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Including air-exchange performance in building regulation




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It is generally assumed that compliance with building codes results in an acceptable indoor air quality (IAQ). Field research however clearly demonstrates that this is often not the case. IAQ-levels can be far from adequate and there are large differences in ventilation performance between systems and dwellings. There is a serious need to assess the actual performance of ventilation systems.

Keywords: Residential Ventilation Systems, Ventilation Performance, Assessment method

Up until today the performance of ventilation systems in residential buildings remains largely unaddressed. It is generally assumed that compliance with building codes results in an acceptable indoor air quality (IAQ). It is also assumed that the various types of code-compliant ventilation systems perform comparably. Field research however demonstrates that both assumptions are incorrect: IAQ-levels can be far from adequate and there are large differences in ventilation performance between systems in dwellings [1, 2, 7, 8, 9,10,11]. With energy performance standards demanding increased airtightness levels and reduced natural infiltration [9,10], there is a serious need to assess the actual performance of ventilation systems.

In most countries, building regulations on ventilation are based either on the capacity of the ventilation provisions to be installed, or on a minimum air-flow for the whole building. Air-exchange performance levels in the individual habitable rooms and wet rooms, based on the operating reliability of selected ventilation provisions, their controls, outdoor wind speed, building airtightness and occupant behaviour, are not considered, despite the fact that these parameters are crucial for occurring IAQ-levels.

In the Netherlands, when the Dutch Standard Committee was requested to develop a new ventilation standard for the Dutch building codes, it was decided to include a performance assessment method for ventilation systems. It was also proposed to base this ventilation performance assessment method on the methodology that was developed by VHK and U-Gent in consultation with the Residential Working Group of EVIA. This methodology was presented on the 2017 AIVC conference in Nottingham [5]. The methodology needed adaptations to fit the demands of the Dutch building regulations [12] under public law. This paper describes both the methodology and how it has been adopted for the implementation in the draft new prNEN 1087, Ventilation systems for buildings. This standard will be published for public comments in spring 2019.

Building codes

Fundamentals

Building codes differ significantly where ventilation rates and IAQ-metrics are concerned, even in EU-countries and despite the fact that national standards bodies participate in CEN workgroups and technical committees. Typically, some countries use the number of persons as basis for the ventilation rates, while others use floor-area as a metric or the carbon dioxide-level and/or the RH-level.

The common denominator in the different approaches is the fact that a certain airflow capacity of the ventilation component or -system is to be installed. The assumption is that when code compliant airflow capacities are installed – regardless of the type of system – code compliant air exchange rates are achieved. The logical consecutive assumption is, that all code compliant ventilation systems perform comparably on achieved air exchange rates and consequently on IAQ. However, both field surveys and model research clearly indicate that the impact the type of ventilation provisions and its controls have on the actual occurring air exchange is significant [2,3,9,11] As a result there is a wide range of IAQ-levels that are actually achieved and the IAQ-level is often significantly worse than aimed at in building codes and standards.

On another note, no distinction is made for ventilation needs during absence and presence of inhabitants. During absence ventilation is only required to prevent accumulation of building- and interior products emissions, while during presence ventilation would be aimed at inhabitant-produced emissions. In other words, ventilation during absence or presence of inhabitants has different aims.

IAQ and ventilation rates

Using IAQ directly as a performance indicator requires a clear understanding of what good IAQ actually is. All polluting substances would then have to be defined as well as their allowed threshold values and required ventilation rates.

Recent research, including work in the AIVC-setting, time and again gives new understanding on parameters that define a healthy IAQ [14, 15, 16]. It is often concluded that more research is needed to enlarge the degree of certainty of the advised ventilation-rates. This approach, although in itself valuable, is not expected to lead to new ventilation strategies or largely different ventilation rates than those in the current standards and building codes. Most clearly it is stated by Carrer et. al. [15] that: '*… none of the mentioned standards present a coherent, clear and consistent strategy on how to design ventilation rates that refer to and respect directly health requirements …*'

However, there is consensus that regarding IAQ, source control (or in other words selecting the right building material, furniture and decorative products) is the primary strategy [14, 15]. In addition, ventilation plays a key role in reducing the remaining exposures [14]. In this perspective the most recent recommended ventilation rates must be perceived. It is clear that RH-levels nor CO_2-concentrations match with the complexity of IAQ. But as indicators for the air exchange rates for respectively wet spaces and habitable spaces, the parameters are most adequate and consequently most widely used [13, 14].

Notable in this context is that, in the HealthVent guidelines with regard to the ventilation system, it is emphasised that proper design, operation and maintenance are relevant for compliance of the system to the thus defined ventilation rates [15]. The effectiveness of the system (are the intended air exchanges actually achieved in all wet and habitable spaces) is not mentioned.

Dutch Building Act (Bouwbesluit)

The main document in Dutch building code is Building Act (Bouwbesluit), currently Bouwbesluit 2012, last revised in July 2018 [12]. In this document the ventilation rates for all building types are specified. For all building, excluding residential, the ventilations rates are defined by the number of people the building is designed to use. For residential buildings and single dwellings, the rates depend on the area of 'verblijfsgebied' a difficult to translate typical Dutch conception, which is best referred to as 'habitable space'. In general, it is the total surface of all habitable rooms, without the distinction of the type of use of the rooms. For wet or exhaust spaces it is however possible to differentiate between bathroom, toilet and kitchen.

The Dutch Bouwbesluit gives minimum capacities for ventilation of habitable spaces and exhaust spaces. For schools, office buildings and other utility buildings, the requested capacity depends on the amount of people the building is designed for, as stated in the calculation when applied for a building permit. In this paper we will focus on residential buildings. The ventilation requirements in Bouwbesluit 2012 for all dwellings are (and unchanged since mid-80s) are presented in **Table 1**.

Table 1. Ventilation requirements according Bouwbesluit 2012.

Type of room	Minimum ventilation capacity to be installed
habitable spaces	0,9 l/s·m² (with a minimum of 7 l/s per room
toilet	7 l/s
bathroom	14 l/s
kitchen	21 l/s

The capacity should be calculated in accordance with NEN 1087:2001. The Dutch Standard Committee was requested to revise this standard and decided to include a performance assessment method for ventilation systems, based on preliminary research [1, 10].

Consequences for quality-assessment

To actually achieve the requested ventilation rate, all influencing factors which affect air exchange in a room should be evaluated and taken into account. The rate of air exchange is considered to be representative for the amount of fresh air and the transport of pollutants, independent of the nature of the pollutants in a specific situation. Thus, the ventilation system and degree of air exchange it provides, is representative for the probability that a healthy indoor air quality is present during occupation. The 'quality of a ventilation system' is the result of the characteristics of all components including controls, the rate of influence of the building and surroundings and the probability of proper use by the inhabitants.

During the development of the revised Dutch ventilation standard, the authors proposed to base the requested quality assessment method on the methodology that was developed by VHK and U-Gent in consultation with the Residential Working Group of EVIA. This methodology was presented on the 2017 AIVC conference in Nottingham [5]. For this assessment method the following definition is adopted for the air-exchange performance of residential ventilation systems: 'the ability to achieve the requested air exchange in each room of a dwelling for the purpose of extracting and/or diluting concentrations of all hazardous and annoying substances' [5].

Obviously, also this approach has its disadvantages. It will not be possible to predict the exact IAQ in a specific room in a specific building under all circumstances. It is limited to an educated and substantiated expectation of to what extent and with what probability the requested air exchange can be achieved. In that sense, this approach fits with the generally phrased goals for ventilation in the Dutch building act, which states: 'a building has such a provision for air exchange that an unfavourable indoor air quality is prevented'. [13; art 3.29 lid1, translation by the authors].

Assessment method

General overview

The methodology that is developed and proposed [6], assesses the actual occurring air exchange rates on room type level during presence and absence. This specific Air Exchange Performance (AEP) determines to which extent the ventilation system is able to remove and/or dilute pollutant concentrations in the various rooms, especially during presence when exposure occurs. Compared to current practice, where only the air exchange rate over the building is assessed, this represents a major step towards more relevant ventilation performance assessment. Current practice after all does not differentiate between the places in which the air exchanges occur nor between periods of presence or absence. This implies that with current assessment methods, a system that mainly ventilates the corridor, is similarly valued as a system that ventilates the habitable spaces. Likewise, no distinction is made between air exchanges that occur during presence or absence; both are considered equally relevant. Clearly current practice does not lead to a proper assessment of the ventilation performance [14].

Explanation

Based on the principle that is described in the paper 'Methodology for assessing the air-exchange performance of residential ventilation systems' [5], a calculation method is proposed, that assesses the air exchange rates that occur in both habitable spaces and exhaust spaces during periods of absence and presence.

In the assessment method (**Figure 1**), two room types are used, with a matching ventilation strategy:

Habitable Spaces (HS: living rooms, bedrooms, study, etc.), with long exposure of inhabitants to polluting substances in the indoor air during presence. The reference ventilation strategy is to accommodate air-exchange during presence, where supply of sufficient fresh outdoor air is key, and the exhaust is adjusted accordingly. During absence, basic ventilation rates are required to prevent accumulation of building- and interior products emissions.

Exhaust Spaces (ES: kitchen, bathroom, toilet, laundry room), with short exposure of inhabitants, but possibly high humidity levels which are leading. The reference ventilation strategy is the extraction of sufficient air so that moisture/odour is removed. Also, during absence of inhabitant's extraction of air is needed until humidity levels are below threshold values, to be followed basic ventilation rates.

The following technical specifications and parameters of the ventilation system are needed:

- Type of air-exchange provisions (direct/indirect, driving force)
- Installed maximum airflow capacity (limiting factor for achievable air exchange rates)
- Type of operation and/or controls (affects systems ability to achieve requested air-exchanges at the right time in the right place)
- Type of filtration of supply air (indication of filtration performance for situations where quality outdoor air is insufficient).

***Initial focus on residential ventilation* systems**

- *Only applicable to ventilation systems that are properly installed (in accordance with prevailing buildings codes, national practitioner guidelines and manufacturer guidelines)*
- *Air-exchanges for the purpose of extracting cooking fumes are excluded from the assessment (dedicated solution (cooker hood) is default)*
- *Mechanical ventilation systems using continuously alternating flow directions are excluded from the scope (no representative field research available)*
- *Only technical system features will serve as input for the assessment*

Figure 1. Scope of proposed assessment method.

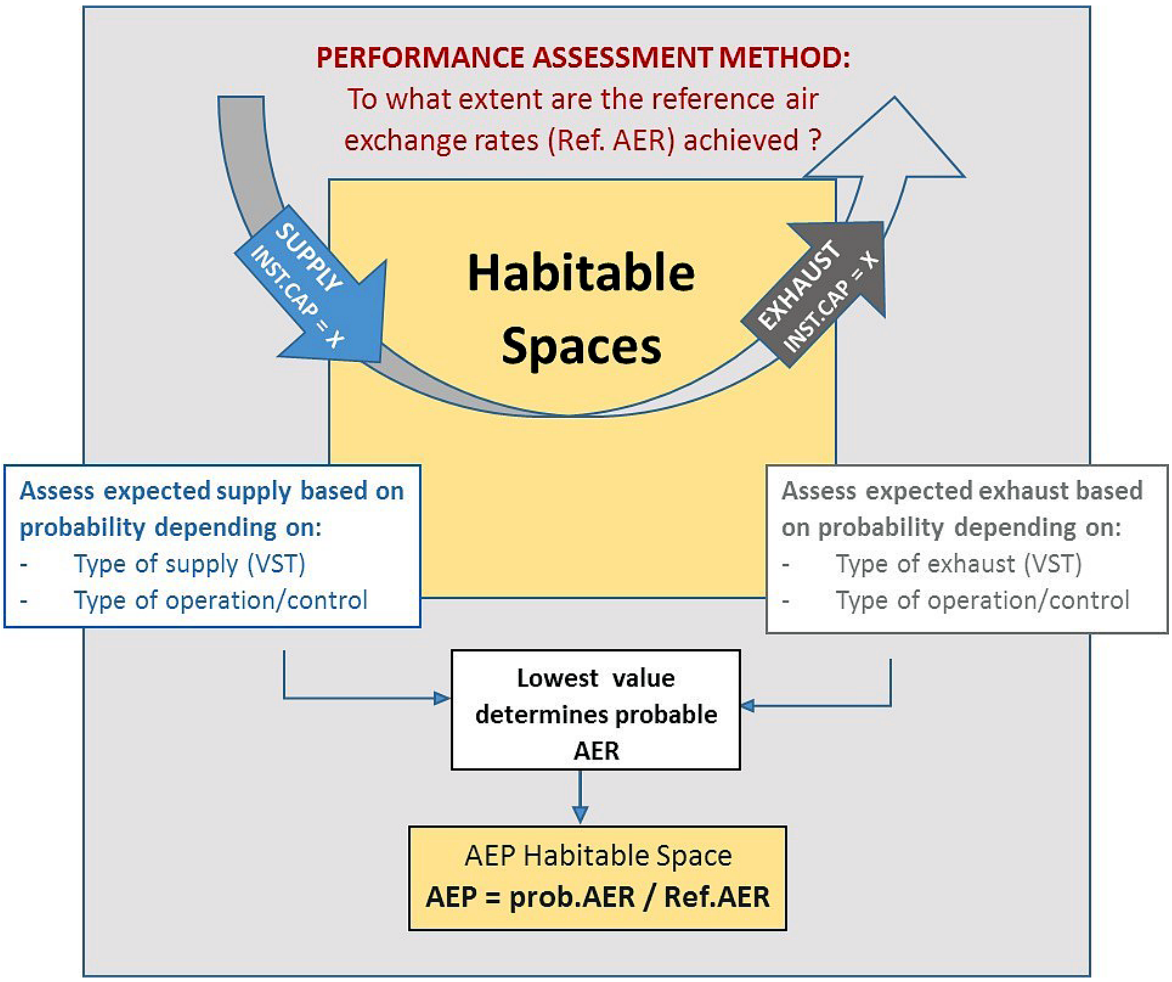

Figure 2. Illustration explaining the ventilation performance assessment method.

The reference air exchange rates (AER) will be based on the air exchange rates that are described in prEN16798-1 [4]

Ventilation system type (VST)

The European Ventilation Industry Association distinguishes seven different ventilation system types in the various European markets. These system types can be identified by the type of air exchange provision they use in habitable spaces and exhaust spaces. The Dutch Standards Committee intends to implement this clear classification in the new Dutch prNEN1087. **Table 2** gives a short overview of the characteristics of these system types by describing the type of the air exchange provisions.

Calculation of Air Exchange Performance

The proposed assessment method distinguishes between periods of occupancy and periods of absence. As a consequence, additional information on occupancy patterns is requested (to be based on typical dwelling occupancy data).

Next, for the air exchange provisions used in the various ventilation system types mentioned in **Table 1**, the controls that are applied determine to what extend ventilation provisions are switched to the requested capacity during periods of occupancy and absence. For ventilation provisions that depend on natural driving forces, the probability of the availability of these driving forces (wind, stack or both) need to be taken

Table 2. Ventilation System Type (VST)VST.

	Roomtype	Air exchange provision		Abbrev.
1	Habitable spaces	supply	Natural Direct Supply	NDS
		extract	Natural Indirect Extract	NIE
	Habitable spaces	supply	Natural Indirect Supply	NIS
		exhaust	Natural Direct Exhaust	NDE
2	Habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Natural Direct Exhaust	NDE
	Habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Natural Direct Exhaust	NDE
3	Habitable spaces	supply	Natural Direct Supply	NDS
		extract	Mechanical Indirect Extract	MIE
	Habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
4	Habitable spaces	supply	Natural Direct Supply	NDS
		exhaust	Mechanical Direct Exhaust	MDE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Exhaust	MDE
5	habitable spaces	supply	Mechanical Direct Supply	MDS
		extract	Mechanical Indirect Extract	MIE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
6	habitable spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE
7	habitable spaces	supply	Mechanical Direct Supply	MDS
		exhaust	Mechanical Direct Exhaust	MDE
	exhaust spaces	supply	Mechanical Indirect Supply	MIS
		exhaust	Mechanical Direct Exhaust	MDE

into account. These are determined, based on physical principles and statistic data.

Finally, the building or dwelling itself has an influence on occurring air exchanges rates, leading to the necessity to incorporate certain building parameters (air tightness and number of habitable- and wet spaces) into the calculation method.

Based on this data, the probable occurring air exchange rate (AER) is determined. By dividing the probable AER by the reference AER (as specified in Building Codes) the Air Exchange Performance is obtained.

Adjustment to the building code

The methodology needed adaptations to fit the demands of the Dutch building Act [12] under public law. Although the method itself is at first a private addition to the national new NEN1087 standard, in coordination with the relevant Department (BZK) the method will hopefully be adapted to fit in the public building code in the future.

Four main adaptations were made:

- Abandonment of the differentiation in type of habitable rooms.
- Adjustment of the reference AER to the requested ventilation according to Bouwbesluit 2012 the removal of the related categories for Air Exchange Performance classes.
- Determination of the occupancy patterns.
- Removal of the ventilation performance label.

The abandonment of the differentiation in type of use (living room, bedroom or study) makes the method less specific for a specific dwelling and specific use, but is essential to accommodate the principles of the Dutch building act.

Forthcoming

Next step will be to fit the first AEP-results of this new assessment method with field research results and the outcome of multi-zone airflow models, thus providing a substantiation for the use of this assessment model and the versatility of the new AEP- and AER parameters. Based on that outcome, the Dutch standard committee will decide on the implementation in the new standard NEN 1087. Furthermore, the results will be presented to CEN-TC 156, for evaluation, comments and possible input for further development, both in the methodology itself as eventually in the EN 13141- and EN 16798-series.

Conclusion

The adjustments that were necessary to make the methodology suitable for use in building regulation, resulted in more generic performance values for habitable spaces, but nevertheless not less valuable. It is therefore essential to point out that the performance assessment method cannot be used to predict the IAQ-levels that can be expected, but that it is intended to compare ventilation systems on their ability to achieve the requested air exchanges in the right place on the right time. With it a relatively simple method will become available within the context of building regulations, making it possible to – apart from ventilation capacity requirements - set limit values for performance indicators. ■

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