Białystok University of Technology

Faculty of Civil and Environmental Engineering

AN IMPACT OF AIR INFILTRATION ON HEAT TRANSFER THROUGH LIGHTWEIGHT BUILDING PARTITIONS FILLED WITH LOOSE MINERAL WOOL

PHD THESIS ABSTRACT

Piotr Kosiński M. Sc. Eng.

PhD's thesis prepared
in the Chair of Building Engineering and Building Physics
at the University of Warmia and Mazury in Olsztyn

Promoter:

Civ. Eng. Robert Wójcik, Prof.

Olsztyn, 2014

Contents

1. Introduction

Air infiltration is most often considered as a part of indoor air exchange system. In the current European legislation, including regulations and building codes, the air infiltration phenomenon is included in ventilation calculations. Sometimes infiltration is analysed parallel to the rain impact on wet materials.

The study of international literature as well as the results of long-term measurements of air tightness of building envelopes revealed the scale of problems with the infiltration in many types of constructions. The measurements have been conducted in: residential, commercial, factory and utility buildings. Many types of constructions of various age have been analyzed. Most of the measurements have been conducted in buildings in which, due to poor thermal protection, the exploitation was very difficult and even almost impossible. The heat consumption in these buildings was much higher than calculated. In many cases the criteria of the air tightness of a building envelope was not fulfilled. On the other hand, there were also cases, where a building envelope met the criteria of required airtightness, there was no cross air channel flow through building envelope and the Blower Door test results were positive, but a building demands more heat than it was due to calculations. After the thoroughly analysis of results of airtightness it was possible to conclude, that in a building envelope there exist both cross air channel flows, as well as wind-washing the porous and fibrous materials embedded in a building envelope. The second problem mostly concerns air permeable fibrous thermal insulations. Whenever there are no channel flows, but the wind-washing the exterior materials exists, in the building envelope occurs a problem of the seeming air tightness.

There are technical solutions, which deliberately accept the filtration of air in the insulating layer, guided by the necessity of possible drying of building materials. Some scientific papers even suggest that the air infiltration decrease the heat losses through ventilation. In result there occur heat losses in building heat balance which are underestimated and therefore difficult to take into account during calculations. Heat changes on the inner surface of the building partition occurs with a delay to the initiation of the wind. However, even the short-term local wind loads on thermal insulations result in temperature decreasing and therefore possible condensation on the inner surface of the building partition. There exist many examples of frost damages and ecological problems in adjacent area to installation holes in a building envelope.

The work focused on the impact of the air infiltration on heat transfer in a building envelope. The subject is actual, because the knowledge of thermal effects and heat losses caused by the air infiltration is still underestimated. Laboratory investigations concern thermal performance of loose mineral wool. In recent years the popularity of loose fibrous insulations has been growing. Many renovated buildings as well as new ones, are insulated with loose cellulose granules or loose mineral wool. These materials are particularly susceptible on air permeance.

New regulations concerning thermal protection have been on law in Poland since January 2014. Under these requirements, Polish buildings will be led in few stages to low-energy standards. It is recommended in regulations to check the air tightness of a building envelope, but these regulations do not concern wind-washing possibilities. Therefore, the fulfillment of a building envelope air tightness as defined according to standards, does not guarantee the fulfillment of required construction partitions heat transfer coefficient.

Fig. 1. New building insulated with mineral wool panels not protected against wind-washing

Fig. 1 presents new building insulated with mineral wool panels before wood cladding cover. The presented solution may fulfill the seeming air tightness requirements, but there will be wind-washing effects inside the thermal insulation. Gaps between mineral wool panels and air gap between insulation and cladding will result as an air chimney, and finally will cause the air filtration through the mineral wool. A black material covering thermal insulation panels does not form a continuous wind barrier. In effect the presented partitions will not fulfill the thermal requirements despite the required thickness of insulation. The case presented on Fig. 1 is not the only one. Many new buildings are designed and constructed without a wind barrier.

The purpose of the work

The general aim of the present work is to determine the quantitive impact of the air infiltration on the heat transfer through a lightweight wall insulated with loose mineral wool. Two thesis were examined in the dissertation:

– heat transfer by convection, characterized by Rayleigh number, dominates in the thermal insulation layers formed of loose mineral wool exposed to wind-washing,
– heat transfer through building partitions insulated with mineral wool, depends strongly on protection against wind-washing; wind-washing in partitions without a wind barrier, decreases thermal protection of mineral wool.

The structure of the work

The work is divided into four main parts. The first part provides an overview of related international literature and gives general background on global airtightness issue while the second part describe the airtightness measurements and its corresponding requirements. The third part consists of results of laboratory tests of thermal properties of loose mineral wool, i.e.: heat conduction, air permeability and heat transfer during wind-washing. All of the results were analyzed. In the fourth part the experimental and simulation results were compared. The conclusions were presented at the end of the work.

2. The analysis of current scientific achievements in the field of airtightness of building envelopes

The building airtightness is an issue, that largely has been recognized, but mainly in the ventilation field. In many papers, the qualitative analysis of the impact of air infiltration on the thermal state of building envelope has been conducted. However, there is a lack of quantitative thermal analysis in the field of air infiltration in thermal insulation materials.

3. The energy balance in rigid heat conductor with reference to air filtration

The thermofiltration phenomenon may occur in porous materials during wind-washing. It means that a classical method of computing the heat transfer coupled with air mass transport, only by the Fourier law, should be modified. To the classical method of calculating thermal transmittance and heat transfer coefficient there should be added an equation that describes the air filtration. For this reason, the local energy balance including thermofiltration, can be described as a differential equation (1):

$$\frac{\partial}{\partial t}(\rho U)\,dV = \nabla \cdot \left(\lambda \nabla T + \kappa \frac{c_p \Delta T}{\nu} (\nabla p + \rho g) \right) + \rho r, \tag{1}$$

where:

ρU – the internal energy density (J/m^3),

λ – the heat conduction coefficient (W/(m·K)),

κ – the air permeability coefficient (m^2),

c_p – the specific heat of dry air (J/(kg·K)),

ΔT – the temperature difference (K),

ν – the kinematic viscosity (m^2/s),

∇p – the pressure gradient (Pa/m),

ρ – the dry air density (kg/m^3),

g – the gravity acceleration (m/s^2),

ρr – the internal heat source density(W/m^3).

Wind-washing causes the heat transfer between a building envelope and the environment. This phenomenon is described by the heat transfer coefficient on external surface of a building partition. Assuming steady-state flow and incompressibility of the fluid, it is possible to determine the heat transfer coefficient using the theory of similarity. Although it is assumed that the Peclet number refers to turbulent flow, it is the Rayleigh number that presumably can be used to describe the effect of the forced convection heat transfer in the fibrous thermal insulating material with open pores. The Rayleigh number relating to fibrous materials can be described as (2):

$$Ra = \frac{\beta \cdot g \cdot \delta \cdot \kappa \cdot \left(\rho c_p\right)}{\nu \cdot \lambda} \cdot \Delta T, \tag{2}$$

where:

β – the thermal expansion coefficient (1/K),

g – the gravity acceleration (m/s^2),

δ – the insulation thickness (m),

κ – the air permeability coefficient (m^2),

ρ– the dry air density (kg/m^3),

c_p – the specific heat of dry air (J/(kg·K)),

ν – the kinematic viscosity (m^2/s),

λ – the heat conduction coefficient of dry air (W/(m·K)),

ΔT – the temperature difference on both sides of insulation (K),

4. The examined material

Two types of thermal insulation materials were investigated in the work: loose mineral wool and cellulose granules. A special methodology of insulation application was developed to create a precise model of existing walls. Before the experiment investigation, the materials were stored in laboratory conditions. Observations and measurements were carried out on randomly chosen samples of materials.

5. Typical windy conditions in a sample location – Olsztyn

One of the most important issues in the work was to determine windy conditions for a specified location. It was mandatory in order to assess the real impact of wind loads on a building envelope. The obligatory data to fulfill an experiment were acquired on the basis of the analysis of typical windy conditions on the basis of Olsztyn's location. The database was available on the official website of the Polish Ministry of Infrastructure. The meteorological data acquired in a local weather station were simultaneously analyzed. The data indicates that the windy conditions are constantly transforming, and it is expected to exacerbate wind speed. Even during the severe frosts season there often appear violent gusts of wind.

6. The research methodology

The research program was based on the prior knowledge and experience acquired in the work on thermal buildings protection. Experimental studies on the impact of the air infiltration on the heat transfer through lightweight partitions filled with loose mineral wool was entered in four separate tasks:

1. Determination of the variation extent of the thermal conductivity of loose fibrous insulations: mineral wool and cellulose granules under no infiltration conditions
2. Determination of the variation extent of the air permeability of loose mineral wool.

3. Determination of the thermal resistance of the frame wall filled with loose mineral wool insulation under the windless conditions
4. Determination of the variation extent of thermal resistance of the frame wall filled with loose mineral wool insulation under windy conditions

6.1. The methodology of measurements of the thermal conductivity coefficient of loose fibrous insulations under no infiltration conditions

The measurements were performed in a heat flow meter apparatus Laser Comp FOX 602. The test sample of loose fibrous materials was laid in the measuring frames and initially manually compacted as in existing buildings. The HFM apparatus allows automatic clamping plate samples and it was used for compaction of the test material.

6.2. The methodology of measurements of the air permeable coefficient of loose mineral wool

The apparatus used to determine the air permeability coefficient of loose fibrous materials was constructed with plexiglass tube. The tube with an inner diameter of 60 mm and a wall thickness of 3 mm was divided into three sections so that it was possible to remove the inner section filled with the test sample from the system. On Fig. 2 the scheme of the measurement apparatus is presented. During experiment the pressure difference between two taps in the central section and corresponding air speed of the exhaust was recorded.

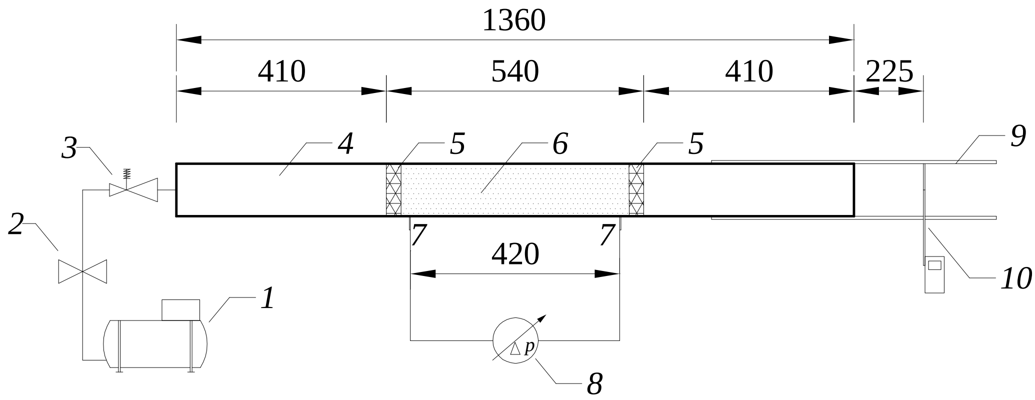

Fig. 2. The scheme of the test stand for the measurement of air permeability of loose fibrous materials: *1* – an air compressor, *2* – a valve, *3* – an air regulator, *4* – a plexiglass tube, *5* – strainers, *6* – test specimen, *7* – pressure taps, *8* – pressure gauge, *9* – nozzle, 10 – thermo-anemometer

The air permeability coefficient of loose mineral wool was determined from the approximation of Forchheimer law (3).

$$-\frac{dp}{dx}=\frac{\mu}{\kappa}\cdot v+\beta\cdot\rho\cdot v^2, \tag{3}$$

where:

dp– is the pressure difference between pressure taps (Pa),

dx – is the distance between pressure taps (m),

μ –is the dynamic viscosity (Pa·s),

κ – is the air permeability coefficient (m^2),

β – is the Forchheimer coefficient (1/m)

ρ – is the fluid density (kg/m^3),

v – is the velocity of fluid flow (m/s).

6.3. The methodology of measurements of the thermal resistance *R* of the frame wall filled with loose mineral wool under the windless conditions

The measurements were conducted in a climatic chamber Hot Box Taurus TDW 4040. The frame wall model dimensions were 150 x 150 x 13,75 cm (height x width x thickness). A frame wall construction was attached to peripheral pine frame. Next gypsum boards were attached. Next the model was filled with loose mineral wool. Next a wind barrier was attached. Hot Box measurements was treated as the reference point under windless conditions. Since the chamber does not allow the windy conditions, it was necessary to perform additional non-isothermal chamber.

6.4. The methodology of measurements of the thermal resistance *R* of the frame wall filled with loose mineral wool insulation under the windy conditions

The measurements were conducted in the non-isothermal climate chamber (Fig. 3), which was designed and constructed specifically for this purpose. The chamber was totally airtight. The dimensions of a model of frame wall insulated with loose mineral wool were: 166,3 x 197,5 x 13,75 cm (height x width x thickness). The purpose of the study was to determine the impact of the air infiltration on heat transfer through different wall models differing with insulation density and a wind barrier system (Fig. 4).

Four wall models corresponding to existing buildings were investigated. The models were constructed in such a way that each subsequent model arose from the previous by gradually reducing the risk of wind-washing the insulation layer.

The first model - frame partition, gypsum cardboards on internal side, insulation made of loose mineral wool with a density of 90 kg/m^3.

The second model - frame partition, gypsum cardboards on internal side, insulation made of loose mineral wool with a density of 118 kg/m^3.

The third model - frame partition, gypsum cardboards on internal side, insulation made of loose mineral wool with a density of 118 kg/m^3, poor wind barrier without continuity on the exterior side.

The fourth model - frame partition, gypsum boards on internal side, insulation made of loose mineral wool with a density of 118 kg/m^3, the wind barrier on the exterior side.

Gypsum cardboards were painted with acrylic paint to obtain the emissivity ε = 0,97. Heat flux sensors, thermocouples and thermo-anemometers were placed on the wall surfaces. The Almemo system was used to measure and record the thermal parameters. All measurements were carried out remotely.

In a cold part of a chamber, a fan test consisting of 1, 2 and 4 fans was performed. The use of a larger number of fans had the task of generating a rapid gust of wind. Smoke tests and CFD

FloVENT analysis gave a knowledge of the air speed in the chamber. A system consisting of one fan was sufficient enough to perform various wind speed tests. Precise control of fan speed was made possible by a potentiometer coupled with a differential pressure gauge.

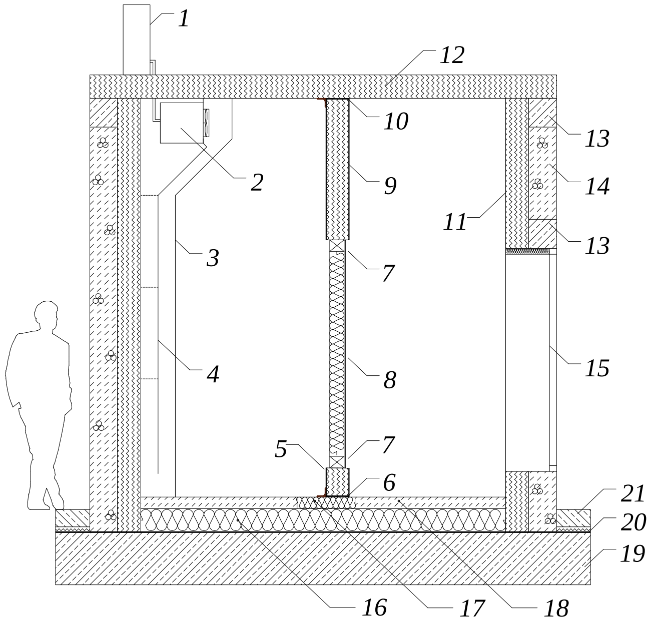

Fig. 3. A cross section of a non-isothermal climatic chamber: *1* – a chiller, *2* – a cooler, *3* – an aluminium casing of cooler, *4* – an internal baffle separating air flows, *5* – a plinth, *6* – a waterproof barrier, *7* – a peripheral pine wood frame, *8* – a model test specimen, *9* – a climatic chamber baffle, *10* – a polyurethane sealant, *11* – the inner surface of the outer wall panels, *12* – a floor of the chamber made of sandwich panels, *13* – concrete peripheral wreaths, *14* – the outer layer of the outer brick walls of aerated concrete, *15* – a window, *16* – a floor thermal insulation, *17* – a styrofoam insulation in the floor, *18* – a concrete floor, *19* – a laboratory floor, *20* – a thermal insulation and anti damp proof of laboratory floor, *21* – a concrete floor

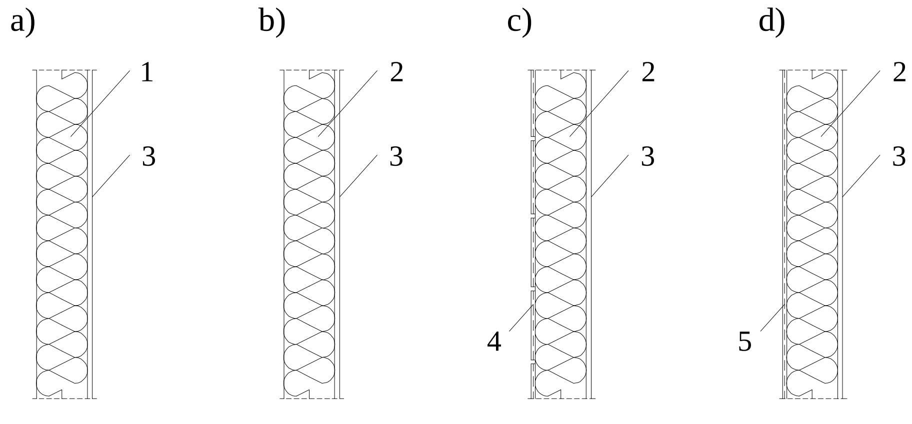

Fig.4. Four investigated models: *a* - the first case, *b* - the second case, *c* - the third case, *d* - the fourth case, *1*– mineral wool with density 90 kg / m^3, *2*– mineral wool with density 118 kg/m^3, *3*–a gypsum board, *4*–a poor wind barrier without continuity, 5 –a wind barrier

During the research, the heat flux density and the temperature changes were registered in a function of wind speed. Thermal changes were converted to thermal resistance changes. Simultaneously, infrared radiation emitted by the test specimen was detected by the FLIR scientific camera SC7200 with detector resolution of320x256 pixels and a thermal sensitivity of 20 mK. The camera allows to record a sequence of infrared frames.

7. The results

7.1. The measurements results of the thermal conductivity coefficient of loose fibrous insulations under no infiltration conditions

Fig 11. presents the 270 results obtained during HFM measurements. The results were achieved in non-isothermal conditions at an average temperature of the sample +10°C.

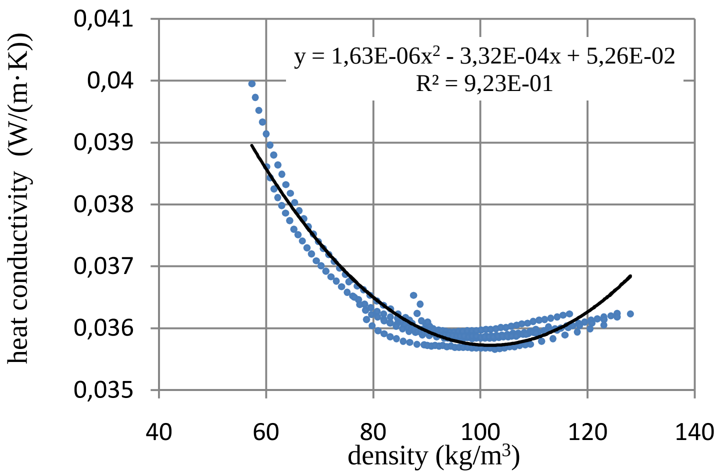

Fig. 5. A relation of heat conductivity in reference to loose mineral wool density

7.2. The results of measurements of the air permeable coefficient *κ* of mineral wool

The air permeability of the loose mineral wool is inversely proportional to the density of material. Table 1 shows the calculated values of the coefficient of air permeability and the corresponding values of the Rayleigh number.

Table 1

The calculated values of the air permeability coefficient and the Rayleigh number

Density(kg/m^3)	$T_1 - T_2$(°C)	Air permeability coefficient κ (m^2)	*Rayleigh number*(–)
80	20,0	1,484E-09	0,389
85	20,0	1,153E-09	0,302
90	20,0	9,049E-10	0,237
95	20,0	8,058E-10	0,211
100	20,0	7,915E-10	0,208
105	20,0	5,913E-10	0,155
110	20,0	5,209E-10	0,137
118	20,0	5,088E-10	0,133
120	20,0	4,171E-10	0,109
125	20,0	3,450E-10	0,090
130	20,0	3,798E-10	0,100

7.3. The results of measurements of the thermal resistance *R* of the frame wall filled with loose mineral wool insulation in the windless and windy conditions

Table 2 presents the average values of thermal resistance of the frame partition in windless conditions. Measurements were made for a fixed temperature of 20 °C on hot and 0 °C on the cold side.

Table 2

The average values of the measured thermal resistance of the two partition models differing with density of the thermal insulation

	A case	
	90 kg/m^3	118 kg/m^3
Thermal resistance ((m^2·K)/W)	3,476	3,797

Below on Fig. 6 the results of the variability of the thermal resistance of model partitions are presented. The tests were performed at four set wind speeds. The results are presented for one, selected measurement area.

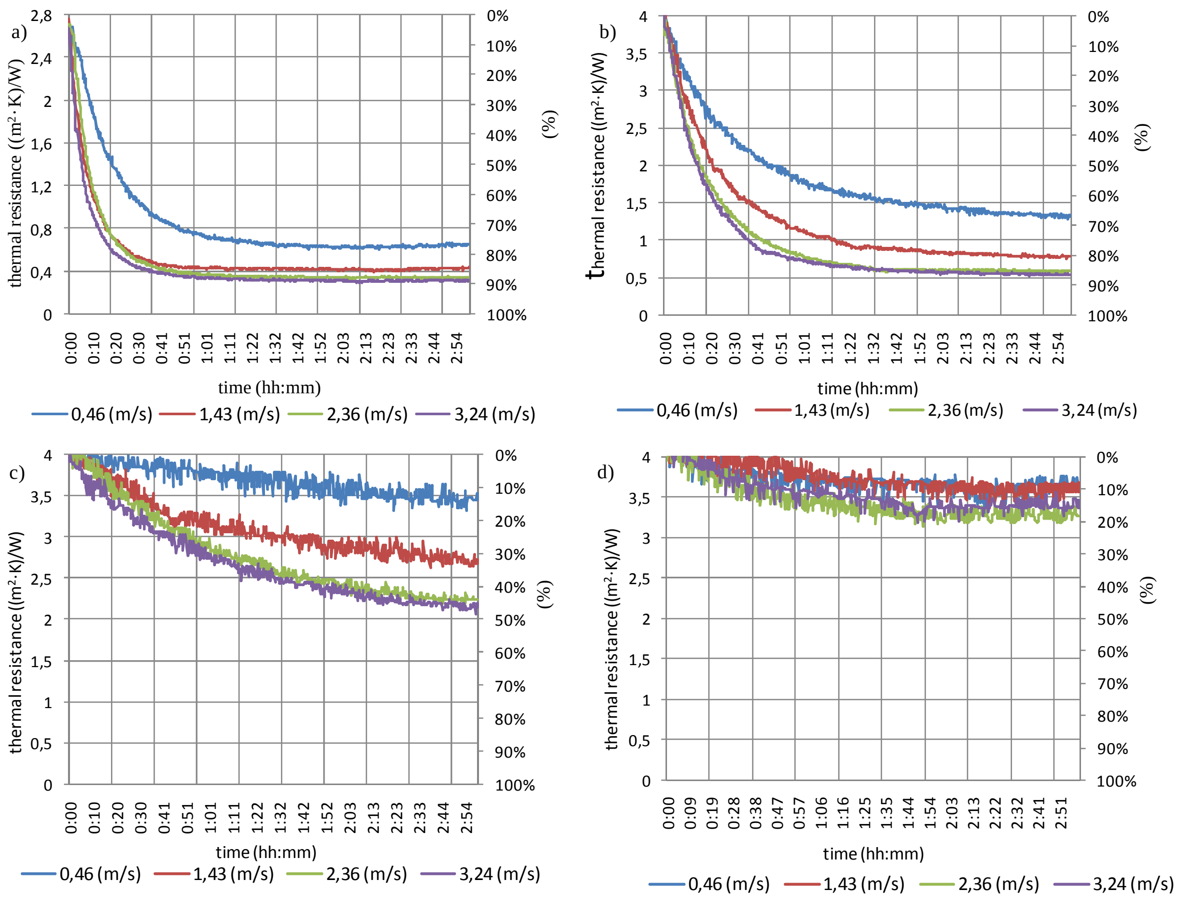

Fig. 6. Changes of thermal resistance at constant wind speeds registered for the fifth measurement area: *a* – the first model, *b* – the second model, *c* – the third model, *d* – the fourth model

Below there are presented examples of thermograms recorded for various partition models in windless and windy conditions.

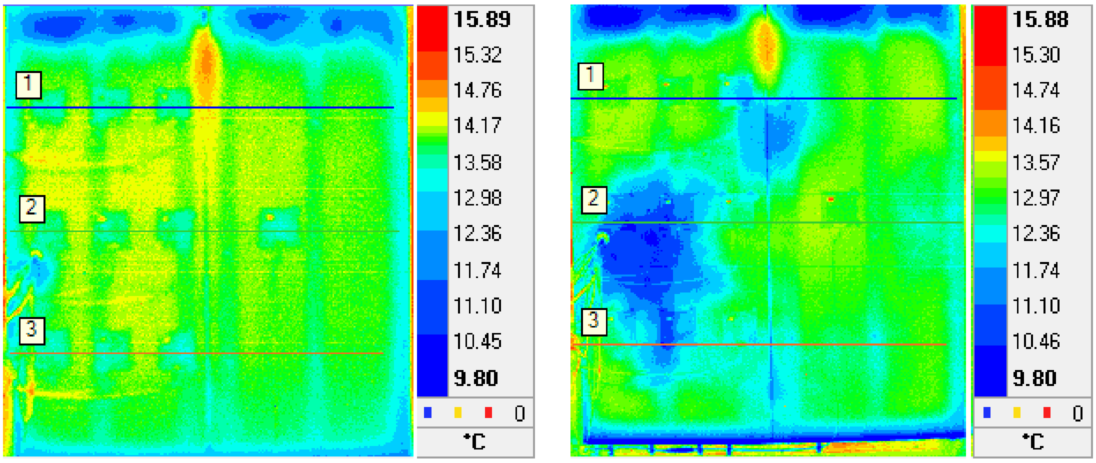

Fig. 7. The first model, the thermograms registered in windless conditions on left. and under windy conditions, the wind speed v = 3.24 m / s, Ti = 15,44°C, Te = 0,55°C

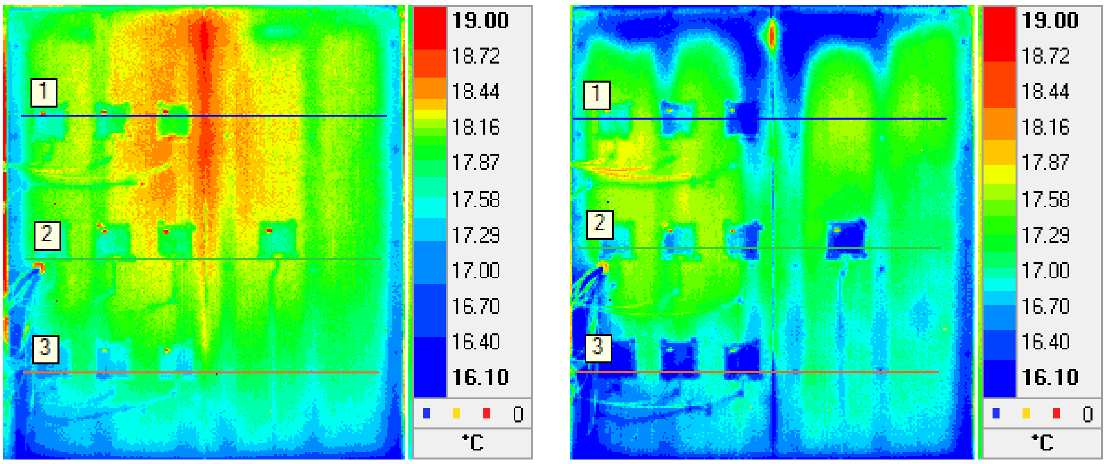

Fig. 8. The third model, the thermograms registered in windless conditions on left and in windy conditions, the wind speed v = 3.24 m / s, Ti = 18,94°C, Te = 0,54°C

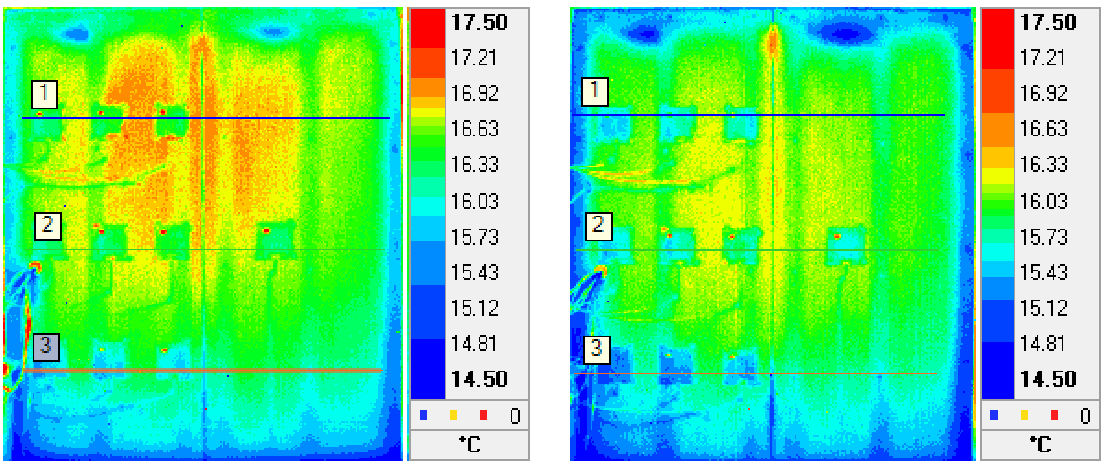

Fig. 9. The fourth model, the thermograms registered in windless conditions on left and in windy conditions, the wind speed v = 3.24 m / s, Ti = 17,28°C, Te = 0,26°C

The stationary methods for measuring the thermal properties of partitions do not cover the whole problematic area of a specimen, but only selected areas. Infrared detection proved to be the only effective method of identifying areas thermally changed due to the air filtration.

On the basis of stationary heat flux measurements and dynamic measurement of infrared radiation it was possible to conclude as follows:

– the reduction of the thermal resistance of building partitions increases proportionally to the wind speed,
– for maximum measured wind speed, the thermal resistance reduction reaches 80÷88% for the first model, 80÷87% for the second model, 80÷87% for the third model, 12÷22% for the fourth model,
– changes of the thermal resistance of building partitions decrease proportionally to reduction of air permeability of thermal insulation,
– despite decreasing air permeability by compaction of thermal insulation, the only effective solution against permeability is a tight wind barrier.

8. The simulation model and the comparative analysis of the simulation results andthe laboratory results

The thermal simulations were performed in the steady state conditions without the influence of wind and with the influence of wind on thermal insulation. The simulations were performed using the Control Volume Method in the Delphin software. Physical data for the simulation, as well as temperature difference and wind speed were adopted on the basis of laboratory measurements. Temperatures T_i = 15.44°C, T_e = 0.55°C, wind speed v = 3.24 m/s correspond to the differential pressure of 6.44 Pa. Each time after the simulation model achieved the thermodynamic equilibrium in windless conditions, it was started to get loaded with windy conditions.

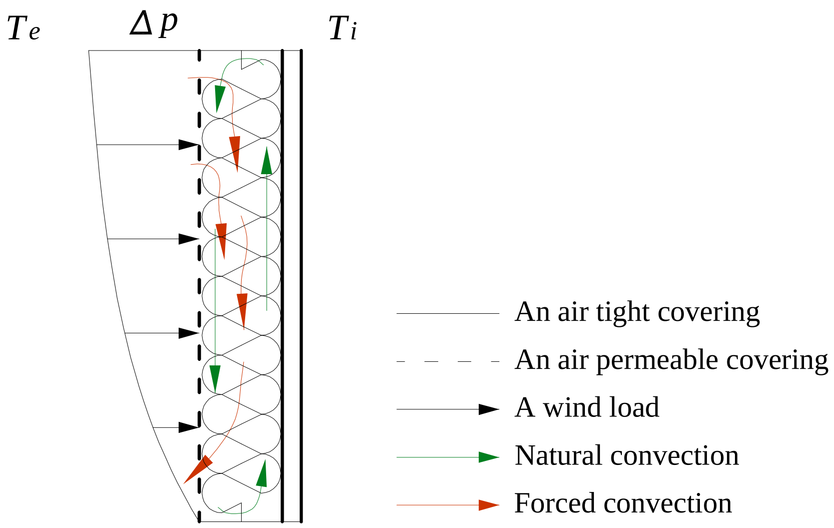

Fig. 10. The simulation model

The simulation results achieved for the model presented on Fig. 10 differ from the experimental results. The simulation heat resistance reduction (36%) was lower than achieved in laboratory experiments. The reason for that was due to not taking into account the local model discontinuities in sticking between fibres of the loose insulation. In the next step, the model was modified by inserting in the thermal insulation thin 4 mm gaps with a length less than the width of partition. The model was changed in 6 steps by various length of the gaps: 33, 67, 100, 112, 120 and 125 mm. On Fig. 11 there are shown isotherms in a cross section of the partition achieved for gaps: 33, 100 and 125 mm.

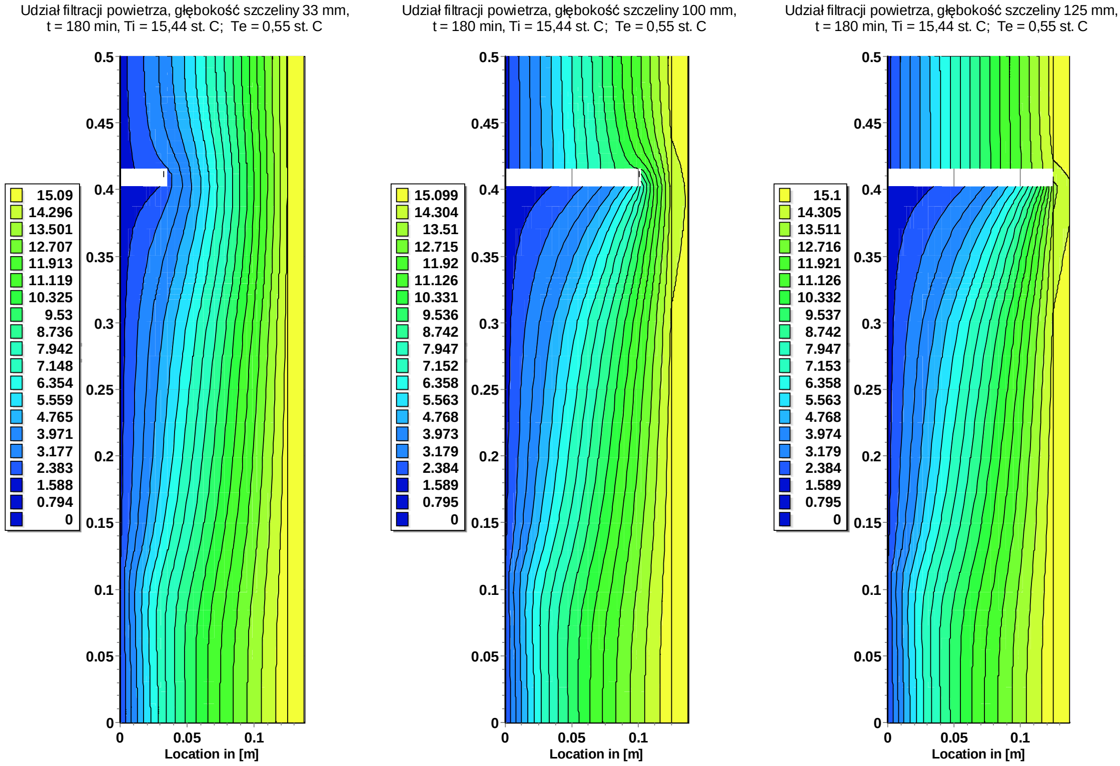

Fig. 11. The isotherm maps illustrating the effect of the local discontinuities in sticking between fibres on thermal behavior of partitions, 90 kg/m^3 density of mineral wool, T_i = 15,44 °C, T_e = 0,55 °C, v = 3,24 m/s: *a* – 33 mm, *b* – 100 mm, *c* – 125 mm

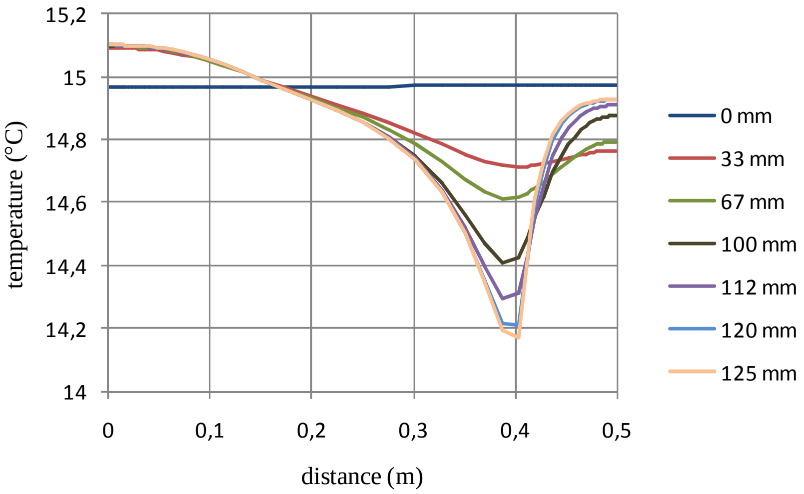

Fig. 12. The effect of the local discontinuities in sticking between fibres on thermal behavior of partitions, 90 kg/m^3 density of mineral wool, T_i = 15,44 °C, T_e = 0,55 °C, v = 3,24 m/s:

On the basis of the thermal simulation results and compiling these results with the laboratory experiment it was possible to conclude:

– computing thermal simulations does not take into account the local model discontinuities in sticking between fibres of the insulation,
– the chosen modification of the model by including the local discontinuities is valid and should be continued by developing additional parameter of simulation –the fibres separation factor.

9. The conversion of heat conduction coefficient in the function of the air infiltration

An analysis of variability thermal properties of the loose mineral wool as a function of air permeability was performed using the method of principal component analysis. Each component index explains some of the variance in the original variables. The analysis was conducted for measuring areas differing in individual characteristics of the material and geometry. On the basis of these analysis it was possible to identify those characteristics of the partition (primary variables), which are important for the description of the effect of infiltration on the heat transfer through the envelope. A covariance matrix corresponding to four specimen models was created. The analysis showed an impact of several factors on thermal changes of insulation properties in windy conditions. These factors include: the type of the partitions, including the formation of a thermal insulation layer and its protection against wind, natural subsidence of the embedded mineral wool in the partitions, the local deviation from the adopted density thermal insulation and the presence of air gaps.

Through a principal component analysis it was possible to determine the components of the conversion of heat conductivity of loose mineral wool as a function of air permeability. The conversion is expressed in relationships (4) – (9):

$$\boxed{\lambda_2 = \lambda_1 \cdot F_{inf},} \qquad (4)$$

where:

λ_1 – is the heat conductivity coefficient without air infiltration (W/(m·K)),

λ_2 – is the heat conductivity coefficient with air infiltration (W/(m·K)),

F_{inf} – is the conversion factor due to the infiltration (–).

$$\boxed{F_{inf} = 0{,}989 + k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot v^{0{,}5},} \qquad (5)$$

where:

k_1 – is the factor due to the type of construction of thermal insulation layer (–),

k_2 – is the factor due to local density of the insulation fibres (–),

k_3 – is the factor due to air gaps in construction (–),

k_4 – is the factor due to the subsidence of fibres (–)

v – is the wind speed (m/s).

On the basis of several year lasting research focused on heat transfer in various building partitions insulated with loose mineral wool it was possible to determine the values of k_i factors in the formula for converting heat conductivity of the thermal insulation. The following equations have been formulated on the basis of analysis of comparative test results.

$$k_1 = \begin{cases} 0.224 - \text{mineral wool exposed to a wind}, \rho \le 95\,\text{kg}/\text{m}^3, \\ 0.132 - \text{mineral wool exposed to a wind}, \rho > 95\,\text{kg}/\text{m}^3, \\ 0.016 - \text{mineral wool partly exposed to a wind}, \rho > 95\,\text{kg}/\text{m}^3. \end{cases} \quad (6)$$

$$k_2 = \begin{cases} 1.15 - \text{local lower density of mineral wool}, \\ 0.82 - \text{local higher density of mineral wool}, \\ 1.00 - \text{others}. \end{cases} \quad (7)$$

$$k_3 = \begin{cases} 4.00 - \text{a distance to air gap in wind barrier lower than } 0.35\,\text{m}, \\ 1.00 - \text{others}. \end{cases} \quad (8)$$

$$k_4 = \begin{cases} 1.05 - \text{an occurence of mineral wool subsidence in building partition}, \\ 1.00 - \text{others}. \end{cases} \quad (9)$$

10. Conclusion

1. Forced convection caused by a wind is an important factor in the process of heat transfer through building partitions filled with loose mineral wool. A reduction of heat properties of the partition depends on the air permeability of thermal insulation. The higher density of thermal insulation, the smallest air permeability and as a result the less sharpness of heat changes. However, during the long-term wind conditions, the increasing of the density of material minimally affects the reduction of heat loss caused by forced convection.
2. There is a clear correlation between wind speed and interacting thermal changes in the building partition. The faster wind blows, the higher reduction of thermal resistance of partition is. Even at low wind speeds, about 0.5 m/s, there is a convection heat transfer in wind-washed thermal insulation layer.
3. Factors that affect the heat transfer through building partitions exposed to wind-washing are: a wind speed, a type of construction including the formation of an insulation layer, a natural compaction of thermal insulation material, a local deviation from the adopted density of thermal insulation and the presence of air gaps in a wind barrier.
4. In windy conditions thermal properties of insulation decrease in case there is no wind barrier in the building partition.
5. The Rayleigh number can be used to describe the effect of the forced convection heat transfer in the fibrous heat insulating materials with open pores. On Fig. 13 there is presented the summary of density of loose mineral wool and calculated Rayleigh numbers. Implementation of loose mineral wool with density lower than 90 kg/m^3 was impossible in the wall. On the other hand, it is possible to implement the density higher than 118 kg/m^3, but lower than 130 kg/m^3, what was proven during the heat flow meter measurements. Therefore, it is recommended to reduce the critical value of Rayleigh number in a case of loose mineral wool to the value 0.090.

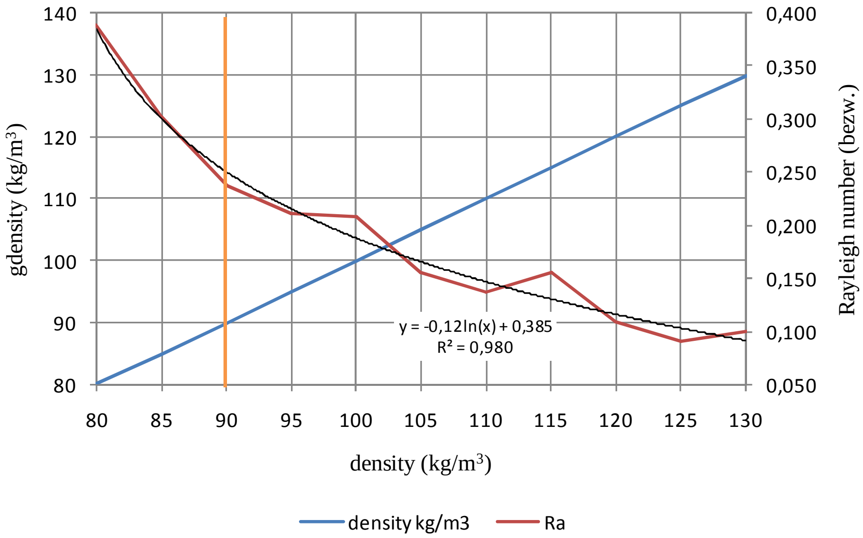

Fig. 13. Rayleigh numbers corresponding to the loose mineral wool density

6. Existing thermal models to simulate coupled processes of heat and mass transfer does not include local discontinuities between fibres of loose thermal insulation. This led to discrepancies between the simulation and the laboratory results. The suggestion is to modify thermal models by developing additional parameter of simulation – the fibres separation factor.
7. In order to determine the effect of infiltration on heat transfer through a building envelope insulated with loose mineral wool, it is recommended to convert heat conductivity coefficient using (4) – (9) relation during computing the heat resistance of thermal insulation.
8. The suggested methodology may be useful in the hygrothermal calculations in the building partitions not protected against wind-washing. The methodology can also be useful to estimate the real heat losses and possibility of vapor condensation in existing building partitions.

The perspectives

The actual work will be extended by thermal research in non-isothermal climatic chamber on other thermal insulation materials such as loose wood wool, slabs of wood wool and mineral wool. The future study will also take into account other types of construction partitions. It is necessary to promote the existing research results among designers and building engineers,. In future perspective, it is planned to modify the air infiltration thermal models by developing additional parameter of simulation – the fibres separation factor. There is also a need for a statistical analysis of long-term wind load on the heat demand calculations and analysis of short-term wind load on the risk of mycological problems.