Errors in Air Permeability Rationing as Key Sources of Construction Quality Risk Assessment

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Abstract. The article deals with different approaches to the valuation parameters of air permeability $n_{50}$ and $q_{50}$. Examples of erroneous conclusions about the state of the building are presented as well as the ways to obtain reliable results. There are obtained comparative data of the air permeability parameters on examples of buildings with different configuration and with different values of compactness factor.

1. Introduction
Estimation of microclimate parameters in the premises is one of the main topics of current researches in the field of construction, energy saving and hygiene. Particular attention is paid to the parameters of air supply to residential and public buildings. The relevance of these studies is explained with two factors. Firstly, one is working to reduce the ventilation rate standards. [1, 2]. Secondly, the role of qualitative air composition rises.

The special significance of the qualitative air exchange characteristics proves itself in modern buildings as a person spends most of his life in this room. Air environment of modern buildings has a complex composition and it depends on the air pollution level and intensity of internal contamination sources. These sources are mainly in the decomposition products of polymeric materials, which are part of finishing materials, as well as objects of the domestic situation. Furthermore, the concentration of carbon monoxide gas is constantly changing. Prolonged exposure of these factors, particularly in combination with other (temperature and humidity, the electric and magnetic field, radioactive background, etc.) can have an extremely negative impact on human health, his performance and general health.

2. Formulation of the problem
Reducing ventilation rate normative values in the design is aimed at reduction of heat losses due to convective heat exchange component. Having set (according with [1, 3, 4]) calculated value of air exchange equal to 3 m³/h with 1 m² the amount of thermal energy required for heating the incoming air can be easily calculated. The mode provision is a significant problem, since modern construction standards include reducing of air exchange rate to save energy. By reducing the "safety margin" of living space, importance of fidelity design conditions increases.

Currently there are two methods for determining the minimum required ventilation, sufficient to provide an acceptable indoor air quality.

1. A method based on specific standards of ventilation,
In this method the amount of air coming from the environment is determined depending on the purpose of the room and its mode of operation. This method is used to calculate the parameters of ventilation in the premises not intended to change their destination, volume and nature of entering the room contaminants during the operation period.

2. A method based on the calculation of allowable concentrations of pollutant substances,
   In this method, the desired amount of air is determined depending on the size and nature of the contaminants in the room. This method is used to calculate ventilation parameters in the premises intended to change their destination during operation, and where intense sources of pollutants may be present or may appear.

Both methods are based on established standards. However, in fact builders often do not follow the requirements of the project in favor of the existing materials or due to insufficient qualification. Due to the fact that air parameters can not be controlled with organoleptic method, special measuring technology is required to quantify the ventilation rate and to calculate the cost of thermal energy on the convective heat loss.

Field test method for determining air permeability parameters of buildings has been defined in GOST 31167-2009 [5]. The essence of this standard method is that air in the test room is pumped or sucked off out, and after establishment of steady air flow through the fan at a fixed pressure differential between the tested premises and the outside environment, air flow through the fan is measured and equated it to the air flow, filtered through fences, limiting the test room. Generalized characteristics of air permeability of the test space enclosures are calculated using the measurement results.

3. Rationing of air permeability parameters
   When rationing air permeability parameters usually two parameters are determined:

1. Air changes - a value, indicating how many times within 1 hour indoor air is completely replaced to a new one:

   \[ n_{50} = \frac{Q}{V_{\text{pr.}}} \text{[h}^{-1}] \]  

   where \(Q\) is measured flux \([\text{m}^3/\text{h}]\);
   \(V_{\text{pr.}}\) is the volume of the measured premises \([\text{m}^3]\).

2. Air permeability:

   \[ q_{50} = \frac{Q}{S_{\text{encl}}} \left[ \frac{\text{m}^3}{\text{m}^2 \cdot \text{ч}} \right] \]  

   where \(Q\) is measured flux \([\text{m}^3/\text{h}]\);
   \(S_{\text{encl}}\) is area of enclosing structure \([\text{m}^2]\)

On the territory of the Russian Federation, the following regulations on the air permeability valuation parameters: CR 50.13330.2012 (updated SNiP 23-02-2003), GOST 31167-2009.

Valid values of air exchange multiplicity \(n_{50}\) according to CR 50.13330.2012 are presented in Table 1.

| №  | purpose of the building                     | Value \(n_{50}\) [h\(^{-1}\)] |
|----|--------------------------------------------|-------------------------------|
| 1. | For all types of buildings                 | \(\leq 4.0\)                  |
| 2. | Buildings with mechanical ventilation      | \(\leq 2.0\)                  |
| 3. | passive house                              | \(\leq 0.6\)                  |

According to GOST 31167-2009 the following classes of air permeability of building envelopes are determined:
Table 2

| Multiplicity of air at $D_p = 50$ Pa ($n_{50}$, h$^{-1}$) | The class name |
|------------------------------------------------------|----------------|
| $n_{50} < 1$                                         | Very low       |
| $1 < n_{50} < 2$                                     | Low            |
| $2 < n_{50} < 4$                                     | Normal         |
| $4 < n_{50} < 6$                                     | Moderate       |
| $6 < n_{50} < 10$                                    | High           |
| $10 < n_{50}$                                        | Very high      |

Multiplicity of air exchange rate with pressure difference $n_{50}$ is used for estimating the air permeability parameters both as in CR 50.13330.20121 and as in GOST 31167-2009. Using this setting can increase the risk of commissioning buildings with low energy efficiency and possible defects in the quality of construction.

These risks can be reduced by normalization air permeability parameter $q_{50}$, used as a main component for the objective evaluation of building envelopes air permeability.

This conclusion can be drawn as air permeability $q_{50}$ (1 m$^3$ air, passing through 1 m$^2$ surface of the enclosing structure for 1 hour at pressure difference 50 Pa) describes the properties of the enclosing structure against heat transfer by convection exchange. Thus, the use of multiplicity of air exchange coefficient $n_{50}$ for estimating the air permeability is not correct and inherently does not allow evaluating objectively the properties of the building structure for the entire wide range of buildings this standard to be used.

The main reason for not using $n_{50}$ is the building factor compactness. Coefficient of the building compactness is a ratio of the total outer surface area of the building envelope to entrapped heated volume of the building (the ratio of the enclosing structure area to the internal volume of the building). This ratio varies widely depending on the linear dimensions of the building.

However, it is possible to calculate the rated value $q_{50u}$ using the following formula:

$$q_{50u} = \frac{\Delta p \cdot T}{353 \cdot R_u^{mp}},$$

where $\Delta p$ is the difference in air pressure on the outer and inner surfaces of the building envelope, Pa, Ia

$T$ is the ambient temperature during testing.

$R_u^{mp}$ is normalized total resistance of air permeability to building envelope determined on CR 50.13330.20121

There are considered examples of measurement parameters $n_{50}$ and $q_{50}$ for buildings with different values of compactness coefficient.

Example 1

There are three typical apartment blocks (1 section) with a total volume 27 304 m$^3$ and building envelope area 7072 m$^2$. Compactness coefficient is 0.26.

Figure 1. Model of a typical apartment block.
Example 2.
There are four typical logistic centers with total volume 1 150 000 m³ and building envelope area 207 215 m². Compactness coefficient is 0.18.

![Figure 2. Model of a logistic center](image)

Example 3
There are four typical grocery supermarkets with a total volume 13570 m³ and building envelope area 5792 m²

![Figure 3. Model of a grocery supermarket.](image)
4. Discussion of the results

Analyzing the experience of countries where the measurement of air permeability (including required) have been practiced for many years and have accumulated enough experience to evaluate the air permeability the parameter $q_{50}$ is used. These are the United States, Canada, UK, Ireland, France ($q_4$), Denmark ($w_{50}$). Conversely, countries that have taken as a basis for regulations on the multiplicity of air exchange $n_{50}$, have problems with measurement of medium and large buildings, as according to the regulations required to obtain a sufficiently high power setting Blower Door. It leads to the impossibility of carrying out a test, or an increase in its value, but the actual measurement results show significantly better results with modern constructions than required by national regulations. Underreporting standards are indicated and it does not stimulate an increase in the quality of design and construction.

5. Conclusion

These examples demonstrate the disparity of existing national standards to the real state of the air permeability of design and modern technologies in construction. In each group of buildings, only one actually corresponds with the standards. Furthermore, with the increase in linear dimensions the compactness factor tends to decrease and, accordingly, the apparent severity of standards in reality leads to a significant weakening of the requirements for air permeability. Also large buildings generate large heat losses in absolute values. Accordingly, they require greater control and an objective factor for evaluating the properties of heat-shielding constructions.

In conclusion, it should be noted that the use of $n_{50}$ increases the probability of errors in calculations, since to calculate internal volume the net floor area calculation is required (in accordance with EN13829). When changing the actual internal volume of the building in the process of completion of construction or operation (re-plan of internal structures) respectively and calculating volume will change for measuring and it will lead to different results for the same measured flow.

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