

IMPACT OF DIFFERENT BUILDING MATERIALS ON  
SUMMER COMFORT IN LOW-ENERGY BUILDINGS

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The aim of the current paper is to analyse thermal comfort and overheating risks in the low-energy buildings in a summer season under Latvian climate conditions both experimentally and numerically. An interior temperature and relative humidity are analysed under free-floating conditions. Two cases are analysed: in one case, the solar influence through the window is taken into account; in the other this influence is omitted. Three different building solutions are observed: two building structures which mainly consist of the mineral wool and wooden materials and one structure from aerated clay bricks and mineral wool. The experiments have been implemented in test stands in Riga, Latvia. The numerical simulations based on measurements obtained from test stands have been performed using software *WUFI Plus*. The results show that the wooden constructions have high overheating risks.

**Keywords:** *building materials, low-energy building, summer overheating, test buildings, thermal comfort.*

## 1. INTRODUCTION

Directive 2010/31/EU of the European Parliament aims at promoting the energy performance of buildings and building units [1]. By 31 December 2020, according to [1] all the newly constructed buildings are to become nearly zero-energy consumption buildings. Better insulation of houses, low air exchange, optimal use of solar heat gains are recommended in the countries with a long heating season, e.g., 7-month period for Latvia. However, an opposite effect can be observed in summer when rooms can overheat, especially in case of nearly zero-energy houses. A high indoor temperature can negatively influence the living conditions, affecting human health; therefore, a comprehensive study of the overheating risks in low-energy houses is strongly recommended.

The living conditions in a summer season have been widely studied. In [2], an optimal 'First-Guess' passive house in Marseille has been investigated, and it has been shown that well-insulated buildings are suitable to provide high winter and summer comfort with minimum energy consumption in warmer climates. Project report [3] provides comprehensive investigation about optimal indoor environment in passive houses. In [4], real English dwellings have been chosen and summertime

temperatures analysed. In [5], a single Slovenian passive house has been analysed and the overheating risks in a summer period have been investigated. Small test houses have been created in Doslovce, Slovenia [6]. However, the net volumes are small: 0.25–0.46 m<sup>3</sup> and the aims of these test houses have been significantly different. INCAS platform with several experimental houses has been built near Chambéry, France [7]. Realistic experimental houses have been described with several bedrooms, 2 floors, and several windows on each side. However, the main goal of the research has been energy optimisation of buildings, e.g., a new free-cooling system has been applied [8] and the impact of different building materials has had a secondary role. In [9], thermal comfort in hot-humid climate has been analysed. One low-energy house has been analysed in [10] and optimised shading structure has been given with the aim to reduce the risk of overheating in the summer months and to achieve the maximum amount of solar energy in winter. In [11], an analysis has been performed with the aim to investigate whether Passivhaus dwellings will be able to ensure high standards of thermal comfort in future and whether dwellings will be protected from overheating in summer. Paper [12] compares the measured indoor temperatures of Danish passive houses with calculated temperatures in a summer season and a dynamic simulation with calculations on an hourly basis has been performed. Paper [13] investigates a low-energy steel frame house and the simulations have been performed to predict overheating risks in various future scenarios. Measurements and computer modelling applied to a low-energy office building in Belgium show that natural night ventilation and an earth-to-air heat exchanger create a good thermal summer comfort [14].

Although the overheating risks of houses have been widely studied; the research of buildings having the same parameters (net volume, roof, floor, orientation, etc.) has not been published yet, the only difference among the houses is a multi-layered wall. Such experiments have been carried out in Riga, Latvia, where five test houses have been built – see Fig. 1. The aims of this paper are to estimate overheating risks in the low-energy houses, to create a numerical model related to experimental houses as close as possible and to estimate how useful the numerical model is for further research.



*Fig. 1. Experimental test buildings (left) and cross-section of one building with mineral wool filled plywood walls (right).*

## 2. NUMERICAL AND EXPERIMENTAL FRAMEWORK

### 2.1. Experimental Test Case

#### 2.1.1. Test Stands: Overview

Five tests buildings (stands) have been built in Riga, Latvia (Fig. 1). All of them have the same orientation, net volume, roof inclination, height above ground. The inner dimensions are 3×3×3 m that gives the total volume of 27 m<sup>3</sup>. Test stands are placed in the way that significant solar shading is not provided. The only significant difference among the test stands is building materials and components used for the walls. The different solutions of walls are chosen so that the calculated  $U$ -values ( $W m^{-2} K^{-1}$ ) are similar for each test stand. The floor and ceiling also have the same  $U$ -values. The analysis of the three test houses described in Table 1 will be provided. More information about these test stands is also available in [15] (in Latvian).

Table 1

Description of Building Constructions for the Three Buildings under Analysis

Construction	Specific weight, kg/m <sup>2</sup>	Materials	$\lambda$ , W m <sup>-1</sup> K <sup>-1</sup>	$U$ , W m <sup>-2</sup> K <sup>-1</sup>
Wall for CER	363	Exterior wind protection slab 0.03 m	0.034	0.151
		Mineral wool 0.125 m	0.043*	
		Lime plaster 0.015 m	0.7	
		Aerated clay bricks 0.44 m	0.175	
		Lime plaster 0.015 m	0.7	
Wall for LOG	152	Exterior wooden logs 0.2 m	0.13	0.150
		Mineral wool 0.2 m	0.044*	
		Vapour barrier 0.001 m	2.3	
		Wooden logs 0.04 m	0.13	
Wall for PLY	79	Exterior plywood 0.02m	0.17	0.154
		Mineral wool 0.2 m	0.041*	
		Plywood 0.02 m	0.17	
		Fibrolite 0.075 m	0.068	
		Lime plaster 0.015 m	0.7	
Floor	41	Exterior plywood 0.021 m	0.17	0.173
		Mineral wool 0.2 m	0.049*	
		Vapour barrier 0.001 m	2.3	
		Plywood 0.021 m	0.17	
		Mineral wool 0.05 m	0.044*	
		Plywood 0.021 m	0.17	
Ceiling	20	Exterior plywood 0.012 m	0.17	0.160
		Mineral wool 0.2 m	0.044*	
		Plywood 0.004 m	0.17	
		Mineral wool 0.05 m	0.041*	
		Vapour barrier 0.001 m	2.3	
		Plywood 0.004 m	0.17	

\* Equivalent thermal conductivity for the whole layer taking into account the frame section

### 2.1.2. Windows and Doors

The triple-glazed window with dimensions 1.2×1.5 m is built into the south façade of each test stand, its height above the floor is 1 m. A frame part of the window is 0.28.  $U$ -value is  $0.72 \text{ W m}^{-2} \text{ K}^{-1}$ . Despite the identical windows in all test stands, the solar radiation coming through the window can slightly differ in case of each test stand. The following explanation can be given: the depth in which the window is placed on the sill is different for each test stand. Solar heat gain coefficient ( $g$ -factor) perpendicularly to the glazing is approximately 0.5. A door is placed into the north wall. The width and the height are 0.95 m and 1.2 m, respectively. The solar radiation through the glazed part of door is practically excluded due to the attached non-transparent film.

### 2.1.3. Multi-layered Walls, Floor, Ceiling

The layers of floors and ceilings, which are similar for each stand, and of walls are characterised in Table 1. Thermal conductivity  $\lambda$  for mineral wool is given taking into account the whole layer with the timber frame; therefore, equivalent value of  $\lambda$  varies for different layers consisting of the mineral wool. Ventilated façade in front of each external wall is used to protect the walls from rain, solar radiation and wind (see Fig 1). The air layer of ventilated façade is approximately 3–5 cm. The outside air can flow from both above and below; it is assumed that the convective heat transfer coefficient (exterior and interior) is  $7.8 \text{ W m}^{-1} \text{ K}^{-1}$  according to [16].  $\lambda$  values can increase due to moisture, especially, for porous/wooden materials. It is taken into account in a numerical model.

Let us now analyse each external wall in detail. In the stand CER, the wall consisting of clay bricks with hollow porous cavities and the insulation material placed outside the wall is typical of construction in the Latvian climate conditions. The building solution of wall of LOG house is not typical of Latvia. The insulation material is incorporated into the wall leaving only a thin layer of wooden material for purpose of decoration on the inside. The risks of moisture accumulation in the wall that can negatively influence indoor relative humidity are high; therefore, a vapour barrier is added behind the mineral wool toward the interior of the LOG stand. The wall of PLY stand is the ‘light’ building construction with low thermal inertia. However, the fibrolite layer of 7.5 cm in thickness incorporated in the external wall of PLY significantly raises the thermal inertia of a construction.

A ventilated loft is located above the room (see Fig. 1) and it is slightly ventilated. It is experimentally determined that the air in the loft overheats due to solar radiation, and temperature there can be very high in sunny days. The maximum temperature observed in the loft was 35–37°C despite the maximum outdoor air temperature, which was 32°C. Moreover, the total number of hours, when air temperature was higher than 30°C in June 2013, was 80, 56, 62 for the loft in houses CER, LOG and PLY, respectively, although air temperature was only 8 hours above 30°C in June. These results show that the loft is not sufficiently ventilated as expected and solar radiation significantly affects climate conditions in the loft.

Buildings are slightly raised above the ground (Fig. 1) to ensure the same weather conditions above the floor for each test stand as for outside air. Since the test

stands have been built only a half year before June, the initial drying of the building components can negatively affect summer comfort due to higher interior initial relative humidity. However, the stands that are chosen for research are drying relatively quickly as the numerical simulations and the sensors in the walls demonstrate.

#### **2.1.4. Natural and Mechanical Ventilation**

All test stands are well-sealed and air-tight; only one controlled ventilation opening in the south façade is built-in (see Fig. 1). Mechanical ventilation placed above doors is running and a regime of ventilation is set up similarly in each test house. The measured air exchange rate  $n$  ( $\text{h}^{-1}$ ) of test stands is 0.45, which is experimentally determined by using a precise tracer gas method, see [17].

#### **2.1.5. Sensors**

Each of the test stands is currently equipped with approximately 40 sensors for measuring total power and electricity consumption, interior air velocity, humidity and temperature in the room, walls, loft, underground, façades, etc. The data are obtained with a time step of 1 minute. The room temperatures and humidity are measured at different stages in the middle of the room according to the height above ground being 0.1 m, 0.6 m, 1.1 m, 1.7 m as well as the height below ceiling of 0.1 m. Finally, one room sensor is set up near one of the walls at the height of 1.1 m and 0.1 m from the wall. However, all room sensors show similar values since the research is aimed at the summer comfort under free-floating conditions; therefore, the data taken from the sensor in the middle of the room above height of 1.1 m will be used.

#### **2.1.6. Weather Station**

Above one of the test stands, a weather station is set up to obtain the data for outside temperature, relative humidity, solar radiation, wind direction and speed. The data of wind speed and direction, as well as the solar influence through the wall are not used for simulations because the ventilated façade created for the test stands excludes this influence. It is assumed that the temperature and relative humidity of the ventilated air layer are the same as for external atmosphere. Based on this consideration, solar radiation through the wall boundary is not taken into account.

### **2.2. Numerical Simulation**

#### **2.2.1. Software WUFI Plus**

The commercial software WUFI Plus is used for calculation of the inner climate conditions. WUFI Plus is a room climate model that connects the building energy balance simulation and the calculation of hydrothermal components. The transient heat and moisture transports are calculated in arbitrary time steps within an arbitrary simulation period. The calculation is performed using the finite volume method. Ventilation for the whole room and radiation for opaque components are also taken into account. Using the building simulation software WUFI Plus, the hygric and thermal ratios in a building, in its perimeter and their interaction can be calculated and quantified as well as the energy demand and consumption of system

engineering. WUFI Plus allows easy and quick changes in construction and assembly, the input of different boundary conditions as well as variances of parameters like material characteristics. WUFI Plus takes into account the hourly outdoor climate values. The model for calculating heat and moisture transfer in a building component is described in [18].

### 2.2.2. Connection of the Numerical Model with Test Stands

Software WUFI Plus is a powerful program to calculate the room climate. However, it is still a challenge to implement parameters in the software WUFI Plus in order to connect the real test stands as close as possible with the numerical model. The net volume of room for test stands has been defined as 27 m<sup>3</sup>. Since each test stand has the internal heat sources (e.g., data loggers, power meters, routers etc.), the constant room heat power has been estimated as 30 W during the whole period. However, slight deviations from this value can be observed, especially, during the time when various experiments are carried out in the buildings.

Window parameters ( $U$ -value, frame factor, solar heat gain coefficient) are taken as the manufacturers have declared (see Subsection 2.1.2). From these values WUFI Plus can calculate heat flows that come through the window due to solar influence. Since the length of a window sill differs in each test stand, real solar heat that comes through the window can slightly differ in each test stand, but these differences are insignificant. The climate on the exterior surface for each test house is defined by the time step of 1 hour, and the data from the weather station are used. Radiative heat transfer coefficient outside is defined as equal to 0 due to the ventilated façade. It is possible that the temperature of the ventilated air layer is higher than outside temperature during the sunny days, but this is not taken into account in WUFI Plus. Climate under the floor of each building is also defined the same as the outdoor climate without solar radiation. As the first approximation we do not take into account the loft; therefore, we have also implemented loft temperature  $T_{loft} = T_{out}$  and humidity  $\phi_{loft} = \phi_{out}$  in WUFI Plus. However, the loft air can be more than 5°C higher than  $T_{out}$  in the afternoon.

Another important factor to be taken into account in simulation with WUFI Plus is the initial moisture in the construction. Since it is assumed that the building constructions chosen in the current paper have been dried relatively quickly, the initial relative humidity has been taken at about 70% on the wall. The calculations in WUFI Plus were started from January 1 with the aim to avoid the transition period when the room climate was not stabilising.

## 3. RESULTS AND DISCUSSION

This section provides an analysis of the overheating risks in different building constructions (see Table 1) in June and August.

### 3.1. Weather Conditions

Table 2 gives an overview on the weather conditions during the measurements. Windows were covered from outside in August with an aim to observe the

role of solar radiation through the window. Similar conditions were ensured in all 3 test stands: no heating and cooling (except the inner sources 30 W), the same mechanical ventilation regime, air temperature and air humidity varied under free-floating conditions.

The observation was implemented during two months: June and August in 2013, when similar climatic conditions continued in Riga, Latvia. The climate conditions are briefly given in Table 2. In some previous years, the average temperature in the summer was between 16–20°C. This means that the climatic conditions in June and August in 2013 were typical of Riga.

Table 2

**Brief Description of the Weather Conditions**

Month	Temperature, °C						Window	Air exchange rate $n$ , h <sup>-1</sup>
	Outside $T_{out}$			Inside $T_{room}$				
	Average	Maximum	Minimum	CER	LOG	PLY		
June	19.5	32	8.1	23.4	26.3	25.4	uncovered	0.45
August	18.2	34.7	8.6	21.8	22.7	22.4	covered	0.45

### 3.2. Analysis of Experimental Results

The experimental results of inner temperature  $T_{room}$  for three test stands and outdoor temperature variations are shown in Fig. 2. An explanation is required about some unusual situations observed in August (see Fig. 2b and Fig. 3b). Human activity of approximately 1 hour was observed on 9th and 12th August on the test stand of PLY and LOG, respectively. It explains why unexpected local peaks of  $T_{room}$  are observed (see Fig. 2b, both solid lines).

As it is shown in Fig. 2, overheating risks in the summer period can also be observed in climatic conditions of Latvia. Despite the average  $T_{out}=19.5^{\circ}\text{C}$  in June, average  $T_{room}$  was significantly higher than  $T_{out}$ , see Table 2. Thereby, it can be concluded that solar influence through the window significantly raises the room temperature. When the windows were covered (see Fig. 2b), the average  $T_{room}$  was not as high as  $T_{out}$ . However, these results of  $T_{room}$  in August are unexpected and show that overheating risks can exist, even if solar radiation through the window is prevented. One of the reasons for the differences between  $T_{room}$  and  $T_{out}$  in August by the fixed air exchange 0.45 h<sup>-1</sup> can be the inner sources (mainly data loggers, approximately 30 W) for each test house. Another explanation is that  $T_{out}$  significantly decreases in the night after 20th August (Fig. 2b, dashed line) and, therefore, average  $T_{out}$  decreases in August. At the same time  $T_{room}$  does not change so quickly.

It can also be observed that  $T_{room}$  for the test stand of CER is more stable than for the wooden constructions LOG and PLY. More precisely, the daily average  $T_{room}$  amplitude in June was approximately 6.5°C for PLY and LOG; however, this amplitude was only 4.5°C for the test stand of CER (see Fig. 3). In August, the situation was similar: 7°C (LOG) and 5°C (CER). It is explained by the massive aerated clay bricks incorporated in the wall of CER that have a high thermal capacity and high thermal inertia.



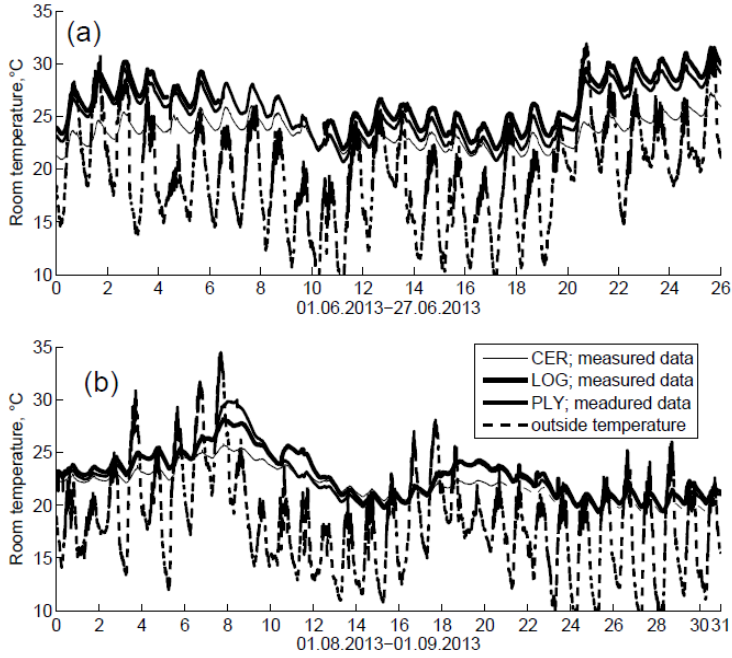


Fig. 2. Measured room temperature for 3 different test buildings. No heating and cooling were applied indoors. Windows were covered in August.

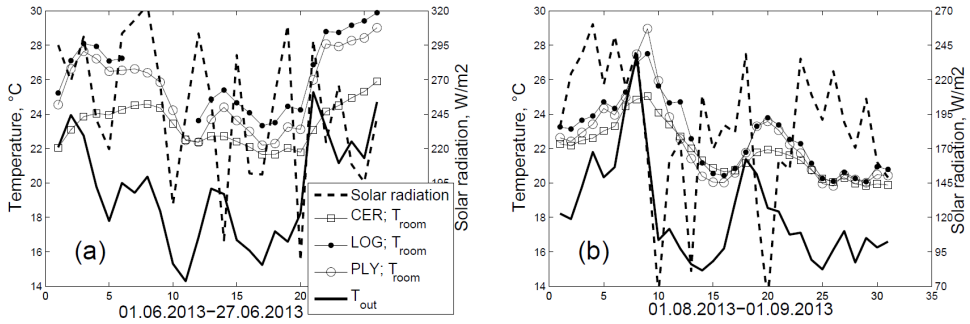


Fig. 3. Daily average temperature and outdoor solar radiation.

In the test stands mainly consisting of wooden materials and mineral wool (PLY and LOG), during some days the indoor temperature may be over 30°C (see Fig. 2a, both solid lines). It was also observed that the room air temperature did not decrease significantly at night between 3rd June and 4th June (only about 2–3°C), although  $T_{out}$  decreased by about 14°C (from 28°C to 14°C) that night. In Fig. 3, the daily average outdoor solar radiation is added for a detailed analysis. Figure 3a demonstrates that  $T_{room}$  fluctuations are more sensitive from  $T_{out}$  fluctuations than a change of solar radiation by current conditions of measurements. This can be explained by outdoor air supply through the ventilation system and daily averaging of data, which reduces the short-time effects of solar radiation. From 14th June to 15th June, the average solar radiation increased twofold (from 150 W/m² to 290 W/m²). At the same time,  $T_{out}$  changed in the opposite direction by 2°C. The result of this ambigu-



ous situation is a decrease of  $T_{room}$ , although the increase of  $T_{room}$  could be expected. However, the reverse effect was observed from 19th June to 20th June – outdoor solar radiation decreased from 310 to 140 W/m<sup>2</sup>, daily average  $T_{out}$  changed from 16.6 to 18.2°C. This resulted in a slight decrease of  $T_{room}$  in all test stands. In Fig. 3b it is shown that the window was indeed well covered from the outside; therefore,  $T_{room}$  responded only to fluctuations of  $T_{out}$ . Comparison of Fig. 2a and 2b shows that changes of  $T_{room}$  due to  $T_{out}$  fluctuations are significantly smaller when windows are covered.

### 3.3. Analysis of Numerical Results

For the base case of numerical model, the inner load, the total air exchange was taken as shown in Table 2. Frame part is 0.3 (uncovered window) and 0 (covered window) in June and August, respectively. The results shown in Fig. 4 were obtained under these conditions. Some warmer periods in June and August were also taken to simulate the room climate under different conditions (see Figs. 5 and 6).

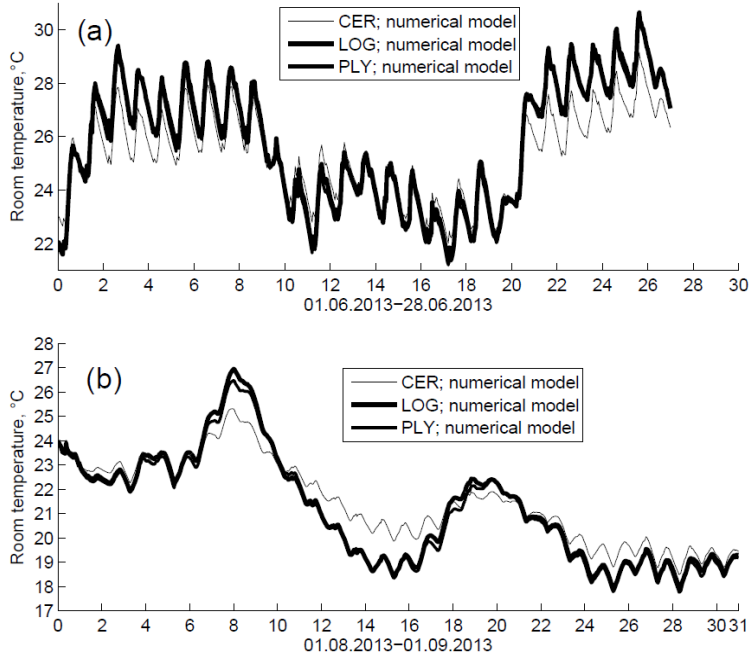


Fig. 4. Room temperatures calculated by using the numerical model.

Further below, a detailed explanation of the conditions of the test stands that have been taken in Figs. 5 and 6 is provided, and the arguments given regarding the choice of these conditions. At first, Fig. 5, representing measured and calculated room temperature for different cases, will be inspected. The dotted line (the second line in the legend) is a base case and it would be the optimal result if the measured data coincided with the dotted line. The dashed line (the third line in the legend) is a modification, where the air exchange coefficient has been increased from 0.5 h<sup>-1</sup> to 1.5 h<sup>-1</sup> to compare how strong the influence of significant increase of the air exchange is on the overheating risks. The thinner solid line (Fig. 5) describes the modification

of the base case, where a role of solar radiation coming through the window has been increased. Coefficient  $s=0.7$  (solar heat gain coefficient or  $g$ -factor) corresponds to a double-glazed window and, therefore, ensures more energy coming through the window to the room from solar radiation. The thicker solid line corresponds to the case of the covered window from the outside. This allows eliminating solar influence. In this case, only the inner heat sources (30 W) and the heat flow through the wall influence the room temperature. However, a slight difference must be kept in mind: in WUFI Plus model it is assumed that windows have been uncovered until 1st June; therefore,  $T_{room}$  normalises only in some days. A solid line with circle markers represents the human activity (for a relaxed, sitting person); in this case, the following data are implemented in WUFI Plus: heat power 101 W (convective 65 W, radiant 36 W), the moisture input 43 g/h. Night cooling (the solid line with pointed markers) is also included in modelling supposed that the window is open every night. In August, the cases of covered window and uncovered window were inspected (see Fig. 6, the dashed line against the thicker solid line).

Data for  $T_{room}$  from the numerical model in June show a similar situation as it has been experimentally measured (see Fig. 5). Only the level of  $T_{room}$  for CER is higher compared to the measured one, which can be explained by slightly higher actual  $U$ -value, which means the highest conduction heat losses at night.  $T_{room}$  of PLY and LOG are almost identical, but  $T_{in}$  for CER is significantly lower in the warmer time period.

Subsequently, some warmer days in June will be analysed in greater detail, see Fig. 5, time period of 19–23 June. At the test stand of plywood (PLY), the measured  $T_{room}$  almost fits the calculated  $T_{room}$  curve for the base case (average thin line vs dotted line). Good agreement is also observed at the test stand of LOG. Only  $T_{room}$  measured in CER significantly (more than 1°C) differs from WUFI Plus calculations. If the air exchange had increased from 0.5 to 1.5 h<sup>-1</sup>, peaks of  $T_{room}$  would decrease by more than 2°C and in that case overheating risks would significantly decline. A completely different situation could be observed, if the solar heat gain coefficient changed from  $s=0.5$  to  $s=0.7$  based on the assumption that double glazed windows could be used. Then  $T_{room}$  could increase by about 2°C (see Fig. 5). If windows were covered, the average  $T_{room}$  could decline by approximately 4°C as well as stabilise, i.e., lesser amplitude of  $T_{room}$  would be observed. The heat flow coming from the human can mostly influence overheating risks in the rooms (see Fig. 5, solid line with circles). The peak  $T_{room}=34^{\circ}\text{C}$  can be reached regardless of the only average daily  $T_{out}=24^{\circ}\text{C}$  at the warmer time. This demonstrates the necessity of active ventilation during the night hours. Solid lines with pointed markers in Fig. 5 demonstrate how significantly  $T_{room}$  decreases in case of the night ventilation. Maximum values of  $T_{room}$  could decrease by 2–3°C compared to the base case (dotted line in Fig. 5). Despite the high natural ventilation at night (5 h<sup>-1</sup>), room air could cool only until 21–22°C on some days, e.g., at night between 22nd June and 23rd June. At that night a minimum of  $T_{room}$  could be higher by about 7°C than the minimum outside temperature. It can also be observed that the impact of different building structures is lower if the night ventilation is applied.

Further, the case of August with covered windows will be discussed. The experimental results in August have been discussed in Subsection 3.2. The calculation

results are shown in Fig. 4b. The comparison of Figs. 4a and 4b also shows that the level of  $T_{room}$  of CER is higher than the measured one. Despite the fact that measured  $T_{room}$  decreased to 20°C, the  $T_{room}$  for wooden constructions (LOG, PLY) decreased to 18°C as demonstrated by numerical simulations. The measured peaks of  $T_{room}$  were also higher. As it was noted in Subsection 3.2, measurements influenced by a slight human activity were recorded in August. These unexpected situations were not taken into account in Fig. 4b.

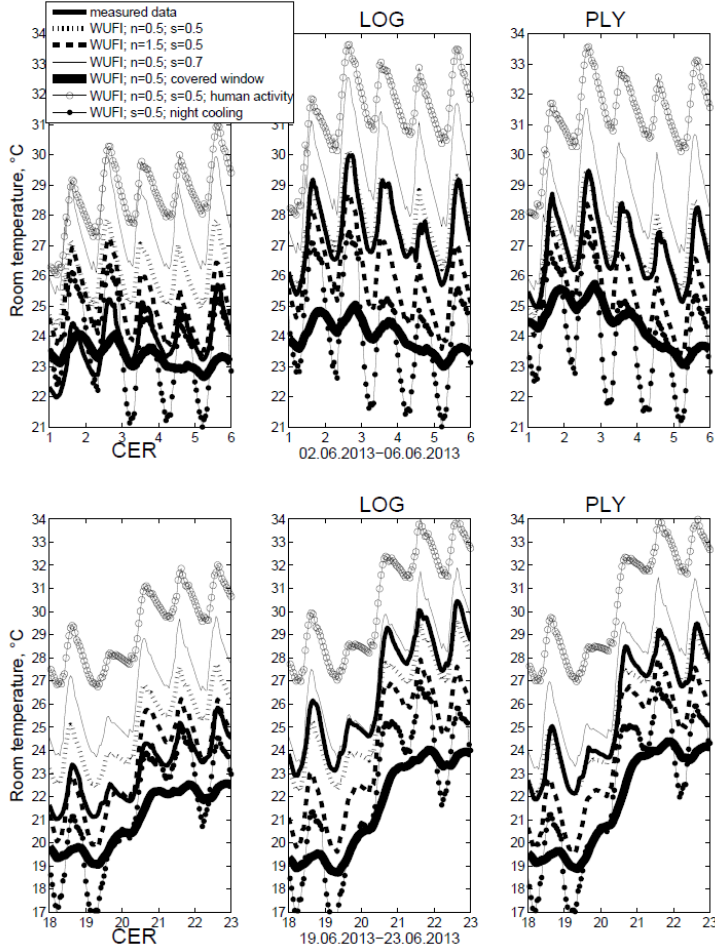


Fig. 5. Measured and calculated room temperature for different cases in June.

As it is shown in Fig. 6, the measured  $T_{room}$  are by 1...1.5°C higher than the ones obtained by numerical modelling (the thinner solid line against the thicker solid line) for both test stands of LOG and PLY despite the fact that both approaches coincided well when windows were uncovered in June (Fig. 5). Moreover, amplitude of  $T_{room}$  fluctuations was lower. An explanation of these differences could be the warm air between the window and a thin covering during the warmer part of a day. This influences both oscillations and the level of the temperature. The peak of  $T_{room}$  was about 2°C higher in the

test stand of plywood on 9th August than it should be in a normal case (Fig. 6 on the right side, thinner solid line). It is explained by a human activity with duration of approximately 1 hour that was not taken into account in the numerical calculations. Comparison of the thicker solid line and solid line with circles (Fig. 6) shows that a human activity can raise  $T_{room}$  by about 4°C.

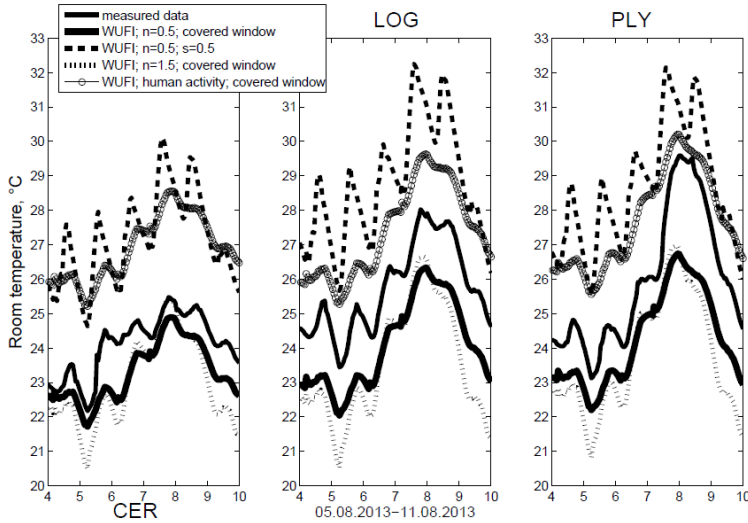


Fig. 6. Measured and calculated room temperature for different cases in August.

#### 4. CONCLUSIONS

The results obtained demonstrate that the overheating risks in low-energy houses are also a highly topical issue in relatively cold Latvian climate conditions. Despite the average outdoor temperature, which is lower than +20°C in June and August in Latvia, the experimental results demonstrate that the room temperature can even exceed 30°C for some hours under the normal ventilation intensity. The triple glazed window built into the south facing wall significantly protects the room from the overheating, so that the outside air temperature is a more significant parameter that influences the overheating risks. The experimental measurements show that the room temperature can be high, even if the windows have been covered from the outside; therefore, the overheating risk is high under the Latvian climate conditions in the both cases regardless of whether the window is or is not covered.

The numerical study gives several advantages and allows verifying whether conditions are similar for all test stands. If experimental and numerical results are in good agreement, then the use of different conditions for the room (different ventilation regimes) can be reliable for comparison and allow proceeding with an objective analysis. As it is shown in the paper, it can be verified whether solar influence through the window is similar in each test house.

Finally, it can be concluded that the use of different building structures (light

and heavy) can significantly influence the overheating risks in the room, as demonstrated by experimental and numerical studies.

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## ATŠĶIRĪGU BŪVMATERIĀLU IETEKME UZ KOMFORTU ZEMA ENERĢIJAS PATĒRIŅA ĒKĀS VASARĀ

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### Kopsavilkums

Darba mērķis ir, veicot gan mērījumus LU Botāniskajā dārzā izveidotajos testēšanas standos, gan pielietojot skaitlisko modelēšanu, analizēt dažādu būvmateriālu ietekmi uz temperatūru telpās un novērtēt pārkaršanas riskus zema enerģijas patēriņa ēkās vasaras sezonā Latvijas klimatiskajos apstākļos. Lai novērtētu izvēlēto būvmateriālu siltumfizikālo īpašību ietekmi, iekštelpu temperatūra un gaisa relatīvais mitrums apskatītajā periodā standos netika uzturēti noteiktā līmenī, bet bija atkarīgi tikai no āra gaisa. Darbā tiek apskatītas trīs dažādu materiālu ārsienu būvkonstrukcijas: divas vieglas, kas galvenokārt sastāv no kokmateriāliem un akmens vates, un viena smagāka konstrukcija no gāzbetona ar akmens vates siltinājuma slāni ārpusē. Eksperimentāli un skaitliski tika analizēti divi gadījumi - ar un bez saules starojuma ietekmes caur logu. Skaitliskā modelēšana, kas ir balstīta uz veikto gaisa temperatūras un mitruma mērījumu datiem, tika veikta izmantojot programmu *WUFI Plus*. Pētījumu rezultāti parāda, ka ēkās, kas pamatā ir būvētas no vieglajām koka konstrukcijām, arī Latvijas klimatā ir augsts pārkaršanas risks vasaras periodā, ja netiek nodrošināta telpu kondicionēšana.

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