THE USE OF A SAMPLING METHOD FOR AIRTIGHTNESS MEASUREMENT OF MULTIFAMILY RESIDENTIAL BUILDINGS – AN EXAMPLE

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ABSTRACT

Large buildings can not always be tested as a single pressure zone. In Europe, different approaches have been proposed concerning the choice of representative parts of the building (sampling method) and the compliance check in situations, when several parts of the building have to be tested separately. The preliminary Czech standard TNI 73 0330 defines a sampling method, as well as subsequent treatment of results and compliance check procedures for multifamily residential buildings. This contribution reports the results of a trial test of TNI 73 0330 method. The estimation of the whole building n_{50} value by means of this sampling method was found questionable, namely due to the potential presence of internal air leakage. Alternative method based on measurements of building parts using so called guard zone technique was proposed. Inconsistency between the compliance check based on the whole building test results and the sampling method test results was identified.

KEYWORDS

airtightness measurements, blower door test, multifamily residential buildings

INTRODUCTION

The airtightness measurements of large buildings can become complicated or even impossible, since in some situations the whole building can not be measured as a single pressure zone. The common reasons are well known: (i) limited performance of the measuring device fan, (ii) absence of the internal openings in building partitions making impossible to connect all the parts of the building into one pressure zone, (iii) impossibility to interconnect all the building parts for organisation reasons (e.g. access refusal). In such situations, different parts of the building can be tested separately, each one as a single pressure zone. Then, the whole building airtightness can be estimated based on the results of these individual tests.

Until now, no generally approved rules have been formulated concerning the choice of representative parts of the building tested (sampling method), the estimation of the airtightness of the building envelope and the compliance check in situations, when several parts of the building were tested separately. Different approaches were proposed e.g. in Germany, France, Belgium and UK [1]. In the Czech Republic, the preliminary standard TNI 73 0330 [2] defines a sampling method, subsequent evaluation of results and compliance check procedures for multifamily residential buildings. The practical applicability of this method was investigated by means of a trial testing of selected multifamily residential building. The results are reported in this contribution.

SAMPLING METHOD ACCORDING TO TNI 730330

TNI 73 0330 defines following three airtightness measurement procedures of low energy and passive multifamily residential buildings for the purpose of compliance check with airtightness requirements. However, the method can be used regardless the energy performance of the building tested. All measurements should be performed using the fan pressurization method according to [3], test method B, by means of standard blower door devices.

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Procedure 1

If possible, the building is measured as a single pressure zone. If the resulting n_{50} value complies with the limit value, the building is supposed to fulfil the requirements.

Procedure 2

If the whole building can not be measured as a single zone, then the residential part is measured separately. If the n_{50} value of the residential part complies with the limit value, the building is supposed to fulfil the requirements. If not, the test can be repeated using an appropriate method allowing exclusion of air exchange between the tested residential part and adjacent spaces through the leaks in the internal partitions (internal air leakage).

Procedure 3

If even the residential part can not be measured as a single zone, than a relevant number of residential part units (e.g. flats) has to be tested separately. The building is supposed to fulfil the requirements if: (i) the n_{50} value of each tested unit complies with the limit value, or (ii) the mean $n_{50,m}$ value of all tested units complies with the limit value and simultaneously the particular n_{50} values of a majority of tested units comply with the limit value (the internal air volume of this “majority” has to be at least 2/3 of internal air volume of all the tested units). If the building does not fulfil the requirement, the tests can be repeated using an appropriate method allowing exclusion of internal air leakage.

The “mean $n_{50,m}$ value of all tested units” is calculated as weighted average of n_{50} values of particular tested units over their internal air volumes. Furthermore, TNI 73 0330 sets rules for the choice of the “relevant number of residential part units” which have to be tested separately. Priority is given to units facing exterior. The units should be chosen so as all types of building envelope elements (walls, ceilings, roofs, etc.) would be subject of the test.

TRIAL TEST OF THE SAMPLING METHOD

Building tested

A multifamily residential building built in 1978 was selected for the purpose of this work (figure 1). The building has 6 floors. The 1st floor contains only garage, technical and storage rooms. The 6th floor contains a boiler room. The residential part contains 16 identical flats located from the 2nd to the 5th floor.

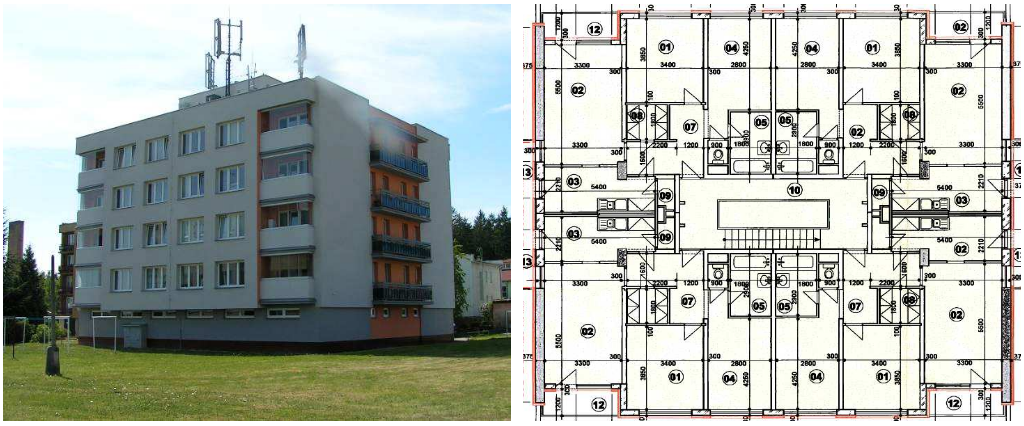

Figure 1.Measured building – frontal view and plan of a residential floor

Method

The airtightness of the building was tested using each of the three measurement procedures according to TNI 73 0330. In addition, the airtightness of one flat in the 5th floor was tested using the so called guard zone technique (GZT) [4] in order to limit the internal air leakage to adjacent rooms. In order to create the guard pressure zone around the flat tested, entrance doors of all the neighbouring flats were kept open during the test as well as all internal doors in these flats. A second blower door fan was fitted into the entrance door of the guard zone. Its speed was automatically controlled in order to maintain zero pressure difference between the tested flat and the guard zone. Only pressurization test was performed using the GZT.

Based on the results, reliability of the estimation of the whole building airtightness from the sampling method results and reliability of the compliance check procedure according to TNI 73 0330 was examined. The magnitude of the internal leakage was evaluated based on the results of procedure and the results of the measurement using the GZT. Finally, an alternative method was proposed for estimation of the whole building n_{50} value from the air permeability of segments of the building envelope measured by means of the GZT.

RESULTS

Overview

Measured part of the building	Test procedure	Internal volume V [m^3]	Depressurization t.		Pressurization test		Average	
			V_{50-} [m^3/h]	n_{50-} [h^{-1}]	V_{50+} [m^3/h]	n_{50+} [h^{-1}]	$V_{50-/+}$ [m^3/h]	$n_{50-/+}$ [h^{-1}]
whole building	1	3 909	3 001	0.77	2 828	0.72	2 915	0.75
residential part	2	3 492	2 953	0.85	2 971	0.85	2 962	0.85
flat 2.1	3	189	573	3.03	777	4.12	675	3.57
flat 3.1	3	189	545	2.88	710	3.76	628	3.32
flat 3.3	3	189	317	1.68	369	1.95	343	1.82
flat 4.3	3	189	1 068	5.65	1 126	5.96	1 097	5.81
flat 5.1	3	189	379	2.01	566	3.00	473	2.50
flat 5.2	3	189	660	3.50	849	4.49	754	3.99
flat 5.4	3	189	479	2.54	605	3.20	542	2.87
flat 5.1+GZT		189			271	1.44		

Table 1. Overview of individual test results – air flow rate at 50 Pa V_{50} and air change rate at 50 Pa n_{50}.

Procedure 3

In case of the building tested, the resulting mean $n_{50,m}$ value should be calculated as weighted average of individual n_{50} values of at least the 5 flats selected according to the rules of TNI 73 0330. Since finally 7 flats were tested, the mean $n_{50,m}$ value can be calculated in different manners from 5, 6 or 7 n_{50} values of different flats. The n_{50} values of flats 2.1, 5.1, 5.2 and 5.4 should be always included in the $n_{50,m}$ calculation, since these flats have a higher proportion of envelope area facing to the external environment. The results are summarised in table 2 (based on TNI 73 0330, all these results are correct and equivalent).

Calculation manner		A	B	C	D	E	F	G
	flat 2.1	3.6	3.6	3.6	3.6	3.6	3.6	3.6
	flat 3.1	3.3	-	-	3.3	3.3	-	3.3
measured	flat 3.3	-	1.8	-	1.8	-	1.8	1.8
$n_{50-/+}$ [h^{-1}]	flat 4.3	-	-	5.8	-	5.8	5.8	5.8
	flat 5.1	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	flat 5.2	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	flat 5.4	2.9	2.9	2.9	2.9	2.9	2.9	2.9
calculated	$n_{50,m}$ [h^{-1}]	3.3	3.0	3.7	3.0	3.7	3.4	3.4

Table 2 Procedure 3 test results calculated in different manners from the particular test results of the flats tested.

Measurement of a flat using the guard zone technique

The flat 5.1 (under the roof) was tested using the GZT with n_{50+} = 1.4 h^{-1} as the result. The air permeability of the flat envelope $q_{50,5.1,ext+}$ was calculated dividing the measured air flow rate at 50 Pa by the area of the surface of the flat envelope facing exterior. Since the air leakage trough the internal partitions was supposed effectively eliminated thanks to the use of the GZT, this value represents the air permeability of building envelope around the flat 5.1.

COMMENTS, DISCUSSION

Procedure 1 - influence of the building shape and size

The procedure 1 test result, $n_{50-/+}$ = 0,75 h^{-1}, seems to be surprisingly good. However, the air permeability of the building envelope $q_{50-/+}$ = 1,56 $m^3/(h.m^2)$, is substantially higher than the values usually achieved in case of single family houses equipped with a high performance air barrier system and having a similar air change rate $n_{50-/+}$. Hence, the satisfactory result was not achieved thanks to the quality of building envelope but it is rather a consequence of a favourable building shape and size (ratio of the envelope surface and internal volume A_E/V).

Procedure 2

The air flow rates measured during the pressurization test are higher than in case of the whole building tests. It is probably consequence of a measurement error (e.g. unfastened temporarily sealing of the intentional openings in the building envelope).

Procedure 3 and measurement of the flat 5.1 using the GZT - internal air leakage

For each flat tested, theoretical, expected $n_{50-/+}$ values were calculated from the measured air permeability of the whole building $q_{50-/+}$ assuming that this value is constant over the building envelope and the internal partitions delimiting the flats are perfectly airtight. These expected values were compared to the measured ones (figure 2, left). The difference between the expected and measured n_{50} values can be caused by either the internal air leakage or variations of the air permeability over the building envelope. However, the magnitude of the difference points out a very significant internal air leakage. The difference between the n_{50} values of flat 5.1 measured with and without the use of the GZT confirms the high significance of the internal leakage (figure 2, right). The difference between the expected n_{50} value and the value measured with the use of GZT can be a consequence of a local deterioration of the building envelope air permeability (compared to its average level) or a consequence of a measurement error.

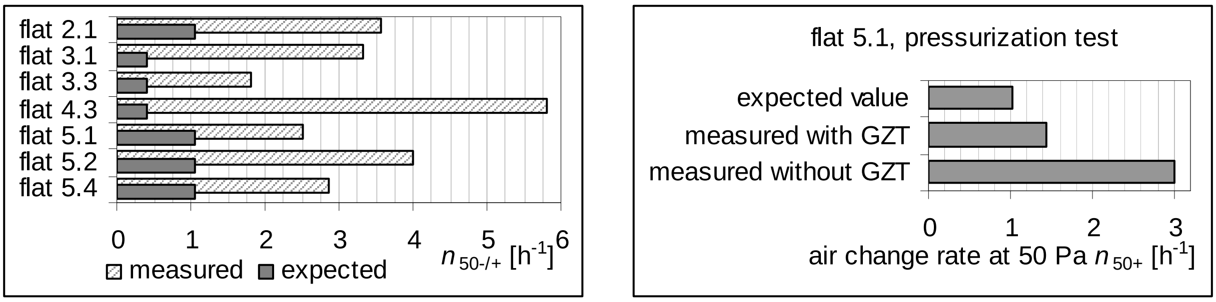

Figure 2 Magnitude of the internal air leakage. Left – measured n_{50} values of flats tested and expected values assuming no internal leakage. Right – flat 5.1 expected n_{50} value and values measured with and without the GZT.

Procedure 3 and measurement using the GZT – estimation of the building n_{50} value

Obviously, the mean $n_{50,m}$ value depends on the choice of the flats included into the assessment (table 2). Regardless the calculation manner, the mean $n_{50,m}$ values are substantially higher than the whole building n_{50} value. The difference may be the consequence of (i) the different shape of the building and flats (different ratio A_E/V), (ii) internal air leakage (which is the dominant factor – see above), (iii) variation of the air permeability over the building envelope. Hence, the procedure 3 test result, $n_{50,m}$, can not represent a correct estimate of the whole building n_{50} value. In case of the building tested, such a simplified estimation would lead to un error ranging from 300% to 400% (depending on the manner of $n_{50,m}$ calculation).

Based on the assumption that the variation of air permeability over the building envelope is negligible, an estimate of the whole building n_{50} value ($n_{50,\text{building}}$) can be calculated from the air permeability of the flat 5.1, measured using the GZT ($q_{50,5.1,\text{ext}}$):

$$n_{50,\text{building}} = \frac{A_{\text{E,building}}}{V_{\text{building}}} \cdot q_{50,5.1,\text{ext}} \tag{1}$$

where $A_{\text{E,building}}$ and V_{building} are the whole building envelope area and internal volume respectively. In the studied case, such estimation of the whole building n_{50+} value would lead to an error of 39 %. Furthermore, the air leakage through the slab on the ground could be neglected in the studied case. Hence, in order to correctly estimate the whole building n_{50} value, only the area of surfaces facing the air should be accounted into $A_{\text{E,building}}$. Then, the estimation error of n_{50+} would be 24%.

CONCLUSIONS

Obviously, the TNI 73 0330 procedure 3 test result ($n_{50,m}$) can neither be directly compared to the procedure 1 test result (whole building n_{50}), nor used as its estimate. More generally - when using a sampling method in order to estimate the whole building airtightness from test results of its parts, the differences in the size and shape of the whole building and the parts tested should be taken into account as well as a potentially significant effect of the internal air leakage. Alternatively to the procedure 3 of TNI 73 0330, the whole building n_{50} value can be estimated more accurately from the air permeability of the external surface of the envelope of the separately tested building parts. Then, the use of methods allowing exclusion of internal air leakage is required (e.g. the guard zone technique). This study proves applicability of this approach despite higher time and equipment requirements. However, the accuracy of this method seems to be limited and should be investigated more deeply.

The mean $n_{50,m}$ value depends on the choice of number of the building parts tested separately and their position inside the building. Therefore, it seems reasonable to introduce certain tolerance when checking the compliance of $n_{50,m}$ with the limit value. The same approach would be followed when evaluating the results of the alternative method.

When several parts of the building are tested separately according to the rules of TNI 73 0330 procedure 3, the majority of them has to comply with the limit n_{50} value (valid for the whole building), so as the building could be declared to fulfil the airtightness requirement. Namely in case of small flats tested and severe limit n_{50} values, the fulfilment of this condition might become difficult. Due to potentially significant impact of internal air leakage, it would require very airtight execution of the envelope of flats, including its internal surfaces.

Furthermore, in case of the same building the procedure 1 test result can comply with the limit value (e.g. due to the favourable shape or size) whilst the procedure 3 test result may not (e.g. due to internal air leakage). Such unclear situation could lead to legal disputes.

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