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Validation of neural network model for predicting airtightness of residential and non-residential units in Poland

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ABSTRACT

This paper presents validation of the neural network model for predicting airtightness of residential and non-residential units. Proposed model developed in previous research utilizes a neural network in prediction of airtightness and it is obtained based on in situ measurements at 58 units in Croatia. Model applicability earlier was tested by independent validation through 20 additional measurements in Croatia and on 5 measurements in Serbia. This paper presents validation of neural network model for predicting airtightness of residential and non-residential units on database formed beyond the regional area. Database used for model validation in this paper consists of 20 residential and non-residential units from Poland with building construction technology similar to Croatian ones. Comparison of the results obtained by measurements and prediction model indicates that the model gives consistent results on the validation data set with similar building construction technology and demonstrates that model is not locally conditioned.

1. Introduction

Directive 2010/31/EU on the energy performance of buildings introduced the concept of the “nearly zero-energy building” [1]. In this directive, the member states agreed to ensure that, after 31 December 2018, new buildings occupied and owned by public authorities will be nearly zero-energy buildings and that, by 31 December 2020, all new buildings will be nearly zero-energy buildings [1]. The member states agreed to take the necessary measures to ensure that, when buildings undergo major renovation, the energy performance of the buildings or their renovated parts will be upgraded to meet the minimum energy performance requirements [1]. But buildings constructed several decades ago often do not meet the energy efficiency requirements according to current legislation in European Union [2]. A significant percentage of such buildings will continue to be used for many more years, and unless they are renovated in terms of energy performance, they will continue to needlessly consume great amounts of energy.

From the practical building technology point of view, it is rational to combine insulation with the air-tightening of the building envelope [3–5]. The air tightness of building constructions is a problem which has been appearing in many publications. Studies on the influence of cracks occurring in the building envelope on the building's air condition were conducted as early as in the 1920s' by Japanese scientists [6]. Up to today, a number of studies on air infiltration through the building envelope have been carried out. Most of the works involve air exchange and ventilation heat loss in buildings. Uncontrolled air flows through building enclosure can lead up to 9 times higher heat transfer [7]. Especially wind washing the porous thermal insulation embedded in the building envelope prevents the fulfilment of the energy requirements [8]. But low tightness of building envelope leads to moisture degradation as well [9–11].

Airtightness measurement are carried out using blower-door equipment and blower-door method to find the relation between the pressure difference over the building envelope, ΔP [Pa], and the airflow rate through the building envelope, Q [m^3/h] [12].

The “building envelope” refers to several types of opaque and transparent perimeter structures or elements, which separate the internal heated (or cooled) space from the external unheated (or uncooled) space.

Requirements for air tightness of Polish and Croatian buildings are as following, the air changes per hour at 50 Pa (n_{50}) should not exceed 3 1/h in buildings with natural ventilation and 1.5 1/h in

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buildings with mechanical ventilation. The measurements in both countries are not mandatory but recommended.

Nevertheless those measurements are often to be found time and money consuming and more important sensitive to weather conditions. Therefore research presented in this paper highlights the need of validation of developed airtightness predictive model and further development of proposed model. Predicting airtightness gives insight into the characteristics of residential and non-residential unit envelopes without the need to conduct field tests, accelerating the preparation in building reconstruction [3].

The airtightness research started in Poland in the 1970s' of the last century [13]. In general, these research focus on the tightness of installed joinery, which was considered as a main cause of excessive air infiltration. Most of mounted joinery in the second half of the 20th century were wooden leaky windows and they were replaced by tighter PVC windows [14]. Nevertheless, the air tightness of Polish buildings has not improved in any significant way. It was only in 2008 after the introduction of mandatory buildings energy certification (based on EPBD), the interest in air tightness and heat losses by air infiltration has fortunately grown and what is most important – air leakages through building envelope has fortunately started decreasing.

Validation of predictive model presented in this paper was preceded by field testing of airtightness of residential units in year 2013. The research was the first of this type in the Croatia and it took place as part of the IPA Cross-border Cooperation Programme between the Republic of Hungary and the Republic of Croatia under the title "A*ir tightness investigation of rooms from the point of view of energy and comfort*", (ID: HUHR/1001/2.1.3/0009), which was co-financed by the European Union. Development of predictive model for residential unit's airtightness prediction by using neural networks and data base obtained from above mentioned research was presented in detail in [3].

The aim of this paper is to analyse obtained neural network predictive model developed in Croatia in year 2014 based on 58 in situ measurement of airtightness and to proceed with independent validation of the model on 20 residential and non-residential buildings in Poland in order to determine its applicability on new data set outside local regional area.

Proposed model could be used for predicting airtightness values already at the initial design phase and also for planning systematic energy refurbishment and/or retrofit of residential buildings in order to achieve adequate energy efficiency in accordance with EU recommendations [2].

2. Previous research

The term airtightness pertains to the intensity of uncontrolled flow of air through the building envelope as a result of pressure difference between interior and exterior air. Uncontrolled leaking of air can occur through joints, connections between different materials, dilatations and other permeable points in the building envelope. Limiting airtightness requirements are often to be found in building regulations [12]. The method most often used for measuring airtightness is the pressure difference method, the "blower door" test. All measurement results from Croatia and Poland used for database creation fulfil EN ISO 13829:2002 (*Thermal performance of buildings – Determination of airtightness of buildings – Fan pressurization method*) criteria [15]. In EN ISO 13829:2002, depending on the purpose, there are two methods described [16,17]:

- Method A – the condition of the external building envelope needs to be representative for the season of the year when heating or cooling systems are used, without additional sealing.
- Method B – all the designed openings in the building envelope need to be sealed.

The new version of ISO 9972:2015 (*Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method*) mentions three methods. Depending on the purpose there are:

- Method 1–the test of the building in use where the natural ventilation opening being closed and the whole building mechanical ventilation or air conditioning opening being sealed.
- Method 2–the test of the building envelope where all the intentional openings being sealed, the doors, windows and trapdoors being closed.
- Method 3–the test of the building for a specific purpose, the treatment of the intentional openings being adapted to this purpose according to the standard or policy in each country.

Measurements carried out for purpose of creation of databases in Croatia and Poland follow method A – common building use of EN ISO 13829:2002. During measurements of non-whole buildings, windows and doors of surrounding space were open due to avoid additional pressure differences. So that, the measured space were treated like a single building. Measurements in Croatia and Poland were carried out by using Minneapolis *BlowerDoor* equipment, Fig. 1.

Summarized previous research regarding buildings airtightness prediction and general discoveries reveals following [3]:

- Airtightness can be affected by design and management concept, design details, type of structure, method of construction, type of thermal insulation, the number of storeys, building envelope surface area, floor area, execution quality of works and supervision of construction, season of the year, climate, how well the units are maintained, type of unit, joinery, frame materials, window frame length, total frame length, age of the buildings, number of significant cracks and management context [5,15,18–21],
- The leakage airflow rate might be evaluated using predictive models determined from experimental databases [22] and
- Literature review did not disclose any similar research in which neural networks are used for buildings airtightness prediction.

For the purposes of testing the possibilities of using neural networks for predicting airtightness in residential units an evaluation system (Questionnaire) was created for evaluating input parameters which were found in the course of the study to have an effect on airtightness results.

The input data for the database used for learning in the neural network for predicting airtightness of residential units were classified in four groups of input parameters presented in Table 1.

The input parameters 1 & 2 are based on different characteristics of materials and structures used in residential units. Those different characteristics were used as the criteria for estimation of corrective factors. Estimation of those corrective factors was done by using questionnaire made for model purposes which had to be filled in order to obtain input parameters 1 & 2.

The corrective factors for those parameters are a numerical values depending on material quality, wall and insulation thickness, type of glazing, frame materials and maintenance quality. Detailed presentation of corrective factors determination and their possible values is explained in [3].

On the other hand input parameters 3 & 4 can be calculated depending on geometrical and floor plan characteristics of different residential units and are also given as a numerical value theoretically ranging from 0 to 1.