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Impacts of airflows, internal heat and moisture gains on accuracy of modeling energy consumption and indoor parameters in passive building

Szymon Firląg [a,*], Bernard Zawada [b]

[a] Department of Building Construction, Faculty of Civil Engineering, Warsaw University of Technology, Armii Ludowej 16, 00-637 Warsaw, Poland
[b] Division of Air Conditioning and Heating, Faculty of Environmental Engineering, Warsaw University of Technology, Nowowiejska 20, 00-653 Warsaw, Poland

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ABSTRACT

Passive buildings compared to the standard ones require significantly less energy for heating, so the correct models of every "energy using" building's components are very important. This paper analyzes how various models of the internal heat and moisture gains, as well as natural airflows between building zones, influence the accuracy of the calculation of the energy performance, indoor temperatures and absolute humidity in a single-family passive building. A simulation environment used a detailed twelve-zone TRNSYS model of a house with HVAC system. The model included natural airflows between zones, and internal heat and moisture gains, defined as precisely as possible. The gains were allocated on the basis of special protocols of use filled by the occupants during the two-week measurement. The measurement data were also used for validation of the model. The verified model constituted a basis for calculation of energy performance and simulation of air temperature and absolute humidity change in a building with significantly limited airflow between zones, and heat and moisture gains defined according to standards. The standardized values of heat and moisture gains were defined on the basis of the standard ISO 13790 and national regulations in Poland. The simulations have shown that precise methodology of calculation of heat gains and airflows between building zones is very important for proper computation of energy performance and simulation of indoor temperatures and absolute humidity in passive buildings. Results of carried out analysis have shown that the difference in energy need for heating calculated using precise and simplified methods of internal heat gains determination was 30.1%.

1. Introduction

Passive buildings compared to the standard ones require significantly less energy for heating and ventilation, while internal heat gains are almost the same. The energy demand for heating in passive buildings is less than 15 kWh/m^2, while for example in new residential in Poland – 60–120 kWh/m^2 [1]. Heat gains cover about 20% of whole energy loss in the case of a standard building and up to 65% in a passive house [2].

This fact leads to two important conclusions. Firstly, increasing the heat gains, e.g. by appropriate orientation of windows, may contribute to a significant reduction of energy need for heating. Maximization of gains can at the same time cause increase of energy need for cooling, which was confirmed in the article of Enshen [3]. Secondly, a fluctuation of internal heat gains can cause significant change of the internal air temperature and requires specific control strategies. Appropriate control is necessary to obtain good thermal comfort as well as high energy efficiency. That is why, if we want to predict correctly the internal environment conditions in a very low-energy buildings (like passive buildings – nearly zero-energy buildings) and calculate correctly their energy needs, we have to use precise building and system models. What is even more important, much attention should be paid to the appropriate determination of internal heat and moisture gains as well as airflows between building zones, all of which factors are often determined in a simplified way. For example, simplified methodology defined in standard ISO 13790 [4] can be suitable for buildings with standard energy need, but for very low-energy buildings the methodology has to be more precise. Otherwise real energy performance of buildings can be higher than calculated and energy savings lower than predicted. This aspect is particularly important due to the recast of the Energy Performance of Buildings Directive and implementation of 'nearly zero' energy buildings [5].

Unfortunately there are practically no publications on this subject. The article of Saelens [6] analyzes the influence of occupant behavior and internal gains on the energy performance and thermal comfort of a typical office building. Similar analysis of an office

* Tel.: +48 22 5054746.
E-mail address: sfirlag@nape.pl (S. Firląg).

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building, which takes into consideration architectonic and management improvement actions, can be found in article of Pujol-Nadal [7]. The impact of the factors analyzed in these articles will be probably greater in regard to passive buildings with very small energy demand. Internal heat sources and their detailed time schedules in passive building were described very precisely by Badescu and Sicre [8]. The aim of paper was modeling of renewable energy usage for space heating. The influence of the internal heat sources on energy consumption and indoor parameters was no analyzed.

2. Methodology

The analysis was carried out on the example of a single-family passive house of "JDL: Jangster de Lux" type located in a passive housing estate in Hannover-Kronsberg (Germany). Performance measurements were carried out in 2001 under the project CEPHEUS by Passivhaus Institut in Darmstadt and were described in the reports [9–11]. Measurement results were used for verification of advanced numerical models created for the purpose of the study.

The calculations were carried out using TRNSYS simulation programe (Transient Simulation Programe) which is widely used around the world [12–15]. TRNSYS programe is designed for dynamic simulation of buildings with heating, ventilation and hot water systems, especially those equipped with solar panels. The programe capabilities can be used for detailed analysis of thermal-moisture phenomena in buildings, in particular for calculation of energy need for heating and cooling, maintenance of thermal comfort and indoor temperatures and absolute humidity change [6]. The analysis can include optimization of energy consumption, testing of renewable energy sources, building materials [16], control algorithms, etc., as well as be used for didactic purposes.

Numerical models of TRNSYS can be combined in many configurations with other calculation methods and programming packages (Matlab, Artificial Neural Network, Genetic Algorithms, etc.) [17]. The calculation model used in the programe was verified, both practically and theoretically, in many experiments and research projects [18,19]. Creating model of a passive building requires a very precise consideration of such phenomena as internal heat and moisture gains, air distribution in the building and shading elements. Commonly used assumptions which are simplifying these phenomena, in the case of passive buildings may lead to erroneous calculation results.

3. Models

The impact of simplifying assumptions on the accuracy of calculation results was analyzed on the basis of complex, interconnected numerical models developed in TRNSYS. The models included multi-zone model of a passive house, model of indoor airflow, model of mechanical ventilation and model of space heating. The aim of the analysis was to investigate the sensitivity of models to assumptions regarding internal heat and moisture gains and air distribution.

3.1. Multi-zone house model

Using an application TRNBuild based on block Type56 was created a twelve zone model of the passive house. The task of the model was to reproduce as closely as possible house 13.1 of "JDL: Jangster de Lux" (Fig. 1) type located in a passive housing estate in Hannover-Kronsberg. The non-basement terraced house with gabled roof and external storage room was built using a mixed modular system: ceilings, partition walls between homes, gable walls and remaining load-bearing structures consist of prefabricated reinforced concrete slabs; the highly insulated facade and roof are lightweight prefabricated wood elements. In addition, in the house were installed triple-glazed windows with specially insulated window frames as well as a home ventilation system with a high efficiency heat exchanger Thermos 200 DC.

Description of the estate and house-type "JDL" can be found in [9,20]. Table 1 contains respectively the U-values of the house envelope and the Ψ-values of thermal bridges of the house elements' connections used in the model.

This developed multi-zone model of the passive house allowed for mapping of thermal-moisture phenomena occurring in the real house. The multi-zone model included: the properties of massive, multi-layer building elements, the properties of transparent building elements, thermal bridges, infiltration of outside air, the airflow between rooms, internal heat and moisture gains, the internal heat loss, shading by neighboring objects and house parts.

3.2. Air distribution model

Modeling of air distribution in the house included determination of the supply airflow rates to zones, airflow rates between the zones and exhaust airflow rates form zones. Size of the flows was determined on the basis of the results of detailed measurements carried

Fig. 1. Attic, ground and first floor plans and their zoning in the passive house of JDL type. 1 – living room; 2 – kitchen; 3 – vestibule; 4, 11 – utility room; 5 – WC; 6 – staircase and hall; 7.8 – children's rooms; 9 – bathroom; 10 – bedroom; 12 – technical room, total living area 120.1 m^2.