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Influence of the window roller shutters on the room temperature in residential buildings in Serbia

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Abstract
The roller shutters are an important factor for improving the energy efficiency of buildings, since their application could contribute to direct economic and environmental benefits. Their proper use allows for a significant reduction of heat loss in winter and excessive heat accumulation in summer, which is associated with a reduction in costs related to heating and air conditioning. The ability to adjust the degree of shading, allows the external shutters to control the sunlight, as well as the heat inside the room, which is especially important on hot summer days. As a result of shading regulation, rooms do not overheat, which reduces the need for air conditioning and makes everyday life more comfortable. In this article are presented results of an experiment conducted on the two rooms in a residential building in the city of Kragujevac, Central Serbia. The two rooms are placed on the East building's façade; the first being the so-called test room, which had the roller shutters installed on a window and lowered during the test period, while the second room – the reference one – had no shutters lowered. The objective of the experiment was to investigate the influence of the lowered roller shutters on the room's interior temperature, and consequently the energy consumption for the room's heating and cooling. It was established that the lowered blinds significantly contributed to the comfort of staying in the room, as well as to savings of the energy consumed for the room's heating in the winter and cooling in the summer.

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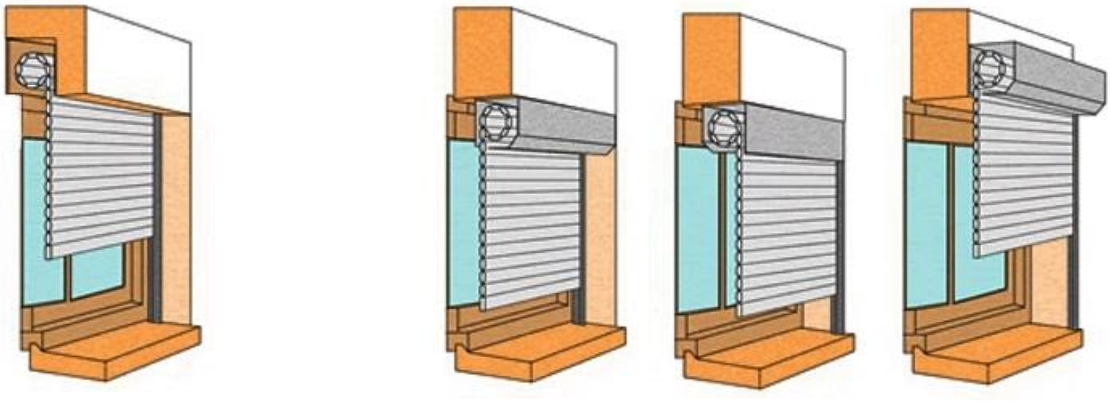
1. Introduction

Roller shutters (or blinds) are special parts of windows with the main role to protect the room's interior against the excessive solar radiation and glare in summer, and excessive heat loss during the winter. When lowered the shutters control the amount of the sunlight, as well as the ensuing heat gain. In summer they prevent the excessive heating, while in winter they contribute to lowering the cooling of the room's interior. External shutters are characterized by a solid construction and a long service life. In addition to protection from the sun, they protect against other adverse weather conditions (rain, wind, hail), as well. Shutters also provide acoustic insulation and protection against unwanted views and burglary.

The roller shutters consist of the so-called fins (slates, battens) strung together by plastic or textile strings over a metal drum. Slates can be manufactured from plastics (PVC with different hollow profiles, i.e., the cross-sections, various colors or textures, etc.), or from extruded aluminum filled with the polyurethane foam. The "old-fashioned' blinds had slats made of different types of woods; the blinds made of the bamboo's bars are still very popular.

The roller shutters can be manufactured in different versions, as the exterior, meaning outside of the widow/building, or as the interior, as the built-in component of the window. The other division is on visible and hidden shutters, the name explains their appearance – the hidden ones are built-in the window and cannot be seen, the other ones can. In addition to energy efficiency, exterior shutters are an important safety feature. Their construction and the material they are made of can deter potential burglars. Different types of roller shutters are presented in Figure 1. The roller shutters made of materials such as hardened aluminum are difficult to penetrate, which significantly increases the security of the house or a building. In addition, shutters can be equipped with motion sensors and integrated with alarm systems, providing a higher level of object protection.

The roller shutters can be controlled (lowered/raised) manually, usually by a belt that is wound over a cylindrical drum (roller), or the control can be motorized, i.e., the slats are pulled up or lowered down by and electromotor. Shutters with a manual system for raising and lowering are cheaper and easier to install, but shutters with a motorized system for raising and lowering increase the user comfort, i.e., they allow remote control, installation of weather sensors and integration with the smart home system.



(a) (b)

Fig. 1. View of roller shutters according to installation method: (a) hidden (internal), (b) external

The most used shutters nowadays are the hidden roller shutters that are actually used in the experiment results of which are presented in this article. They are the built-in part of the window (detachable or undetachable), placed in a housing within the window frame; all the parts can be accessed internally, i.e., from the interior of the room, Figure 1 (a). The other types of the shutters are presented in Figure 1(b), where the shutters' mechanism is placed outside the window frame/building and can be accessed from the exterior of the room/building only. They are most often installed on existing windows, as a retrofit. They are characterized by easy installation and maintenance.

The solar radiation through the window has dual effect on the everyday living comfort in the room. Firstly, it heats-up the interior, which is desirable in winter, causing the reduction of the energy consumption needed for heating. Secondly, during the summer, such a heating-up is not quite desirable since it causes increase in energy consumption needed for cooling of the room's interior. The influence of insolation for lighting the room's interior is also important since it causes reduction of energy consumption needed for room's lighting.

Previously conducted research efforts, dealing with impact of the roller shutters on thermal comfort and/or room's lighting, were devoted to finding the optimal(s) for both aspects and were mainly focused on complex and rather expensive propositions for the roller shutters' design, i.e., number and dimensions of slates, their position – inclination within the shutters, slats profiles and materials, as well as fillings. On the contrary, the research, results of which and reported here, was focused on simple and inexpensive external window shutters, retro-fit installed on a residential building (built in early seventies of the previous century) in a city of Kragujevac in Central Serbia. The shutters' energy efficiency was investigated through calculation of the heat load in two rooms, the test and the reference one, for the two characteristic climate periods – the coldest month of the year – February, and the warmest month of August, both in year 2023.

2. Literature review

Wong and Li (2007) were examining the effectiveness of commonly used passive climate control methods in the naturally ventilated residential buildings. They considered the effect of building orientation, facade construction, special roof system and window shading device on indoor thermal environment and cooling load. They showed that by increasing the length of the fixed horizontal blind, the cooling energy savings of up to 10% could be obtained.

Wankanapon and Mistrick (2011), have dealt with the possibilities for energy savings in use of the roller blinds on windows in commercial buildings in two US cities, Minneapolis, Minnesota (with a dominant heating climate) and Houston, Texas (with a dominant cooling climate). They considered various control parameters for automatic shadow and lighting control, using the energy simulation program EnergyPlus. Authors concluded that due to variety of glazing and shadings, the generalization which strategy is the optimal one cannot be ad hoc recommended. However, they did notice that that the exterior shading devices can be used to further reduce the cooling load that results from sunlight entering vertical glazing, particularly in warmer climates.

Huang et al. (2014) have conducted a series of simulation studies to evaluate the performance of several energy efficient window designs in cooling-dominant climates. The main objective of this research was to evaluate the cost-effectiveness of these windows constructions and to show the influence of window orientation, as well as the latitude of the building's location. Authors claim that the best choice is the low-emission glass, taking into account both the heat load and daylight, while the double-glazing exhibited the worst performance. In this type of climate all the window designs perform better on the east and west orientations, while the worst performance occurs on the north orientation. The difference among orientations becomes insignificant with latitude increase.

Oleskowicz-Popiel and Sobczak (2014) presented a study of the roller blinds effect on the heat losses from the central part of the double-glazing window during the night in the heating season in Central Europe. Their results point that the internal roller blinds can save about 33% and external blinds about 45% of the heat loss through the central part of the double-glazed window, with similar results for a double-glazed window with a low-emissivity coating. Thus, indoor roller blinds and outdoor blinds can save around 29% and 44% respectively. Authors also considered the influence of the outdoor atmospheric air temperature, as well as the external air velocity, on the overall heat transfer coefficient of the double-glazed window without low emission coating layers. The influence of the former is not as strong as the influence of the latter.

Kuhn (2017) presented an overview and comparison of advanced solar control devices for buildings, with the guidelines for the development of new solar control systems. He introduced two separate areas in the analysis, the design space and the evaluation space. The former contains the design parameters based on which the designer selects the particular control devices or develops the new system for a specific building (the color of the slat of a venetian blind, the fraction of holes, a fabric for a roller blind. The latter contains the evaluation criteria that indicate the ability of the chosen design to satisfy the functional and aesthetic requirements (passive solar gain control, or visual comfort).

Kim et al. (2017) have considered design of the horizontal shading devices, which became mandatory to install in some public buildings in Republic of Korea. Their installation may cause indoor environmental problems, due to the fact that they might reduce the indoor intensity of illumination, which may cause additional energy consumption. Authors calculated annual energy consumption by applying the lighting control and it was found that the total energy consumption decreased by reduction of air-conditioning and fans and lighting energy consumption.

Dabbagh and Krarti (2021) have evaluated the potential energy savings of novel switchable insulated shading systems applied to smart windows for US residential buildings. Those switchable shades consist of dynamic and controllable transparent insulating layers protecting the smart windows. The control strategies include dynamic variation of the shades' R-value and adjusting the smart windows' solar heat gain coefficient. For the 15% WWR (window-to-wall ratio) for a building in Golden, Colorado, the switchable windows, operated with 2-step controls, could reduce the annual heating energy end-use, cooling energy end-use, and electrical peak demand by respectively, 27.3%, 37.7%, and 8.3%, when compared to the performance of the same dwelling with unshaded static windows. For the higher WWR of 50 % for the building in San Francisco, California, the savings were even bigger, 68% in heating annual energy end-use, 73% in cooling annual end-use, and 12.1% in annual electrical peak demand compared to the house with unshaded regular windows.

Abdullah et al. (2022) were comparing the residential building windows' thermal performance with and without thermal shutters, insulated with various types of insulation, glares, outside temperatures, and solar radiation. They used the computer simulation software "DesignBuilder" to examine the impact of window shutters design on energy consumption and environmental impact. Authors concluded that using the conventional insulating materials is sufficient for the house to attain a reduction in the heat gain of up to 50%; while the application of the rolling shutters with control strategies recorded a potential reduction in equivalent CO_2 emissions level up to 15%. The economic feasibility can be obtained through the selection of conventional insulating materials that cost almost 10 times less in initial material costs rather than savings from the annual energy consumptions, especially for buildings that have larger windows area.

Mohhamad et al. (2022) investigated the influence of different types of shading devices on the cooling load of a town hall building located in Darwin, Australia, and proposed the optimal shading device. They investigated various types of shading devices, namely eight horizontal fins of different sizes inclined at 0° and 30°, horizontal louvres overhangs of two different sizes, tilted horizontal louvres of different sizes at 180° and 360° , and horizontal louvres inclined at 45°. The results showed that the horizontal fins led to a 5% reduction in the cooling load of the building, with additional savings increase to 8 % by adding a variation to the device angles and length. The overhangs were more efficient than the fins, contributing to 9.2% energy savings, with increase up to 15.5% with design and length variations.

Alkhatib et al. (2023) were the first to identify the most effective of seven alternative control parameters to control the roller blinds. They defined the benefits from using paired control parameters to maximize energy savings and optimize occupants' comfort, investigating the following parameters: total solar irradiation (TR), direct solar radiation (DR), indoor daylight illuminance (ID), outdoor air temperature (OT), indoor air temperature (IT), sky temperature (ST), and operative temperature (OP), both individually and in pairs. The optimum control parameter was defined as one that minimizes energy needs, while maintaining the thermal and visual comfort conditions. The conclusion is that for the three considered European cities (Dublin, Berlin and Madrid), the best control parameter for the rolling blinds control is the indoor temperature, if a single parameter is considered. For the two parameters control, the best combination is outdoor temperature and indoor temperature. Considering simultaneous control with three or more parameters did not provide much improvement in energy savings nor the occupants' comfort.

Hu et al. (2023) have investigated the impact of roller blinds on energy consumption in a subtropical climate. The lighting control experiments were performed on west-facing and south-facing windows in the Subtropical Performance-Testbed for Innovative eNergy Research in Buildings Laboratory (SPINLab). The results presented in that paper show that the energy consumption for cooling was reduced for 10 % and for lighting 90 % for the room with west-facing window. For the room with the south-facing window the sunlight was sufficient to supplement the lighting completely.

Lu (2024) presented results of a series of simulations of an office building in Culver city, California, to compare the performance of conventional static glazing, exterior static and kinetic shades, dynamic glazing, and dynamic glazing working together with static or kinetic shades as a combinatorial system. He developed a scoring system to evaluate the overall performance of a building with energy, visual and thermal performances having the same weight. The higher amount of sunlight and solar heat were coming from the south window all day, while the west window had a high amount of sunlight and solar heat only in the afternoon before sunset. The tinted electrochromic (EC) glazing and static overhangs shielding simultaneous deploying on the two facades resulted in the lower peak cooling loads than for the tinted EC glazing with miniature blinds only deployed on one façade.

3. The heat load and the heat transfer coefficient calculations

Calculations of the heat load transferred through the window into the room's interior and of the heat transfer coefficient are given in detail in Djokovic et al. (2023). Here are those calculations presented in a very brief form.
The heat load through the window can be obtained by measuring the difference between the outside air temperature T_{out} and the inside air temperature T_{in}. It is a sum of the two components. The first is due to the heat transferred through the window $Q_{to,tr}$, while the second component is due to the solar radiation $Q_{to,sol}$.

The heat load due to heat transferred through the window (of an area A) with the heat transfer coefficient U_w is calculated as

$$Q_{to,tr} = U_w \cdot A \cdot (T_{out} - T_{in}) \,. \tag{1}$$

On the other hand, the heat load due to the solar radiation is obtained as:

$$Q_{to,sol} = F_{sh} \cdot g_{gl} \cdot (1 - F_f) \cdot A \cdot I_{sol} \cdot \tau_{sol} \,, \tag{2}$$

where F_{sh} is the room shading factor obtained as:

$$F_{sh} = F_{hor} \cdot F_{ov} \cdot F_{fin} \tag{3}$$

and with F_{hor} being the correction factor for the latitude (here 45° North), F_{ov} the correction factor due to the canopies, F_{in} the correction factor due to the vertical outlets on the façade; tables A1 to A3, respectively. Additionally, g_{gl} is the window glass transmittance factor (table A4), F_f is the window frame factor (tables A5 to A7).; $I_{sol} \cdot \tau_{sol}$ is the mean sum of the solar radiation (table A8).

The heat transfer coefficient of a window U_w is obtained as a function of the heat transfer coefficients of all the window elements – glass, frame, number of chambers, their filling, etc.:

$$U_w = \frac{A_g \cdot U_g + A_f \cdot U_f + l_g \cdot \psi_g}{A_g + A_f} \,, \tag{4}$$

where: U_g is the heat transfer coefficient of the glass, U_f is the heat transfer coefficient of the frame, A_g is the glass area, A_f is the frame area, l_g is the perimeter of glass area and ψ_g is the linear heat transfer coefficient – temperature correction factor for thermal bridges between frame and glass, (tables A9 and A10).

So, the total heat load is then obtained as, ASHRAE Handbook: Fundamentals (2001):

$$\begin{aligned} Q_{to} &= Q_{to,tr} + Q_{to,sol} \\ &= \frac{A_g \cdot U_g + A_f \cdot U_f + l_g \cdot \psi_g}{A_g + A_f} \cdot A \cdot (T_{out} - T_{in}) \,. \\ &+ (F_{hor} \cdot F_{ov} \cdot F_{fin}) \cdot g_{gl} \cdot (1 - F_f) \cdot A \cdot I_{sol} \cdot \tau_{sol} \end{aligned} \tag{5}$$

The heat transfer coefficient of a window with a lowered shutter U_{ws} is calculated as (EN ISO 10077-1:2006):

$$U_{ws} = \frac{1}{\dfrac{1}{U_w} + \Delta R} \,, \tag{6}$$

where ΔR is the additional thermal resistance due to the air layer between the lowered shutter and the window itself.

4. Experimental setup

The tests consisted of the interior-temperature monitoring in two identical rooms, located next to each other, on the East side of the thirteen-story residential building façade, on the fifth floor, in the city of Kragujevac in central Serbia, Figure 2. The rooms' size was cca 12 m^2, each had only one window with 2.4 m^2 area, double-glazed with air filling between the two glasses and a PVC frame. The window glass was low-emission glass 4 mm thick. One room was used as a test room with the shutters lowered, while the second room served as a reference one, with no lowered shutters. The shutters are also made of the PVC slates (fins) with manual control, retro-fit on the building as external.

Fig. 2. Location of test and control rooms

The tests were conducted during the coldest month of the year, in February (01.02.2023 to 28.02.2023) and in the warmest month, in August (01.08.2023 to 31.08.2023). During the coldest month the objective of the experiment was to investigate the influence of the roller shutters on energy consumption needed for heating the room, while in the warmest month, the objective was to investigate the influence on the energy consumption for cooling the room interior. The roller shutters in the test room were lowered from 08:00 to 12:00 in the morning. The temperature was measured using a DS18B20 digital sensor, and an Arduino Uno module was used to collect and process data within the framework of temperature measurement, Figure 3.

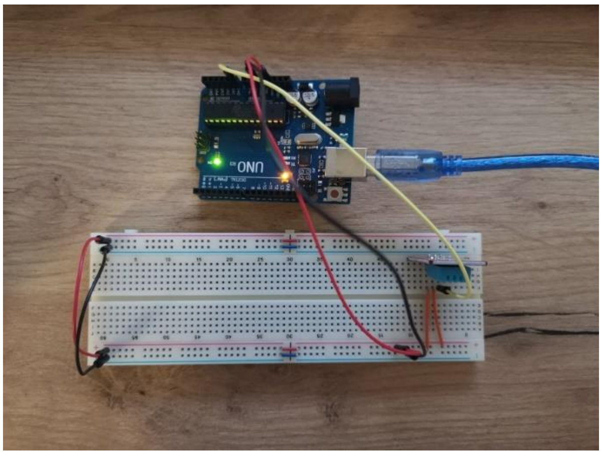


Fig. 3. Arduino Uno module with temperature sensor

5. Results and discussion

The experimental results are presented in figures 4 to 8. The outdoor temperatures for the period(s) of temperatures monitoring were obtained from the website of the Republic Hydrometeorological Institute of Serbia, for the city of Kragujevac in Central Serbia.

The results obtained by the temperature recording are presented in Figure 5. Figure 5(a) presents the results of the temperature recording for a randomly chosen day from the coldest month (11. February 2023) and figure 5(b) presents the recorded temperatures for randomly chosen day in the warmest month (03. August 2023). From Figure 5, one can easily clearly notice the impact of using the shutters on the temperature in the room. In the test room, the room in which the shutters were lowered, the temperature was more comfortable than in the control room. During the winter (February) the temperature in the test room was higher than in the control room, while in the summer (August) the temperature was lower. Figure 6 presents the average temperatures for the whole monitoring periods. For the month of February, the temperature in the test room with the lowered shutters was for an average of 1.76°C higher than in the control room, Figure 6(a). For the month of August, the temperature in the test room was for an average of 3.57°C lower than in the control room, Figure 6(b). The advantage of having the roller shutters lowered is obvious.

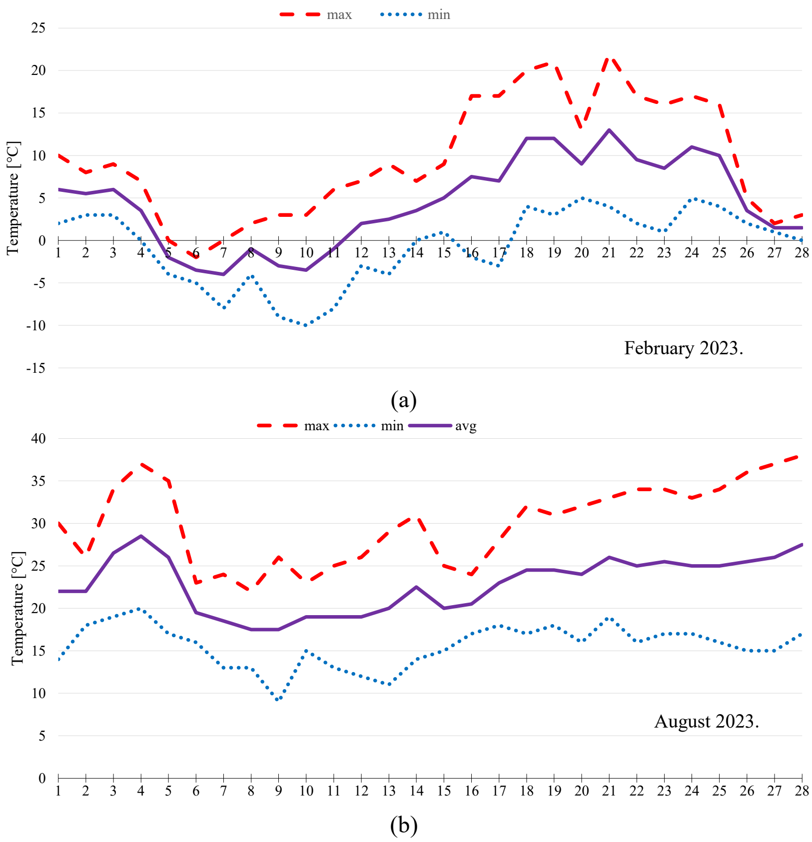


Fig. 4. Outdoor temperature in: a) February 2023 and b) August 2023.

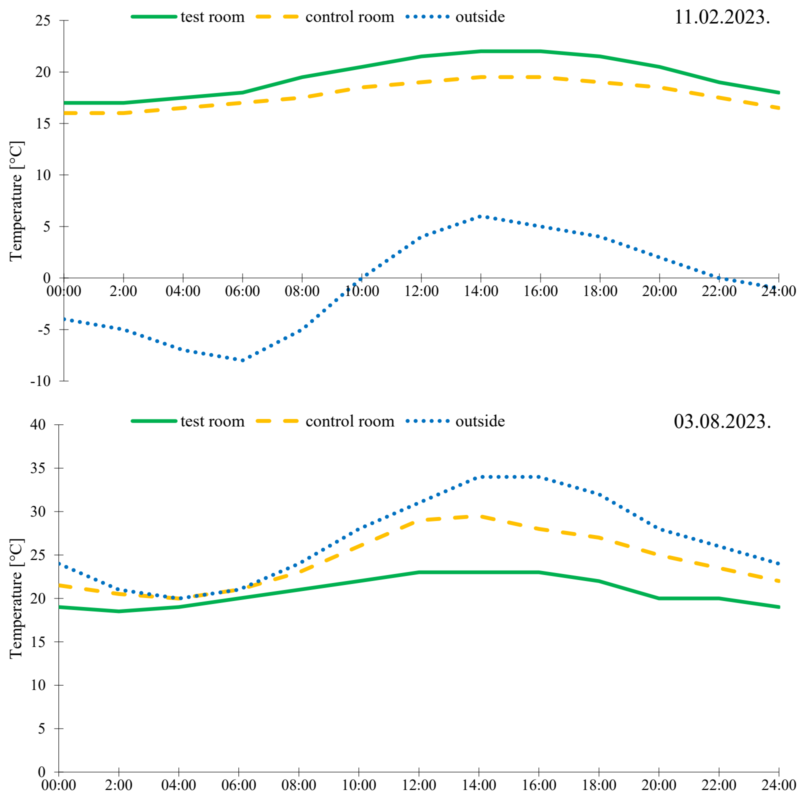


Fig. 5. Temperatures obtained by measuring in the test and control rooms during the day.

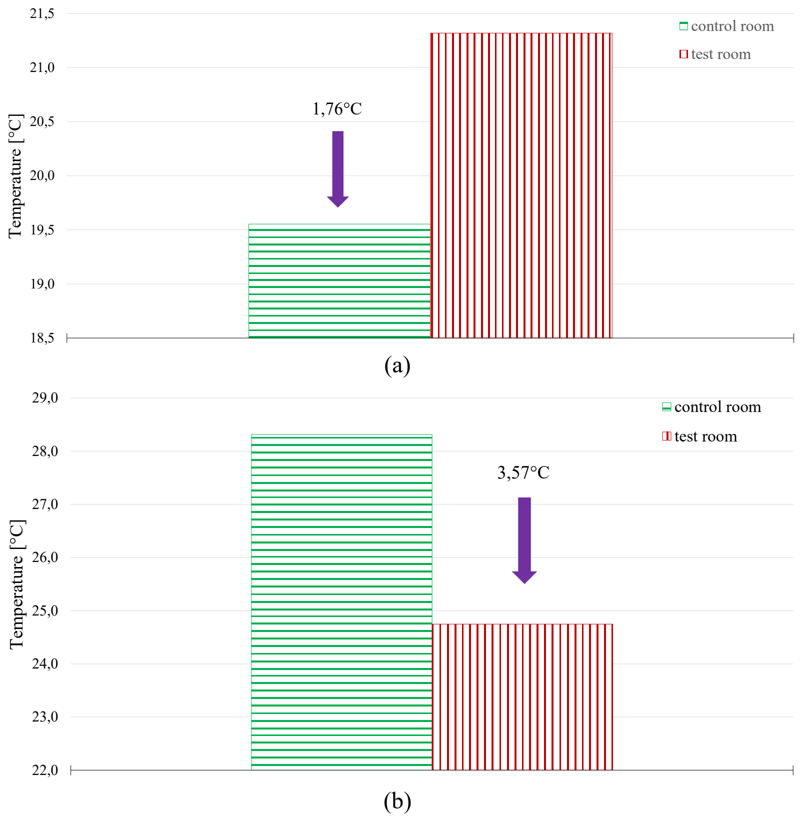
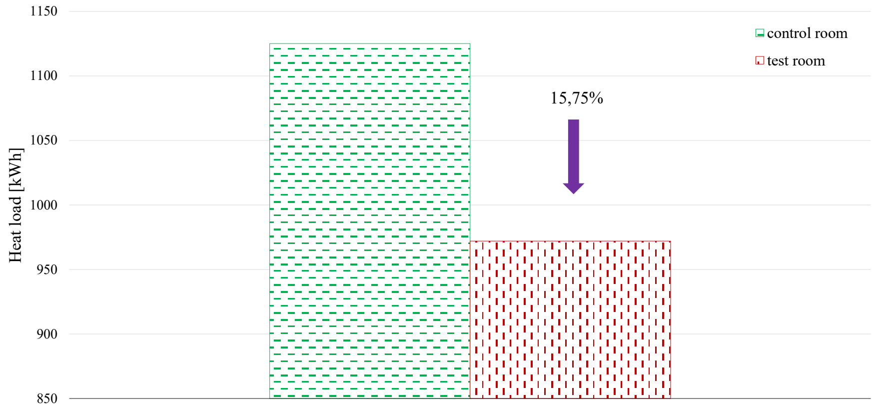


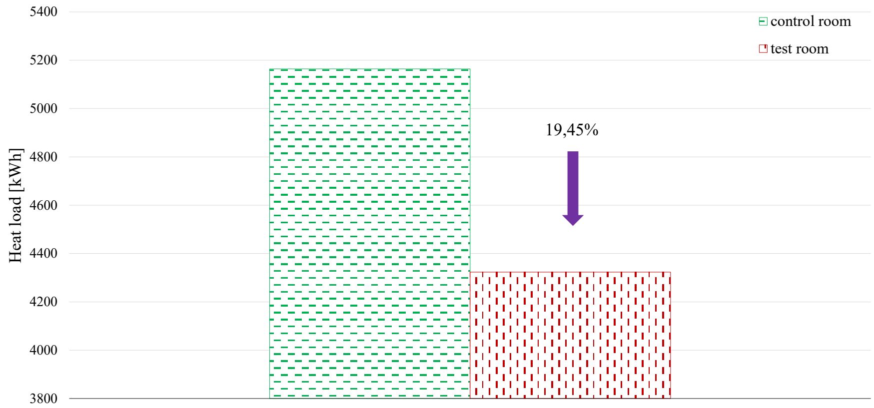
Fig. 6. Average temperature in the control and test rooms for: a) February 2023 and b) August 2023.

The results for the calculated heat load transferred through the window, for the monitored period(s), are given in Figure 7. From the figure can be seen that lowering the shutters in the test room contributes to heat load reduction in the test room, namely for 15.75 % in February and 19.4 % in August. This implies the reduction in the energy needed for heating in winter for 15 % and for cooling in summer for 20 %.

The results shown in Figures 6 and 7 are taken from the analysis presented in the paper by Djoković et al. (2023). The values of the heat transfer coefficient, calculated based on equations (4) and (6), for the widow with shutters lowered in the test room, and for the window without the shutters lowered in the control room, are presented in Figure 8. From the figure, one can see that the value of the heat transfer coefficient of a window without a shutter is higher than the value for a window with a lowered shutter, which was expected



(a)



(b)

Fig. 7. Total heat load in kWh for: a) February 2023 and b) August 2023.

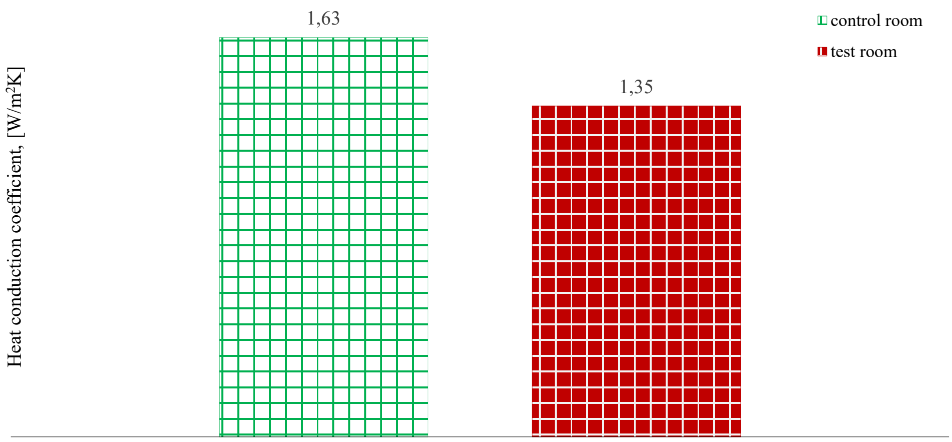


Fig. 8. Heat transfer coefficient for a window without a shutter and a window with a shutter

6. Conclusions

Based on the conducted research on the energy efficiency of the roller shutters, the following observations can be made:
The roller shutters represent important elements of the window's construction, since they enable savings in the energy consumption needed for the room's interior heating or cooling, depending on the season of the year.
Within this research, the tests conducted consisted of the interior air temperature recording in the two rooms of a residential building in the city of Kragujevac in Central Serbia. One room served as the test room, which had the roller shutters lowered down from 8 AM to 12 AM, the other was the control room without the lowering the shutters. Measurements were made for the coldest and the warmest months of the year, February and August in 2023.

The obtained results confirmed that using the roller shutters significantly improves the living comfort in the test room, lowering the average temperature in the summer for 3.57°C and raising the average temperature for 1.76°C in the winter, which caused the energy consumption reduction for 20% (for cooling in the summer) and 15.75% (for heating in the winter). The values of the heat transfer coefficient were higher for the window with the lowered shutters, which was the expected result.

Thus, one can conclude that, despite the shutters in question being the cheap, of a retro-fit simple construction, added as external shutters more than 20 years after the building was erected, their adding to the building/windows construction was justified by the energy consumption savings. The amount of the heat savings for the whole building, at least for the east façade, could be easily calculated. The two rooms and windows are the usual ones, with the shutters constructed for all the others on the building in the same way.

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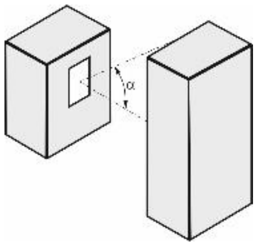
Appendix

All the tables in this Appendix are taken from reference Official Gazette of the Republic of Serbia (2017) and translated to English language, with numbering adapted to the position in the text.

Table A1. The building shading factor due to the surrounding objects

Correction factor F_{hor} for 45° NL			
Angle, °	S	E, W	N
0	1.00	1.00	1.00
10	0.97	0.95	1.00
20	0.85	0.82	0.98
30	0.62	0.70	0.94
40	0.46	0.61	0.90

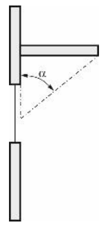


Original number in the cited reference for this table is 6.6.

Table A2. The building shading factor due to canopies

Correction factor F_{ov} for 45° NL			
Angle, °	S	E, W	N
0	1.00	1.00	1.00
30	0.90	0.89	0.91
45	0.74	0.76	0.80
60	0.50	0.58	0.66

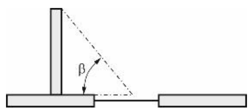
Vertical section



Original number in the cited reference for this table is 6.7.

Table A3. The building shading factor due to vertical outlets on the facade

Correction factor F_{fin} for 45° NL			
Angle, °	S	E, W	N
0	1.00	1.00	1.00
30	0.94	0.92	1.00
45	0.84	0.84	1.00
60	0.72	0.75	1.00



Original number in the cited reference for this table is 6.8.

Table A4. Thermal properties of the transparent building material – GLASS

Glass type	U_g W/(m²·K)	*g*
Single, 6 mm	5.8	0.83
Double transparent, 6-8-6 mm	3.2	0.71
Double transparent, 4-12-4 mm	3.0	0.71
Double transparent, 6-12-6 mm	2.9	0.71
Double transparent, 6-16-6 mm	2.7	0.72
Tripple transparent, 6-12-6-12-6 mm	1.9	0.63
Double low-emission, (air) 4-12-4 mm	1.6	0.63
Double low-emission, (air), 4-16-4 mm	1.5	0.61
Double low-emission, (Ar), 4-15-4 mm	1.3	0.61
Double low-emission, (Kr), 4-12-4 mm	1.1	0.62
Double low-emission, (Xe), 4-12-4 mm	0.9	0.62
Tripple low-emission, (Kr) 4-8-4-8-4 mm	0.7	0.48
Tripple low-emission, (Xe) 4-8-4-8-4 mm	0.5	0.48
Double reflecting (Ar), 6-15-6 mm	1.3	0.25 - 0.48
Double reflecting (Ar), 6-12-4 mm	1.4	0.27 - 0.44

Original number in the cited reference for this table is 3.4.1.4.

Table A5. The heat transfer coefficient – wooden frame

Thickness d_f, mm	U_f, W/(m²·K)	
	Soft wood (500 kg/m³) λ = 0.13 W/(m·K)	Hard wood (700 kg/m³) λ = 0.18 W/(m·K)
30	2.3	2.7
50	2.0	2.4
70	1.8	2.0
90	1.6	1.8
110	1.4	1.6

Original number in the cited reference for this table is 3.4.1.5.

Table A6. The heat transfer coefficient – PVC frame

Material	Frame type - profile	U_f W/(m²·K)
PVC-hollow profile	2-chamber	2.2
	3-chamber	1.7 - 1.8
	5-chamber	1.3 - 1.5
	6-chamber	1.2 - 1.3

Original number in the cited reference for this table is 3.4.1.6.

Table A7. The heat transfer coefficient – metal frame

Metal frame type	U_f, W/(m²·K)
Steel with thermal break	4.0
Steel without thermal break	6.0
Aluminum with thermal break	2.8 - 3.5
Aluminum, improved	1.4 - 1.5
Special profile systems for the passive houses	0.7 - 0.8

Original number in the cited reference for this table is 3.4.1.7.

Table A8. Mean sums of solar radiation and mean monthly temperature of the outside air Mean sums of solar radiation and mean monthly temperature of the outside air, kWh/m²

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Winter
Medium monthly temperature ° C	0.9	3.0	7.3	12.5	17.6	20.6	22.3	22.0	17.7	12.7	7.2	2.6	5.6
HOR	42.75	60.35	103.86	133.65	170.43	181.23	192.83	170.43	127.58	88.94	45.50	33.87	398
S	64.25	76.98	96.43	86.73	86.28	81.43	90.31	99.43	107.38	109.22	66.52	52.80	455
E, W	32.57	55.35	79.80	96.05	112.9	116.78	125.22	114.37	91.32	67.21	34.67	25.53	310
N	17.42	22.38	36.04	44.64	55.69	56.88	58.27	52.83	38.78	29.16	17.93	14.31	145
HDD - 2520	585	458	370	102	0	0	0	0	0	101	373	531	

Original number in the cited reference for this table is 6.9.

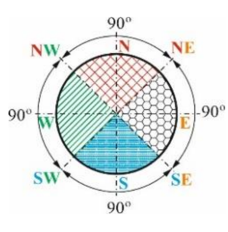
Table A9. The temperature correction coefficient for the thermal bridge between the frame and a glass

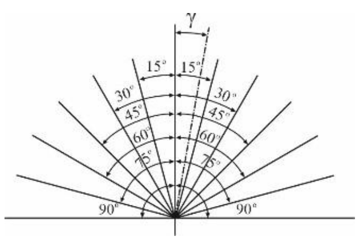
	Correction coefficient, ψ_g	
	Double and multiple glass, without the improvement layer	Double and multiple glass, with the improvement layer
Wooden and PVC frames	0.04	0.06
Metal frames with the break thermal bridge	0.06	0.08
Metal frames without the break thermal bridge	0.00	0.02

Original number in the cited reference for this table is 3.4.1.8.

Table A10. Orientation in the horizontal plane and slopes of the slanted surfaces

Orientation of the façade walls*	Inclination angles of the slanted surfaces **





*Note: The orientation of the facade walls of the building is defined according to the predominant orientation towards one of the four sides of the world (East, West, North and South) and depending on the predominant orientation, the values of the mean sums of solar radiation from table 6.9 are adopted.

** Note: If the calculation is done for slanted facade elements, it is necessary to correct the mean sums of solar radiation, as follows:

1. For the angle of inclination $-15° < \gamma < +15°$ - no correction is made, but the surface is treated as vertical;
2. For the angle of inclination $+30° < \gamma < +75°$ - the correction is made according to the equation: $q_{sol} = q_{sol,tab} \cdot \sin(90 - \gamma)$;
3. For an angle of inclination $+75° < \gamma < +90°$ - no correction is made, but the surface is treated as horizontal.

Original number in the cited reference for this table is 6.10.