CONFERENCE PROCEEDINGS

3RD INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

EDITORS
EVA VANIŠTA LAZAREVIĆ
MILENA VUKMIROVIĆ
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
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Eva VaništaLazarević, Milena Vukmirović, Aleksandra Krstić-Furundžić, Aleksandra Đukić

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EFFECTS OF WINDOW REPLACEMENT ON ENERGY RENOVATION OF RESIDENTIAL BUILDINGS–CASE OF THE SERBIAN BUILDING PRACTICE

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ABSTRACT

Achieving the desired degree of energy efficiency in buildings has become an imperative of nowadays construction.This requirement is set in relation to both new and existing buildings, in order to reduce their energy consumption, but also to improve the overall comfort, especially thermal, contributing in this way to a creation of a healthier place.

Measures that are applied in order to improve energy efficiency in buildings include various interventions on its thermal envelope, which in the case of energy renovation of existing residential buildings is not necessarily all-inclusive.The effectiveness of the measures implemented to assess the appropriate calculation methodology of the energy required for heating, as in the case of existing regulations in Serbia, implies that applied enhancement should contribute to the improvement of their energy class for at least one energy rate. Such improvement, especially in the case of larger buildings, could be achieved only by improving the air-tightness of the existing windows, but their replacement with windows of high energy performances is the most common measure in practice. However, without energy rehabilitation of surrounding façade walls, such intervention could cause condensation along the peripheral, insufficiently insulated, non-transparent structures. Thus, the positive effects of the improvement measures could be questioned.

Taking into account the characteristics of the existing building stock in Serbia, typical situations of existing contacts between the façade walls and the corresponding windows are simulated in the paper, in relation to the risk of condensation and consequent potential users' health problems.

Keywords: energy renovation, window replacement, condensation

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INTRODUCTION

Buildings are recognized as the largest consumers of energy of a society. Therefore, increasing their energy efficiency as a way to reduce the need for energy has become an imperative. The issue of energy savings is equally set in front of the newly designed building, as well as the existing ones. Rule that regulates the issue of energy efficiency in buildings, in the case of Serbia, the Rulebook on energy efficiency in buildings, at the same time seeks and secures the necessary comfort. [1]

In terms of existing buildings and their energy optimization, one of the most commonly used measures in practice refers to the replacement of existing windows with energy efficient ones. This type of intervention acts on an element of the thermal envelope which share in the energy balance of the existing building is far the largest, as confirmed by recent studies conducted on the existing housing stock in Serbia. [2] At the same time, it is an intervention that can be easily carried by the direct user and can be localized to a single housing unit, or even a room. This is certainly one of the reasons for the popularity of this measure which is applied equally to the family houses and the apartment buildings.

Having in mind the typical structure of the thermal envelope of existing residential buildings, primarily the fact that thermal properties of the older buildings are far below those required by modern legislation, it can be assumed that the contact of an improved, well-insulated windows, with uninsulated or poorly insulated façade wall could represent a zone along which one can expect the formation of condensation, with all the negative consequences that this phenomenon can bring, especially for the health of users. The existence of the potential risk of condensation on such connections of typical facade walls of existing residential buildings is exactly the subject of analysis in this paper.

CHARACTERISTICS OF EXISTING BUILDING STOCK IN SERBIA

Recent studies of housing stock in Serbia and Belgrade have indicated the particular characteristics of the existing buildings and their structures, significant for their energy performance. [2, 3, 4, 5]It turned out that the building tradition of the region is such that over a long period of construction, solid brick stands out as the dominant building material, and is still used today. Besides the brickwork, there is a tradition of the use of clay masonry block, while other building materials are represented to a lesser extent. (Figure 1)

In the case of windows of existing residential buildings, different types of wooden windows were usually applied. In the period before World War II dominated the double frame windows with single glazed double sash and a wide box. A similar type of window, but with a narrow box, was typical for the latter period. The situation lasted until the sixties of the last century, whereupon it could be said that application of a single frame, connected double sash windows with single glazing prevailed. The method of installing these types of windows in the façade wall implied the creation of rebate, which somewhat increased the air tightness on the connection of the window and the wall. Size of the rebate has been standardized depending on the type of applied window. (Figure 1) From the eighties of the last century began the mass use of single frame wooden windows with a double glazed unit.

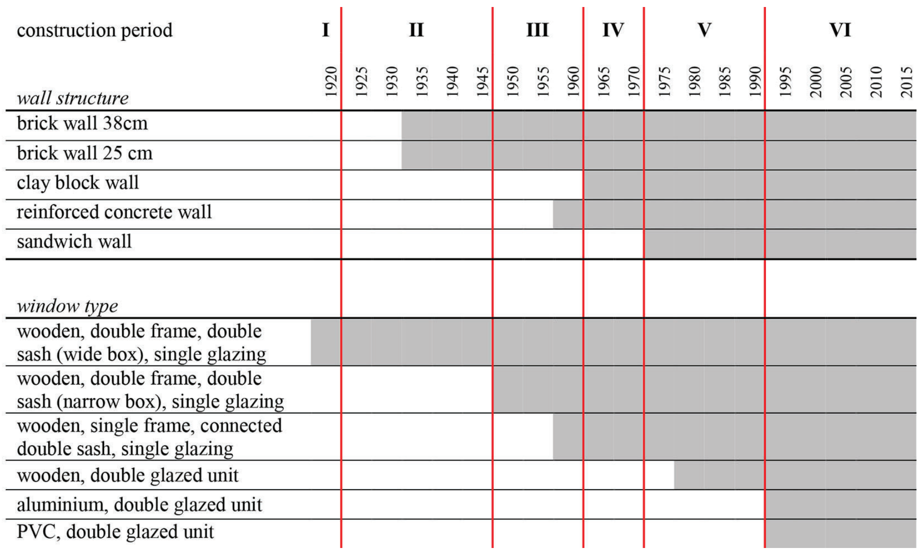


Figure 1: Overview of presence of façade walls and windows on residential buildings by construction periods

DEFINING OF MODEL AND RESEARCH METHODOLOGY

Geometric and material properties of the analysed wall-window connection

As a model which was investigated in this paper a 25cm thick brick wall was chosen, with the presumed value of thermal conductivity λ = 0.67 W/mK. The wall has 2cm thick mortar render on both sides, with specified values of thermal conductivity - λ = 0.51 W/mK the inner render and λ = 0.87 W/mK the external one. It is assumed that energy optimization would be conducted on the wall that dates from an earlier period of construction, so the wall has a rebate of the corresponding dimensions. Contact between the newly installed window with the wall and with the concrete lintel above was considered through relevant details in horizontal and vertical sections. (Figure2; Table 1)

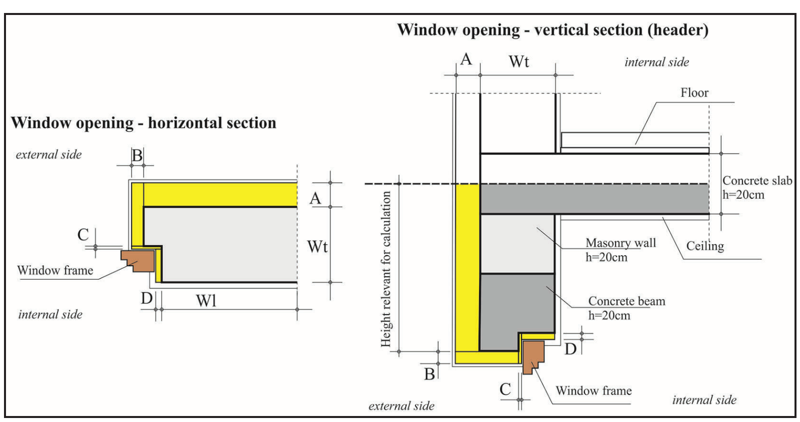


Figure 2: Scheme of typical horizontal and vertical section details of windows – wall connection

Table 1: Input data - the presumed characteristics of the analysed existing wall and the relevant labels

Abbreviation	Term	λ [W/mK]	Thickness [cm]
W	Wall – solid brick	0.67	25
W_L	Wall length (internal)	-	variable (100; 50; 25)
M_i	Mortar internal	0.51	2
M_e	Mortar external	0.87	2

The analysed joints of a wall and a lintel with a window represent the place in the wall structure where a thermal bridge occurs. According to the current European regulations, [6] its effect on the overall thermal performance of the wall is analysed on the length of the wall of 100cm. Since, in practice, the distance between the two windows is usually much smaller, the paper also examines two other cases of the influence of thermal bridge: for wall fragment of 50cm, and of 25cm length. It is assumed that the energy rehabilitation considers replacement of existing windows with those of high energy performance, having 6cm thick frame (Ft).

Research of character of a contact at the junction of the wall and the window was analysed through several different scenarios regarding the manner and extent of energy optimization of wall. Assumptions ranged from the option that only replacement of existing window the wall was carried out, to the option that the outer parts of the wall (external side, outer reveal) were isolated with variable thicknesses of thermal insulation. In all scenarios, relevant areas on a contact of the wall and window frame are treated in the same way - window frame - interior reveal contact zone is isolated with a 2cm thermal insulation, while window frame - rebate direct contact was not isolated. (Table 2)In all situations, it is assumed that thermal conductivity of the applied thermal insulation was λ = 0.04 W/mK.

Table 2: Input data - the presumed additional thermal insulation thickness depending on the position

Label	Term	Thickness [cm]
A	External face	variable (14; 12; 10; 8; 6; 0)
B	Outer reveal	variable (0; 1; 2; 3; 4)
C	Contact rebate-window frame	constant (0)
D	Contact window frame-inner reveal	constant(2)

Climate data relevant for the calculation

Condensation on the analysed contact is potentially possible in the winter period so for the needs of this work the appropriate climatic data which are in accordance with applicable regulations were set. [1] The external design temperature is defined as -12^oC (corresponding to climatic characteristics of Belgrade) with simultaneous relative humidity of 90%.For interior design conditions it is assumed that the temperature of the indoor air was + 20^oC, while the humidity varied. Although the regulation stipulates that the relative humidity of the interior space is 50%, the paper analysed the cases in which internal relative humidity is higher (60, 70 or 80%). Such situation is realistic and often happens in the winter due to the improper use of space, in the first place due to the habit of drying laundry on heating devices without the ventilation of the room. Thus, for some time the relative humidity rises to 80% and more.

The method of calculating the impact of thermal bridge

The influence of thermal bridge that occurs at the contact of the window and the brick masonry façade is analysed by identifying several relevant values: a) the so-called equivalent heat transfer coefficient (U_{eqv}).It is calculated as the ratio of the total transmission losses (surface heat transfer + thermal bridge impact) in regard to the observed surface of the wall.b) The calculation also determines the temperature at the place of the so-called critical point (T_c) as the minimum contact temperature of the interior in the zone of the window opening.

The risk of surface condensation is estimated on the basis of the calculation of the temperature factor f_{Rsi} which is determined for different combinations of the presumed design temperature and relative humidity. As the limit values of the temperature factor for the given different values of relative humidity those that correspond to the respective dew point temperatures are calculated. (Figure 3)

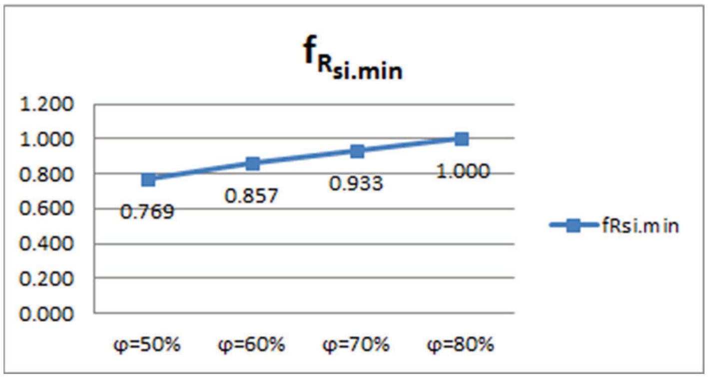


Figure 3: Diagram of limit values of the temperature factor

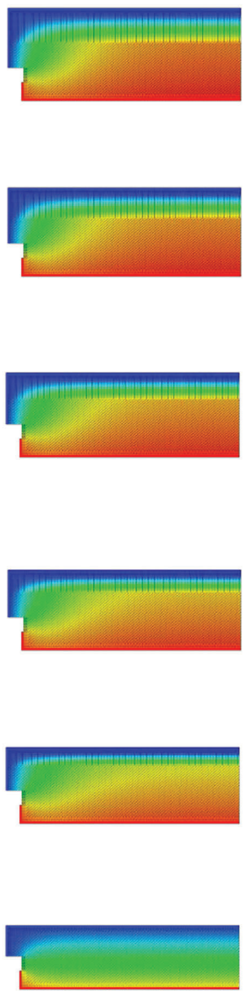
To prevent the formation of mold, it is necessary to fulfil the condition that each point on the inner surface of the wall has a temperature or the temperature factor that is greater than or equal to the critical. [7] Hence, calculating the values of f_{Rsi} obtained for the given variations of energy optimization should be higher than these boundaries, in which case there is no risk of condensation within the analysed wall fragments. All calculations of relevant thermal characteristics of the analysed cases of energy optimization were carried out using the authoring software T-Studio. [8]

RESULTS

In the case of the scenario of the wall length of 100cm, all combinations of variations of wall insulation thicknesses and outer reveal insulation thicknesses were made. The calculated values of U_{ekv}, T_c and f_{Rsi} for analysed cases are presented on the Figure 4. Apart from these parameters, percentage increase relative to the baseline heat transfer coefficient %U- without the influence of the window opening was also calculated and presented.

With increase of thickness of the insulation of outer reveal (position B), the intensity of linear heat losses, as well as the resulting percentage increase of the basic U-value decrease. For non-insulated window jambs, in the case of the existence of façade insulation, the resulting percentage increase of the basic U-value may be increased even double.

In addition, Figure 5 shows the correlation between the values of temperature factor f_{Rsi} for analysed cases of the scenario – the length of the wall segment W_L = 100cm.



	U_{ekv} [W/m²K]	T_c [ºC]	f_{Rsi}	%U
Basic wall; A=14	0.246	18.89	0.965	100.000
A=14; B=0; C=0; D=2	0.566	15.225	0.851	230.081
A=14; B=1; C=0; D=2	0.446	16.656	0.896	181.301
A=14; B=2; C=0; D=2	0.395	17.241	0.914	160.569
A=14; B=3; C=0; D=2	0.367	17.567	0.924	149.187
A=14; B=4; C=0; D=2	0.349	17.752	0.930	141.870
Basic wall; A=12	0.28	18.74	0.961	100.000
A=12; B=0; C=0; D=2	0.605	15.168	0.849	216.071
A=12; B=1; C=0; D=2	0.482	16.575	0.893	172.143
A=12; B=2; C=0; D=2	0.43	17.148	0.911	153.571
A=12; B=3; C=0; D=2	0.401	17.466	0.921	143.214
A=12; B=4; C=0; D=2	0.382	17.669	0.927	136.429
Basic wall; A=10	0.325	18.541	0.954	100.000
A=10; B=0; C=0; D=2	0.654	15.092	0.847	201.231
A=10; B=1; C=0; D=2	0.527	16.466	0.890	162.154
A=10; B=2; C=0; D=2	0.475	17.02	0.907	146.154
A=10; B=3; C=0; D=2	0.445	17.326	0.916	136.923
A=10; B=4; C=0; D=2	0.426	17.52	0.923	131.077
Basic wall; A=8	0.387	18.264	0.946	100.000
A=8; B=0; C=0; D=2	0.716	14.982	0.843	185.013
A=8; B=1; C=0; D=2	0.587	16.308	0.885	151.680
A=8; B=2; C=0; D=2	0.534	16.837	0.901	137.984
A=8; B=3; C=0; D=2	0.505	17.126	0.910	130.491
A=8; B=4; C=0; D=2	0.485	17.308	0.916	125.323
Basic wall; A=6	0.479	17.855	0.933	100.000
A=6; B=0; C=0; D=2	0.799	14.816	0.838	166.806
A=6; B=1; C=0; D=2	0.671	16.066	0.877	140.084
A=6; B=2; C=0; D=2	0.619	16.557	0.892	129.228
A=6; B=3; C=0; D=2	0.59	16.821	0.901	123.173
A=6; B=4; C=0; D=2	0.572	16.985	0.906	119.415
Basic wall; A=0	1.67	12.575	0.768	100.000
A=0; B=0; C=0; D=2	1.729	12.163	0.755	103.533

Figure 4: The analysed cases of the scenario - the length of the wall segment W_L = 100cm

From the analysed cases it may be concluded the following:

Along the typical zone of the wall (no window opening), in all the analysed cases there is no risk of condensation, except near the basic - uninsulated wall, in which case even the 50% relative humidity of internal air becomes critical.

With the increase of relative humidity of indoor air, the risk of condensation is increasing. When relative humidity is up to 60%, all cases with isolated external reveal (position B) meet requirements (minimum insulation thickness is 2 cm).In the case of uninsulated external reveal, the risk of condensation exists.

In the case of indoor air relative humidity of 70%, all the analysed cases fail, since the f_{Rsi} value is lower than the minimum required. However, with the increase of thickness of insulation of external reveal (position B), the temperature factor f_{Rsi} increases, so decreases the risk of condensation.

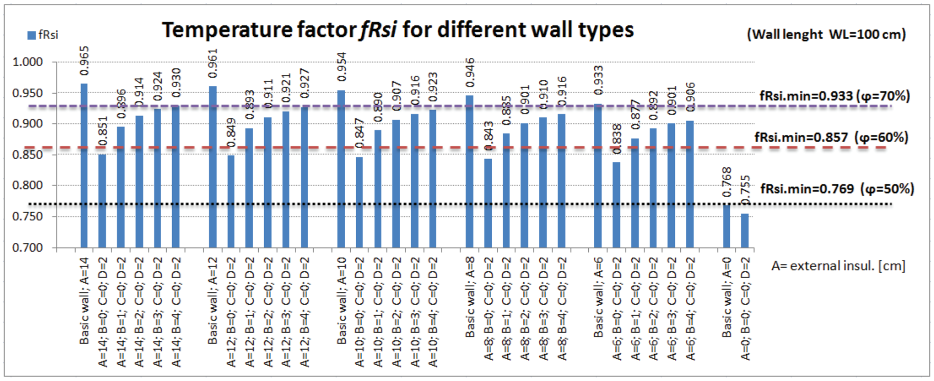


Figure 5: Diagram of the value of the temperature factor for the various variations of the intervention scenario - *fragment of the wall W_L-100*

Next are analysed and mutually compared cases with different lengths of the wall segments (100, 50 and 25cm) in combination with different thicknesses of insulation of external face of the wall - position A (14; 12; 10; 8; 6cm and without insulation). Foreseen is the insulation of the contact: window frame- inner reveal in the constant thickness of 2 cm (position D). In all the cases, thermal insulation of outer reveal is not foreseen (position B), neither is the insulation of the contact of rebate-window frame (position C). (Figure 6)

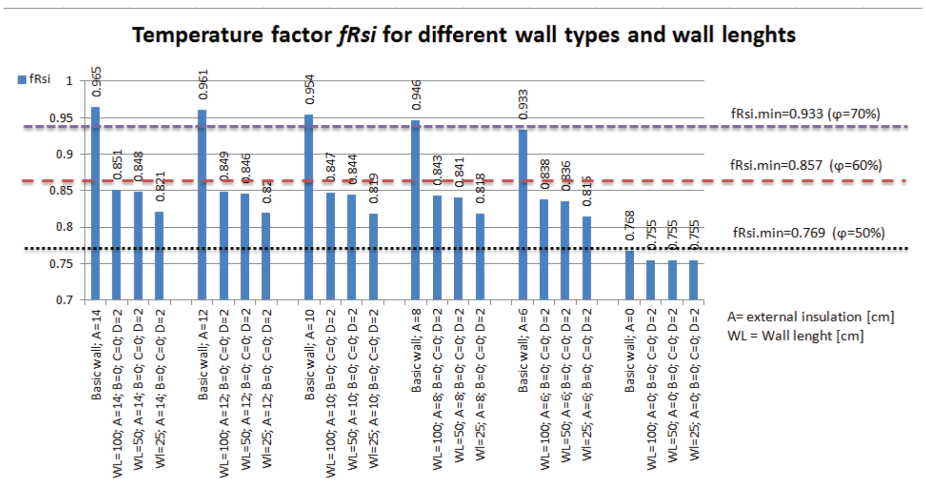


Figure 6: Diagram of the temperature factor values for the selected scenarios of intervention - the length of wall fragment W_L-100; 50; 25

It can be noted the following:

With the increase of thickness of external insulation, f_{Rsi} grows so that for internal relative humidity up to 70%, in all the cases there is no risk of condensation on a typical part of insulated walls (basic wall calculated without the impact of thermal bridges).

When considering the value of f_{Rsi} for different lengths of the walls, including the impact of the window opening, none of the analysed details meet the criteria $f_{Rsi.min}$ for the relative humidity above 60%, but meet in the case that the relative humidity is lower than 60%.

With a decrease in the observed length of the wall (W_L) grows the impact of thermal bridges, f_{Rsi} is falling and the risk of condensation is growing.

The primary, exposed type of the wall, does not meet requirements in any case, since the risk of condensation occurs even when internal relative humidity is 50%.

CONCLUSIONS

At the end of the conducted research, in brief, it could be concluded, the following:

Replacement of windows without insulation of the façade does not exclude the risk of condensation and mould.

Insulating only the face of the façade is not reliable activity for the prevention of condensation on the window-wall contact since it must be combined with the first intervention.

Insulation of outer reveal significantly reduces or abolishes the risk of condensation in the interior. It proved to be enough to insulate the window jambs with 2cm thermal insulation.

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