration, which was held constant at 0.1 ACH. All transparent parts of the envelope were equipped with external blinds with a constant slat angle of 45°.

**Table 1. Configuration and *U*-values of structures which remained constant throughout the study**

| Abbreviation | Configuration | *U*-value [Wm$^{-2}$K$^{-1}$] |
|---|---|---|
| Floor above garage | Inner plaster – 20 cm mineral wool – 20 cm concrete – 6 cm of gypsum plaster – 0.2cm floor tile | 0.163 |
| Floor between building stories | Inner plaster – 10 cm mineral wool – 20 cm concrete – 6 cm of gypsum plaster – 0.2 cm floor tile | 0.303 |
| Roof - balconies | Ceramic floor tiles – 30 cm extruded polystyrene – 20 cm concrete | 0.113 |
| Roof-other | Clay tiles – wood – 22 cm mineral wool – gypsum cardboard | 0.152 |
| External wall of unheated spaces | Outer plaster – 10 cm mineral wool – 25 cm B3 – inner plaster | 0.232 |
| Internal wall separating heated and unheated spaces | Inner plaster – 5 cm polystyrene – 12 cm solid brick – inner plaster | 0.596 |
| Internal wall separating heated spaces | Inner plaster – 12 cm solid brick – inner plaster | 2.099 |
| Slab wall | Bitumen – 20 cm extruded polystyrene – 25 cm concrete – inner plaster | 0.160 |

### *Configuration of external walls*

For this part of the study, five types of clay block, all having the same thickness of 25 cm, were selected as the construction material used for external walls of heated zones, with their thermal properties given in tab. 2.

**Table 2. Thermophysical properties of selected clay blocks and additional materials**

| Abbreviation | Thermal conductivity [W$^{-}$1mK$^{-1}$] | Specific heat [kJkg$^{-1}$K$^{-1}$] | Density [kgm$^{-3}$] | Thickness [cm] |
|---|---|---|---|---|
| B1 | 0.61 | 920 | 1400 | 25 |
| B2 | 0.207 | 920 | 707 | 25 |
| B3 | 0.196 | 920 | 788 | 25 |
| B4 | 0.143 | 1610 | 771 | 25 |
| B5 | 0.072 | 1610 | 754 | 25 |
| SB | 0.76 | 920 | 1800 | 6 |
| Mineral wool | 0.034 | 840 | 80 | 0/5/10 |

In addition these five types, a separate type (B6) was created with the same overall thickness but increased surface mass on the inside. This type was assumed to be made of 19 cm thick B5 block with 6 cm of solid brick, and it was modeled as two separate layers within the wall. A total of 14 different external wall configurations were made with varying thicknesses of insulation (mineral wool), with their respective configurations given in tab. 3.

**Table 3. Configurations of analyzed external walls**

| Abbreviation | Configuration | *U*-value [$Wm^{-2}K^{-1}$] | Mass [$kgm^{-2}$] |
|---|---|---|---|
| SZ1-0 | Outer plaster – B1 – inner plaster | 1.692 | 392.4 |
| SZ1-5 | Outer plaster – 5 cm mineral wool –B1 – inner plaster | 0.485 | 396.4 |
| SZ1-10 | Outer plaster – 10 cm mineral wool –B2 – inner plaster | **0.283** | 400.4 |
| SZ2-0 | Outer plaster –B2 – inner plaster | 0.720 | 219.2 |
| SZ2-5 | Outer plaster – 5 cm mineral wool – B2 – inner plaster | **0.350** | 223.2 |
| SZ2-10 | Outer plaster – 10 cm mineral wool –B2 – inner plaster | **0.231** | 227.2 |
| SZ3-0 | Outer plaster – B3 – inner plaster | 0.686 | 239.4 |
| SZ3-5 | Outer plaster – 5 cm mineral wool – B3 – inner plaster | **0.342** | 243.4 |
| SZ3-10 | Outer plaster – 10 cm mineral wool – B3 – inner plaster | **0.227** | 247.4 |
| SZ4-0 | Outer plaster – B4 – inner plaster | 0.518 | 235.2 |
| SZ4-5 | Outer plaster – 5 cm mineral wool – B4 – inner plaster | **0.294** | 239.2 |
| SZ4-10 | Outer plaster – 10 cm mineral wool – B4 – inner plaster | **0.205** | 243.2 |
| SZ5 | Outer plaster – B5 – inner plaster | **0.274** | 230.9 |
| SZ6 | Outer plaster – 19 cm B5 – 6 cm SB – inner plaster | **0.345** | 235.2 |

Simulations were performed for the Ideal Load continuous building operation with constant winter and summer heating setpoints of 22 °C and 26 °C, respectively. In this case, all the building's internal gains were neglected. To take into account the thermal history of models and allow the warmup convergence to complete, a custom weather file was created. This weather file was a modified EnergyPlus weather file for the City of Niš. The file modification was performed in such a way so that random days from January and July were taken, and artificial months of January and July were created with these days being repeated. All the other months in the weather file remained unchanged. The simulation outputs were surface inside and outside face temperatures. The surfaces representing each cardinal direction were selected from non-neighboring conditioned zones. These outputs were requested for one week after the artificial months in an hourly resolution.

### *Impact on building energy performance*

In this research step, several external wall configurations with similar *U*-values were selected, tab. 4, and a complete model was developed, including HVAC systems and building operation.

External walls in unheated spaces were varied with blocks from tab. 3, but with a fixed mineral wool thickness of 10 cm.

Since this is an office building, it is assumed that it is occupied during weekdays when there is a need for lighting (lighting schedule) and when office equipment is used (equipment schedule), assuming 6 $W/m^2$ of lighting power and 10 $W/m^2$ of equipment power and on av-

**Table 4. Wall configurations**

| Abbreviation | Configuration | $U$-value [Wm$^{-2}$K$^{-1}$] |
|---|---|---|
| W1 | Outer plaster – 14 cm mineral wool – B1 – inner plaster | 0.212 |
| W2 | Outer plaster – 12 cm mineral wool – B2 – inner plaster | 0.203 |
| W3 | Outer plaster – 12 cm mineral wool – B3 – inner plaster | 0.201 |
| W4 | Outer plaster – 10 cm mineral wool – B4 – inner plaster | 0.205 |
| W5 | Outer plaster – 4 cm mineral wool – B5 – inner plaster | 0.207 |
| W6 | Outer plaster – 6 cm mineral wool – (19 cm B5 + 6 cm SB) – inner plaster | 0.214 |

erage 12 m$^2$ of the floor area per occupant. Occupancy, lighting, and equipment schedules of various zones are given in fig. 3.

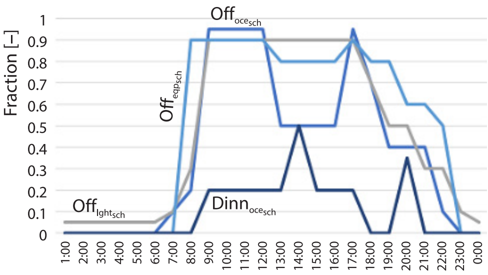

**Figure 3. Occupancy, lighting, and equipment schedules**

For this, two thermostats were deployed: a heating setpoint thermostat with setback temperature and a cooling thermostat with setback temperature. Two distinctive operation regimes were modeled: the heating season from October 15 to April 15 and the cooling season from April 15 to October 15. The setpoint temperatures were varied throughout weekdays in both operating regimes: during the heating season the setpoint value was set at 22 °C until 10 p. m., with a setback value of 20 °C. During the summer season the setpoint value was set at 26 °C during occupied periods (from 9 a. m. until 10 p. m.) with a setback temperature of 28 °C for the rest of the day. According to building occupancy, generic heat supply was modeled as district heating and district cooling, which were available from 10 p. m. Sunday until 10 p. m. Friday in respective seasons of operation.

Two demand side HVAC systems were modeled: a low temperature floor radiant system and a fan-coil system, with priority switching between seasons (during the heating season the radiant system was primary while the fan-coil was secondary and vice-versa for the cooling season). During the heating season, floor panels were always available, while for the cooling season, they were available outside occupied hours. The fan-coil system was available only during occupied hours. Supply water temperatures for heating and cooling varied according to outside temperatures (outdoor reset), with low heating and standard cooling regimes.

The Radiant system was modeled as a variable-flow floor system, separately controlled for each conditioned zone (21 radiant floor circuits were modeled, one per conditioned zone) with the following modelling inputs:
– The 1/2″ PEX pipes were put into floor structures between concrete and gypsum plaster.
– Tube spacing was set to 10 cm with 2-D Conduction transfer function calculation (this led to setting the number of timesteps in simulation 20).
– Heating and cooling design capacities were auto-sized (as well as for other system components in the model).
– The fluid-to-radiant surface heat transfer model was set to ISO Standard to include both convection between fluid and inside of the pipe and conduction through the pipe wall.
– Availability of each floor panel was determined according to the achieved zone indoor air temperature the floor panel was serving (this temperature was set as ±1 °C to the respective setpoint value and operating season).

– The setpoint temperatures floor panels were trying to meet were set 2 °C higher than the indoor setpoint value during the heating season and 2 °C lower than the indoor setpoint value during the cooling season.
– The setpoint control type for panels was set to ZeroFlowPower [27] with a control throttling range of 2 °C and a temperature control type of MeanAirTemperature.

This control set-up forced the radiant panel to operate in the following sequence: during the heating season, the full flow would be set when the mean air temperature was below 22 °C and linearly varied to zero flow when the indoor temperature was 24 °C. During the cooling season, it was mirrored around the summer indoor setpoint.

## Results and discussion

### *Variation in thermal inertia indicators*

Table 5 presents the values of time lag and decrement factor defined as in [25], as primary indicators of thermal inertia, during winter and summer weeks for the modeled building. Their change with unit mass is shown in fig. 4 and correlates well with the results presented by Aste *et al.* [20], Zhang *et al.* [21], Leccesse *et al.* [22], and Belhadj *et al.* [26], since the decrement factor has the value of up to 10% and the time lag has the value of 8-16 hours. It should be noted that these indicators were calculated by using outputs of the simulation and do not represent the values from the standardized procedure [19]. However, it can be helpful to see their variation when a building is exposed to transient outside conditions and when the building lay-out and location are considered.

**Table 5. Average decrement factor and time lag**

| | Summer week | | Winter week | |
|---|---|---|---|---|
| | Decrement factor [%] | Time lag [hour] | Decrement factor [%] | Time lag [hour] |
| SZ1-0 | 9.06 | 8.96 | 8.97 | 8.46 |
| SZ1-5 | 1.02 | 8.32 | 1.28 | 8.11 |
| SZ1-10 | 0.78 | 7.14 | 1.11 | 7.54 |
| SZ2-0 | 3.38 | 8.96 | 3.54 | 8.71 |
| SZ2-5 | 1.08 | 7.89 | 1.53 | 9.39 |
| SZ2-10 | 1.03 | 7.07 | 1.53 | 11.64 |
| SZ3-0 | 2.66 | 12.75 | 2.94 | 10.68 |
| SZ3-5 | 1.02 | 7.64 | 1.49 | 11.11 |
| SZ3-10 | 1.05 | 7.75 | 1.54 | 11.61 |
| SZ4-0 | 1.46 | 11.50 | 2.05 | 15.29 |
| SZ4-5 | 1.22 | 8.57 | 1.66 | 10.86 |
| SZ4-10 | 1.21 | 8.75 | 1.65 | 10.86 |
| SZ5 | 1.66 | 8.50 | 2.31 | 10.64 |
| SZ6 | 0.93 | 9.25 | 1.30 | 9.07 |

The values of time lag and decrement factor are calculated as construction averages for a winter and summer week, while variations per surface orientation are given in figs. The A1-A4 in the *Appendix*. It is interesting to notice that both the decrement factor and time lag show strong dependence on surface orientation and can aid in better building design and orientation if building energy simulations are used.

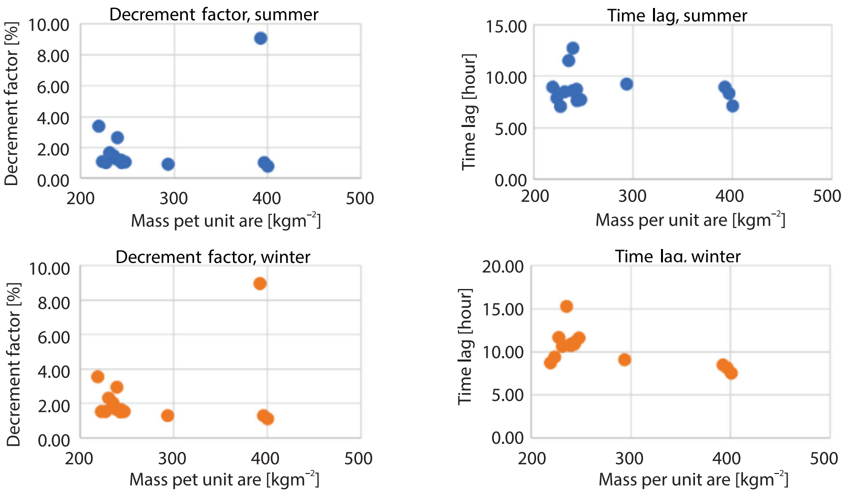


**Figure 4. Decrement factor (left) and time lag (right) *vs.* mass per unit area for 14 clay block structures for summer (upper) and winter (lower) conditions**

The values show that the proposed clay block, B6, on average has similar dynamic thermal properties to commercially available blocks, *i.e.*, it has a potential to dephase heat flux and lower its amplitude. One of the advantages is that this block meets the minimum requirements of Serbia's national legislation and has the potential to provide huge savings in labor hours per wall unit area construction.

## *Impact on building energy performance*

The analyzed building with six configurations of external walls from tab. 4 and with the systems serving as described previously was simulated with weather data for the city of Niš. As the reference case for comparison, the results with wall W3 were taken, keeping in mind that it had the lowest *U*-value. The reference case heating energy consumption was 5.390 kWh (specific energy consumption for space heating of 7.2 kWh/m$^2$), while cooling energy consumption was 11.825 kWh (specific energy consumption for space cooling of 15.8 kWh/m$^2$). The percentage differences are illustrated in fig. 5. Differences in heating and cooling capacities for both HVAC systems were infinitesimal.

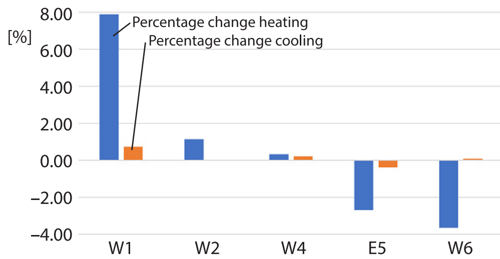


**Figure 5. Percentage change for heating and cooling energy demand amongst analyzed external walls**

From the aforementioned figure, it is evident that block B6, with higher mass, has the highest reduction in heating energy consumption (3.65% leading to specific energy consumption for space heating of 6.9 kWh/m$^2$), with a negligible difference in cooling energy consumption (as is the case for the rest of the analyzed clay blocks). This was expected since increased mass helps store heat, especially from internal gains, which is helpful during heating operation, considering that the radiant system was set as primary. For the cooling season, minimal differences were expected since the fan-coil system was designated as the primary system, and the radiant system operation was reduced to unoccupied periods with higher setpoint values, so the thermal mass did not have a major effect (specific energy consumption for space cooling has the value of 15.75 kWh/m$^2$). Since the analyzed building has highly insulated envelope constructions, there is a strong possibility that the impact increased mass has on energy consumption would be even larger for less insulated envelope constructions.

## Conclusions

The thermal inertia of a building is significant for its energy performance and is influenced by the materials used in building construction. Regularly used materials for external wall configuration in Serbia are clay blocks, but the selection of the block and the configuration with a smaller *U*-value does not guarantee better energy performance when a dynamic change in the building is considered. This paper shows that a clay block with higher mass positioned near the inside wall surface, and coupled with the building low temperature radiant floor system, can lead to energy saving for heating, with a negligible effect on building cooling energy consumption, with similar *U*-values between configurations and the same building and HVAC system operation. In fact, the wall with increased mass had the highest *U*-value out of all the analyzed cases, and still led to energy consumption reduction due to higher thermal inertia. This is important for traditional construction practice in Serbia, with masonry brick walls and insulation on the outside surface, especially in the residential sector where cooling is not on the list of top priorities in most cases. Although not yet produced, the proposed new type of clay block showed similar dynamic properties as commercially available clay blocks under the same conditions.

Also, wall radiant systems, which are not common in Serbia and were not investigated, could prove even more efficient due to increased wall mass, and would require a separate study, especially if heat pumps were to be used on the supply side.

The approach and results presented in this paper show that there is a potential for reducing energy consumption for space heating by increasing the mass of the clay block within usual block dimensions, however, the interest for producing such blocks remains unknown. Experimental investigation of mechanical and thermo-physical properties is strongly related to this interest. Assuming this type of block gets produced and satisfies mechanical properties, the best way to use the described approach is to scale the model down to a test cell model, replicate the test cell (to have physical measurements) and apply the standardized procedure in addition test cell simulations.

*Appendix A*

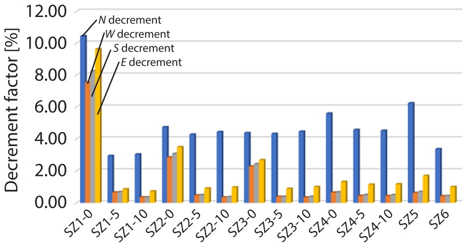


**Figure A1. Decrement factor per orientation-winter**

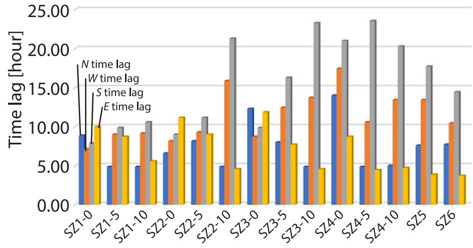


**Figure A2. Time lag per orientation-winter**

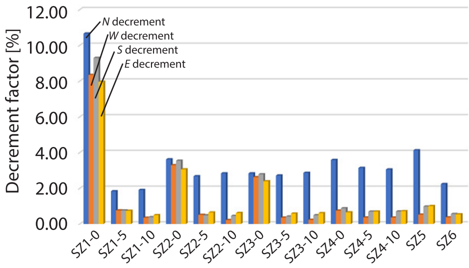


**Figure A3. Decrement factor per orientation-summer**

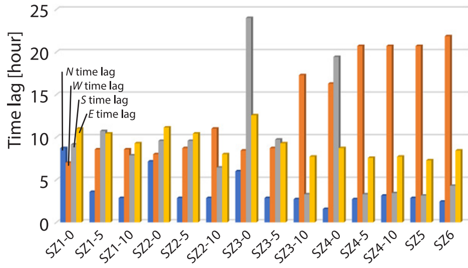


**Figure A4. Time lag per orientation-summer**

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