

Evaluation of thermal performance of window lintel construction detail

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Abstract. Ceramic bricks belong to the oldest and most used building material since the ancient ages. Notwithstanding, this favorable building material passed through many improvements and currently used ceramic brick is substantially improved compared to bricks from ancient production. The contemporary demands are paid especially on the mechanical resistance, high vapor permeability, outstanding thermal insulation properties, thermal accumulation function and noise insulation. On this account, the hygrothermal properties of construction detail composed by a contemporary lightweight hollow brick together with window lintel is investigated within this paper. Compared to laboratory methods aimed at the measurement of small samples, the semi-scale analysis represents a valuable approach for building materials testing. For this purpose, a system composed of two climatic chambers separated by the connecting tunnel with desired building construction detail is used. The brick block and window lintel is placed in a chamber connection tunnel, thermally insulated by mineral wool to ensure one dimensional transport and studied in sense of loading by real climatic data from Czech Republic. This valuable analysis allows long-term monitoring of the wall cross-section temperature and relative humidity profiles of particular elements in real scale. The obtained results represent valuable information for the practical application of the studied brick block in building practice. Such comparison allows optimization of building envelopes in order to improve their energy efficiency.

1. Introduction

Increased attention of this period is paid on the thermal stability of building envelopes. The optimization and improvements focused on decrease of the thermal conductivity is one of the most investigated topic by building designers and engineers. The ceramic burnt bricks are still the most often used building material across developed countries and their history can be traced back to antiquity. Despite of development of many modified or competing product based on cementitious material, wood construction, sandwich element made from recycled materials, the popularity of application of ceramic bricks is still high. This fact can be assigned to their favorable properties based on very good mechanical resistance, thermal insulation performance, thermal accumulation parameters, resistance to outdoor climatic fluctuations, high water permeability and no health risk [1]. However, building envelopes are not consisted only by bearing elements such as bricks or building blocks from various materials but also by specific construction elements with different characteristics, technical purpose and properties [2]. In this sense, it can be mentioned all atypical construction detail such as niche, door, windows and related lintels. The displacement of these elements pose significant risk for occurrence of thermal bridges and consequently associated phenomena [3].

The advanced design of individual building elements is necessary for reduction of energy consumption associated to the building operations without deterioration of indoor thermal comfort.



Based on the sustainability principle, which paid attention in building sector especially on construction of low and passive houses, the thermal performance of the whole building envelope still requires research. The latter mentioned building standards are sensitive on the site, building orientation, ventilation, applied insulation materials, thermal storage capacity of used materials and design of windows or other similar elements. The evaluation of energy efficiency of used elements is essential for construction of modern building envelopes with desired functional properties. Moreover, these parameters are important for maintenance of interior comfort and is related to living condition for residents [4].

The assessment of the thermal conductivity or thermal resistance can be perceived as one of the most often used parameter for building materials classification. In this respect, the thermal properties and thermal insulation plays an important role in current building industry [5]. The thermal performance of the building envelopes is closely linked to the moisture content contained in pores of building materials. Namely, the water presence in the pore space is responsible for deterioration of thermal performance due to significantly higher thermal conductivity of water compared to thermal conductivity of air. Therefore, the definition of thermal performance in relation to the humidity level is very important [6].

In summary, the proper understanding of correlation between outdoor conditions, thermal performance of building materials, quality of the indoor environment together with energy consumption associated with building operations is essential for compliance of sustainable development principles within the building design.

The determination of the thermal conductivity of materials is usually carried out within laboratory conditions by transient or steady-state methods. The main advantage of the transient method compared to the steady-state is its shorter measurement time. However, the accuracy and reproducibility of the measurement is questionable. On the other hand, the steady-state method is used as a reference method. The thermal conductivity is determined in this case by Fourier law equation. The arrangement is based on the measurement of heat fluxes induced by the temperature difference between heated and cooled plate of the measurement device. The weak point of this method is consisted of measurement of small samples and thus the transferability of the obtained data is limited, especially when the heterogeneity of particular building elements is taken into account.

In the light of these assumptions, this paper is focused on determination and comparison of thermal performance of window lintel together with hollow brick block. Since these materials are utilized for construction of building, the determination of their thermophysical properties represent important parameter for their application. Here, the studied construction detail is placed in the climatic chamber system and real scale measurement is carried out.

2. Studied materials

The window lintel fabricated by Heluz CZ, was chosen for this study. This element was together with hollow brick block subjected to experimental assessment of hygric and thermal properties during the winter period determined by the semi scale experiment.

The basic material properties of the hollow brick (Table 1) were determined by the measurement of the bulk and matrix density. Bulk density was accessed gravimetrically, matrix density by means of water vacuum saturation method. Consequently, the total open porosity was calculated. The moisture dependent thermal conductivity is presented in Table 2. Provided results were measured by commercial device ISOMET 2114 (Applied Precision) working on dynamic measurement principle.

Table 1. Basic physical properties of particular materials

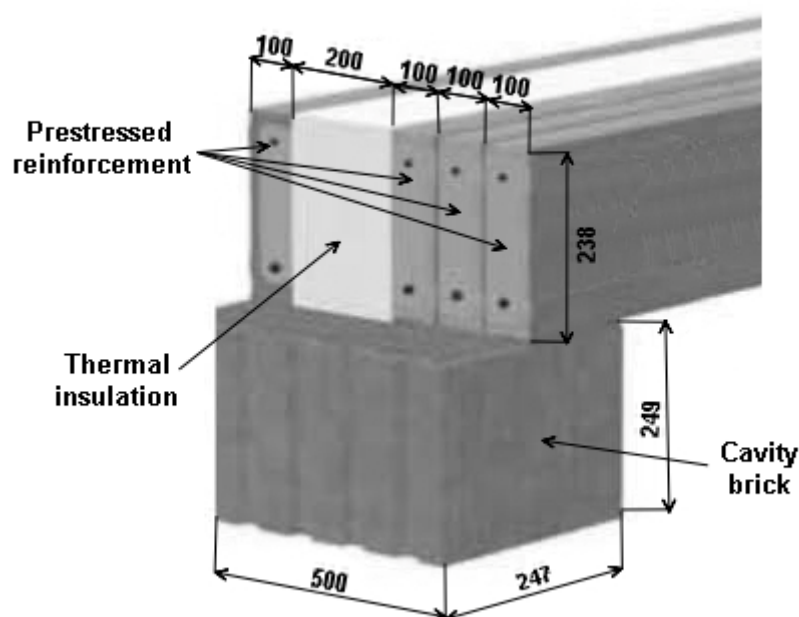
Bulk density (kg/m³)	Matrix density (kg/m³)	Total open porosity (%)
1 389	2 830	50.9

Table 2. Thermal conductivity of the brick body

Moisture content (m^3/m^3)	Thermal conductivity (W/mK)
0.0	0.3
0.11	0.44
0.13	0.57
0.29	0.75
0.36	0.88
0.46	1.03
0.49	1.06

3. Semi-scale experiment

The light-weighted hollow ceramic brick as well as window lintel are produced by the Heluz Brick industry (Czech Republic). This type of elements is usually used for the thermal insulation masonry with a width of 500 mm. The window lintel is composed by four elements. Three of them are prestressed concrete reinforcements with about 100 mm thickness completed with polystyrene thermal insulation with thickness about 200 mm. The detail of construction detail placed in the connection tunnel of climatic chamber system is depicted in Figure 1.

**Figure 1.** Description of studied construction detail

The semi-scale experiment was realized in a climatic chamber system assembled in laboratory of Department of Materials Engineering and Chemistry [7]. System is composed of two climatic chambers equipped by connecting tunnel for placing the studied construction (Figure 2). Maximum volume of the tested specimen, which is possible place into the connecting tunnel, is about 0.35 m^3 with surface exposed to the simulated outdoor conditions of dimension $0.7 \times 0.9 \text{ m}$. The construction of the individual chambers is based on common commercial solutions for controlling temperature and relative humidity conditions but the solution of connections between the chambers and the tunnel and of the organization of additional admission holes for parallel measurements are designed in our laboratory.

Within this study the investigated window lintel construction detail of real dimensions was placed into the tunnel, equipped by the combined temperature and relative humidity sensors and thermally

insulated from sides in order to achieve dominant heat and moisture transport through the studied elements (Figure 3). For realization of the semi-scale experiment simulating outdoor climatic conditions, the temperature and relative humidity in the first climatic chamber used for simulation of indoor climate was maintained at the constant temperature at 21 ± 0.3 °C and relative humidity at 30 ± 2 %RH. The second chamber was used for simulation of difference outdoor conditions based on the reference year (TRY) [8] by meaning of hourly changes. TRY use averaged real weather data for specific locations from several decades from the past. Here, the winter period was chosen due its importance and demanding conditions for testing of thermal performance of building envelope. Finally, the climatic chamber system was closed, and required temperature and relative humidity values were set. On the exterior side, there were simulated typical climatic conditions for Prague, whereas the climatic loading started with data corresponding to 1st November and the experiment was stopped on date corresponding to 31st February. Hence, the whole winter period, which is the most critical part of the year from the point of view of heat losses, was simulated.

The data logged by measuring devices were evaluated and critical morning data (corresponding with 8 am) were chosen for comparison.

Continuous monitoring of the temperature and relative humidity distribution along the hollow brick thickness was carried out by combined sensors from Ahlborn, Germany. Sensors have measuring range from 5% to 98% RH with a 2% uncertainty. The temperature measurement is done using NTC thermistors with an uncertainty of 0.1 °C. The temperature profiles and relative humidity profiles were logged in 10-minute interval.

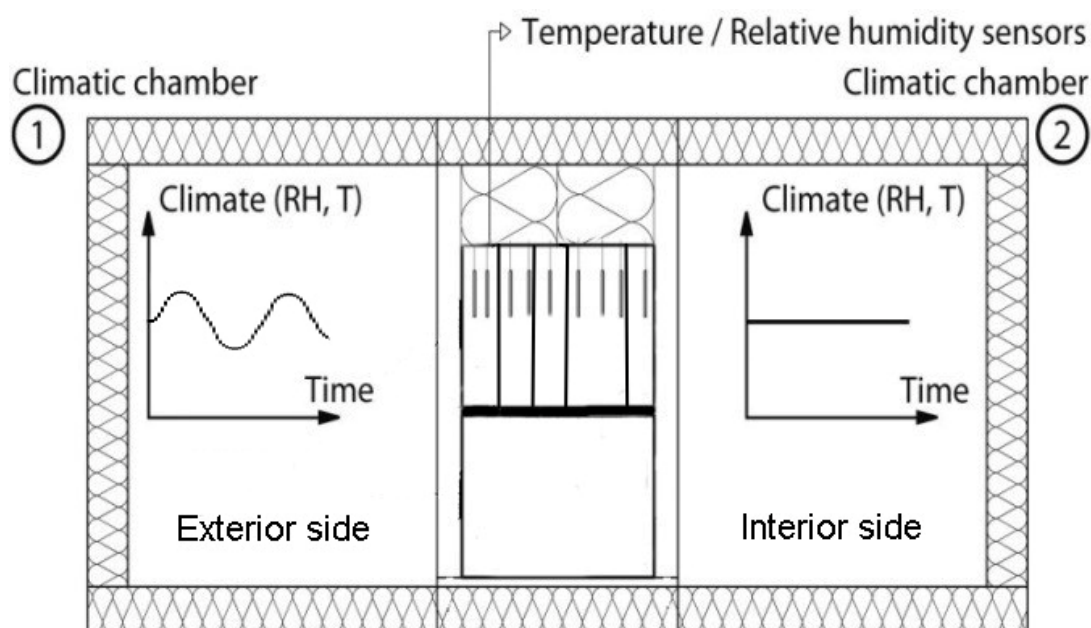


Figure 2. Schema of the experimental setup in cross-section

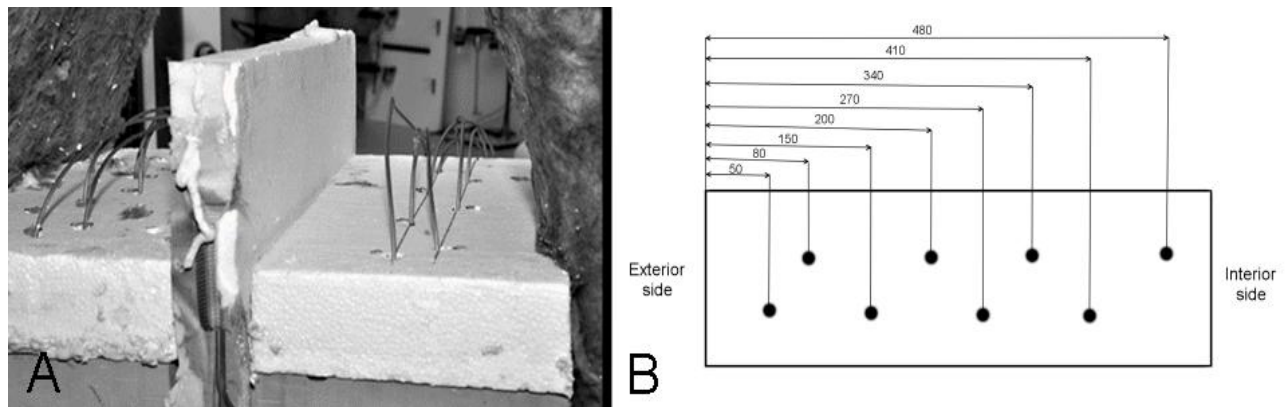


Figure 3. Sample insulation (A) and sensor positioning (B)

4. Results and discussion

The temperature and relative humidity wall cross-section profiles of window lintel and hollow brick block are plotted in Figures 4 and 5. Looking at the temperature profiles one can observe high sensitivity of the researched construction detail on the exterior temperature variations. On the other hand, only slight changes can be distinguished between the window lintel and the hollow brick. While the thermal conductivity of the concrete part has worse thermal performance, the applied insulation layer with 200 mm of polystyrene insulation improved insulation properties of the window lintel. From this point of view, the overall thermal response of lintel is slightly better compared to hollow brick despite the poor thermal insulation properties of prestressed concrete reinforcement which composed main part of the element. The thermal insulation function of both brick block and window lintel can be considered good in general, what is promising for practical application of the developed material in building practice. At 150 mm distance from the interior surface, there were measured temperatures of the brick about 18 °C, what is very good for the conditioning of the interior climate. Basically, there were only small differences between interior temperatures and the temperatures of the brick at the distance of 150 mm from the brick surface. This observation is even more distinct for window lintel with the polystyrene insulation layer.

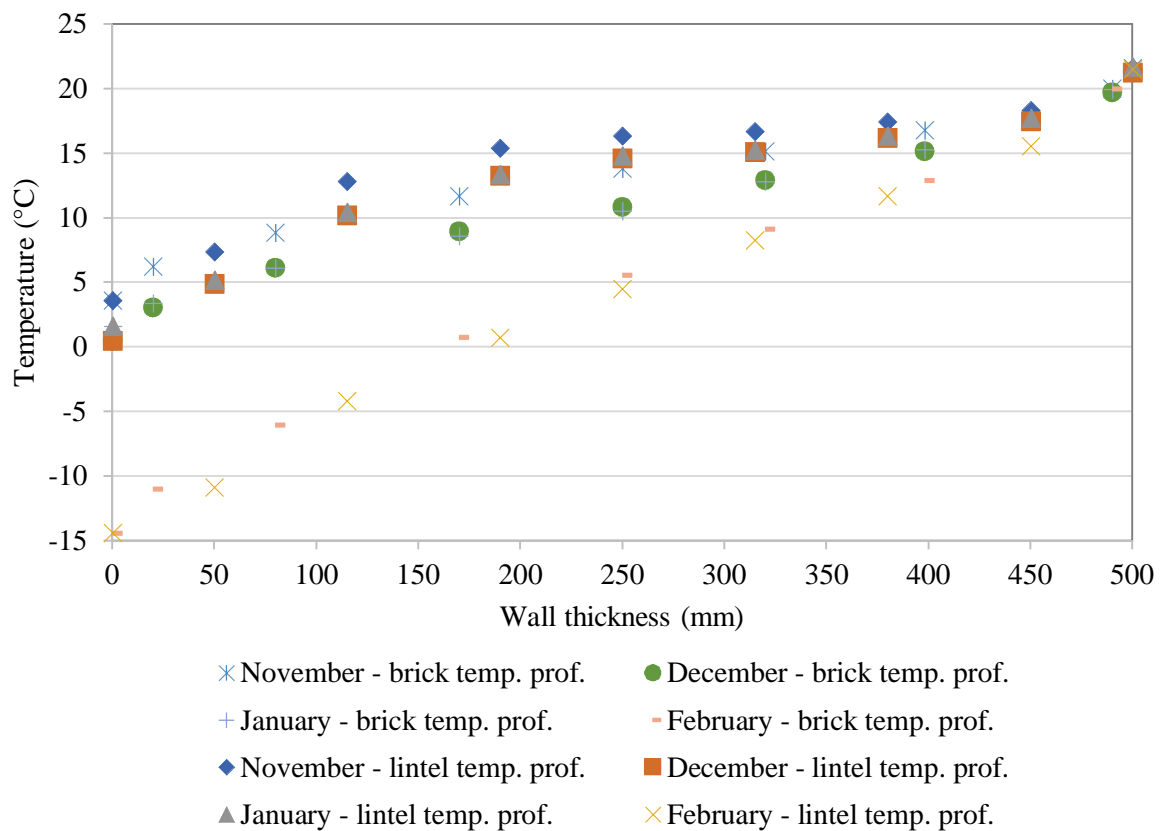


Figure 4. Measured temperature profiles in wall cross-section

Relative humidity profiles reflected the simulated relative humidity in the exterior chamber. Typically, the high values of relative humidity were measured for climatic loading corresponding to period from November to February. Here, the relative humidity values were < 60% up to 400 mm distance from the interior surface of the window lintel. Contrary to this finding, the relative humidity profiles obtained for the hollow brick were significantly different. Here, gradual decrease of the relative humidity was achieved and even 100 mm from the interior surface was relative humidity higher than 80 %. Based on the obtained data, the moisture transport was pronouncedly affected by the polystyrene insulation layer. The very low water vapor permeability of polystyrene, the relative humidity dropped from about 95% to about 60 %. This fact can be correlated with the worsening of the thermal performance of the hollow brick. The increase of the water vapor in bricks cavities induced shift in the thermal conductivity thus, insulation performance of the hollow brick was decreased. Moreover, different material response to the varying exterior conditions could be perceived as the potential risk especially on the contact surfaces of the particular elements.

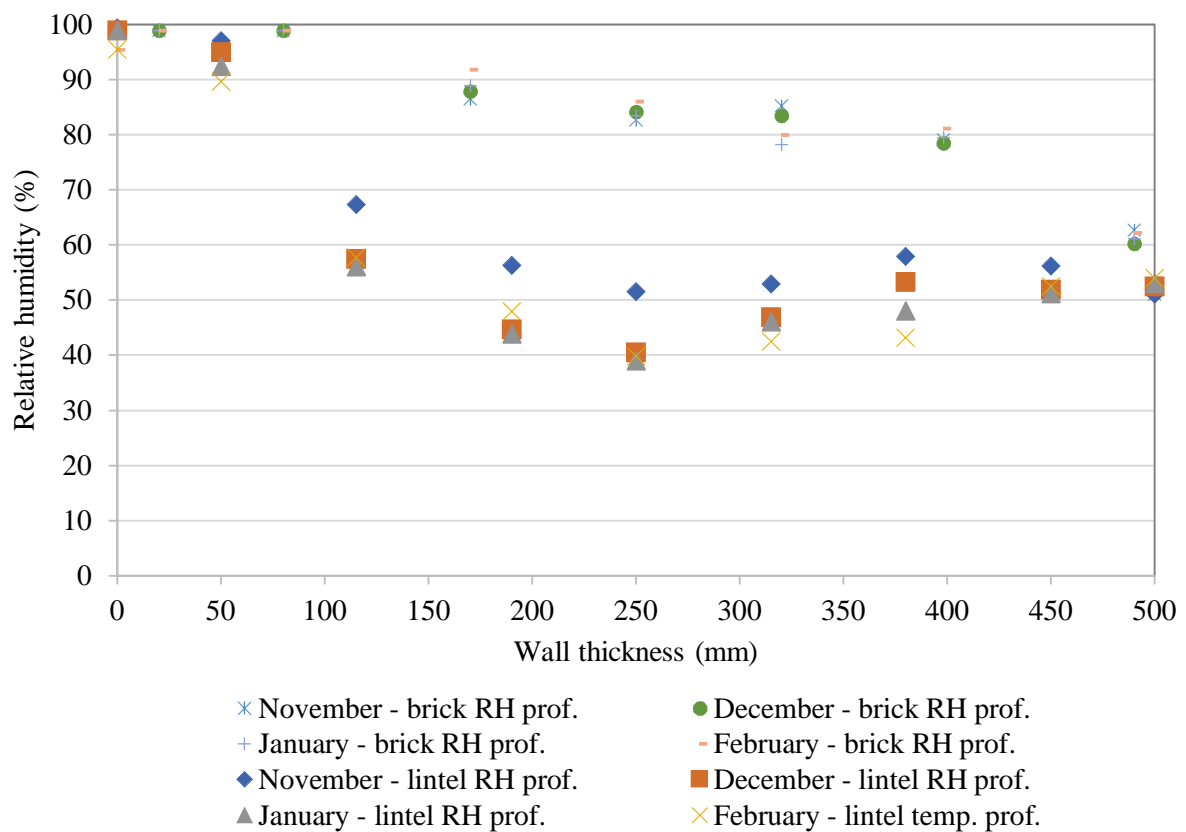


Figure 5. Measured relative humidity profiles in wall cross-section

5. Conclusions

The utilization of semi-scale analysis for experimental assessment of hygrothermal performance of the large construction element was found to be effective way for such type of analysis. The relatively low cost of the experiment in a combination with the suitable accuracy of the temperature and relative humidity profiles during long-term continuous measurement makes good prerequisites for an extensive use of the technique.

Applied climatic load has made it possible to evaluate the functionality of the tested construction detail during the winter period, which can be perceived as the most demanding and critical season especially from the thermal losses and related energy demands. The obtained results revealed a good hygrothermal performance of the window lintel. Concurrently, the significant influence of applied insulation layer in the window lintel to water vapor transport properties was revealed.

Acknowledgement

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6. References

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