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## IMPACT OF PREPARATION PROCEDURES ON RESULTS OF AIRTIGHTNESS TESTS

### WPŁYW PRZYGOTOWANIA BUDYNKU NA WYNIKI BADAŃ SZCZELNOŚCI

#### Abstract

Requirements connected with the designing of low-energy and passive buildings impose an obligation to conduct airtightness tests during the building process and after the completion of building works. Proper building preparation is required before initiating an airtightness test. In case of commercial buildings with complicated HVAC systems, the proper preparation may appear to be very complicated and can unfavorably affect the tests results. On the example of tests conducted in the low-energy office buildings in Wrocław, the authors describe the problems met during airtightness tests.

*Keywords: air leakage, fan pressurisation method, airtightness of the buildings,  $n_{50}$  coefficient, low-energy buildings*

#### Streszczenie

Wymagania związane z projektowaniem budynków energooszczędnych oraz pasywnych narzucają obowiązek przeprowadzania badań szczelności budynków w czasie procesu budowy oraz po jego zakończeniu. Do rozpoczęcia badań szczelności wymagane jest poprawne przygotowanie budynku. W przypadku budynków użyteczności publicznej ze skomplikowanymi systemami ogrzewania, wentylacji oraz chłodzenia poprawne przygotowanie budynku może okazać się bardzo skomplikowane oraz może bardzo niekorzystnie wpływać na wyniki testów. Na przykładzie badań dwóch energooszczędnych budynków biurowych zlokalizowanych we Wrocławiu autorki opisały problemy napotkane w czasie prób szczelności.

*Słowa kluczowe: badania szczelności budynków, współczynnik  $n_{50}$ , metoda wentylatorowa, budownictwo energooszczędne*

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## 1. Polish requirements regarding building airtightness

Requirements regarding airtightness of the buildings described in the Polish national standards are just recommendations not obligations. Based on the experience of other countries it is obvious that the airtightness measurements give the possibility of field work control and a reduction of the building energy usage.

At present according to Polish building legislation, airtightness measurements are not obligatory. According to national standard Rozporządzenie w sprawie warunków technicznych jakim powinny odpowiadać budynki i ich usytuowanie [1], it is recommended that all detached buildings, commercial buildings, as well as industrial buildings and all building joints between walls and connections between windows and the building envelope should be designed and constructed to ensure the total airtightness.

However, Polish regulations recommend the airtightness measurements and determining the  $n_{50}$  coefficient, which describes the number of air changes per hour at a 50 Pa pressure difference. The recommended maximum values of  $n_{50}$  are as follows:

- a) For buildings with natural ventilation  $3.0 \text{ h}^{-1}$ .
- b) For buildings with mechanical ventilation  $1.5 \text{ h}^{-1}$ .

Building measurements are however obligatory in case of passive buildings where the  $n_{50}$  coefficient should not exceed  $0.6 \text{ h}^{-1}$ . Also, in case of low-energy buildings, the airtightness of the envelope is determined at the designing stage and must be controlled in the building process and after completion of building works.

## 2. Airtightness measurements according to PN-EN 13829

The airtightness measurements should be conducted according to standard PN-EN 13829 'Thermal performance of buildings. Determination of air permeability of buildings. Fan pressurization method' [2].

In the standard, two different methods are acceptable depending on the purpose:

- a) Method A – test of the building in use.
- b) Method B – test of the building envelope.

In both methods, all openings in the building envelope such as windows, doors and chimney ducts should be closed. All interconnecting doors within the building should be opened during the entire air leakage test. All heating systems taking air from the outside, mechanical ventilation and air conditioning must be turned off. The open chimneys should be cleaned of ash. All air intake and exhaust mechanical ventilation and air-conditioning ducts should be sealed. Openings for natural ventilation should be opened in the case of method A and closed in the case of method B.

## 3. Analyzed buildings

Authors conducted the airtightness test of two low-energy office buildings, called Centrum Ekologiczne, located in Wrocław after the completion of building works:

1. Building A (Fig. 1a) – two storey office building, building volume 1074 m<sup>3</sup>, usage area 377,5 m<sup>2</sup>.
2. Building B (Fig. 1b) – two storey office building, building volume 305,5 m<sup>3</sup>, usage area 108 m<sup>2</sup>.



Fig 1a. Building A



Fig. 1b. Building B

Tests were conducted using the Blowerdoor set (Fig. 2) with the digital controller Retrotec 3000 and Fantastic program to analyze test data.



Fig. 2a. Blowerdoor fan – external view



Fig. 2b. Blowerdoor set –internal view

Per requirements regarding building airtightness, specified in the building project,  $n_{50}$  should not exceed 1.5 h<sup>-1</sup>. The measurements must have been conducted two times due to the incorrect building preparation and inaccurate construction works.

The authors conducted the first measurements in July.

The measurements were conducted in the following weather conditions:

- external air temperature: 20°C,
- wind speed on the Beaufort scale based on own observation: 1,
- air temperature inside the flat: 18°C.

The buildings were prepared for the tests (method B), all openings in the building envelope such as windows, doors, ventilation ducts and openings next to the lightning devices were closed. Inside the building with the mechanical ventilation system, there is a lift shaft with a separate mechanical ventilation system. For the purpose of testing, the elevator shaft was cut off from the analyzed building volume. Figs. 3, 4 present the preparation of different building parts.



Fig. 3. Preparation of lighting fixtures



Fig. 4. Preparation of lift shaft

Tests were conducted in two pressure states: pressurisation and depressurisation (per [2]). Results of the first test were very unfavorable. Index  $n_{50}$  in the first pressurisation test was equal to  $n_{50} = 2.98 \text{ h}^{-1}$ . The value was almost two times higher than the project limit value of  $n_{50} = 1.5 \text{ h}^{-1}$ . Those negative conditions were caused by both inaccurate building erection and inaccurate building preparation. After the tests, all preparation works were checked carefully and all unsealed or ineffectively sealed openings were corrected. The tests in building A were repeated five more times. Results of all tests are presented in Table 1.

In all conducted tests, the results were higher than  $n_{50} = 1.5 \text{ h}^{-1}$  however the correction of building preparation works improved the first result by 30% (from  $n_{50} = 2.98 \text{ h}^{-1}$  to  $n_{50} = 1.94 \text{ h}^{-1}$ ).

In case of building B the first test results were also much higher than  $n_{50} = 1.5 \text{ h}^{-1}$ . Results are presented in Table 2.

Table 1

#### Results of airtightness tests of building A conducted in July

	Test 1 pressurisation	Test 2 pressurisation	Test 3 pressurisation	Test 4 pressurisation	Test 5 pressurisation	Test 6 depressurisation
$n_{50}$ [1/h]	2.98	2.25	2.01	1.95	1.94	2.58

Table 2

#### Results of airtightness tests of building B conducted in July

	Test 1 pressurisation	Test 2 depressurisation
$n_{50}$ [1/h]	2.96	2.94

During the tests, all air leakages were monitored using a fog generator, an anemometer and an infrared camera. It allowed for the detection of both openings in the building envelope caused by inaccurate erection as well as the inaccurate building preparation (Figures 5 and 6). To make the monitoring possible and to increase the air flow through the openings, a pressure difference of up to 100 Pa was forced. It revealed the location of leaks but also loosened the sealed openings. This is the reason why the constant monitoring of all sealed openings should be done.



Fig. 5. Detection of leakages with fog generator and anemometer



Fig. 6. Detection of leakages with infrared camera



Fig. 7. Loosened sealed opening during the airtightness test



Fig. 8. Loosened sealed opening during the airtightness test

The problem of a too high  $n_{50}$  value in both buildings was mainly connected with the suspended ceilings in the buildings. Unfortunately, the roof construction above the ceiling was not tight – the air leakages were noticeable next to lighting fixtures mounted in the ceiling construction, however, direct monitoring of the roof construction was not possible.

The next set of tests was conducted in November after the repair works of the building envelope tightness and after proper building preparation. The results of those tests were significantly better, Table 3 presents the results of the final tests conducted in buildings A and B.

Table 3

**Results of final measurements of building A and B**

	Building A	Building B
Number of air changes at 50 Pa, $n_{50}$ [1/h] <b>pressurisation</b>	<b>1.3</b>	<b>2.13</b>
Number of air changes at 50 Pa, $n_{50}$ [1/h] <b>depressurisation</b>	<b>1.46</b>	<b>1.96</b>
$n_{50}$ [1/h]	<b>1.38</b>	<b>2.04</b>

The measurements were conducted in the following weather conditions:

- external air temperature: 22°C,
- wind speed on the Beaufort scale based on own observation: 1,
- air temperature inside the flat: 20°C.

In the case of building A,  $n_{50}=1,38\text{h}^{-1}$  was smaller than the permissible value of  $n_{50} = 1,5\text{h}^{-1}$ . Unfortunately, in case of building B, even after the caulk works, results were still not acceptable.

#### 4. Conclusions

Airtightness field tests require the extensive and very precise preparation of the building. In the case of commercial buildings, it appears to be one of the most important aspects which can significantly affect the final tests results. The field tests conducted by the authors and described in the article showed that the incorrect preparation of the building envelope can unfavorably affect the  $n_{50}$  value even by up to 30%. The conducting of tests must be connected with the simultaneous monitoring of all sealed openings with infrared cameras, using fog generator and anemometer.

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