IAQ 2020: Indoor Environmental Quality Performance Approaches

Ventilation Effectiveness of Alternating Façade-integrated Ventilation Devices in a Dwelling

Sven Auerswald, M.Sc.
Fraunhofer Institute for Solar Energy Systems
sven.auerswald@ise.fraunhofer.de | +49 (0) 761 / 45 88 - 5901

1

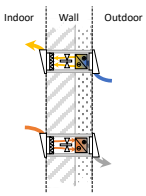
Acknowledgements

- Raghavakrishna Devineni:
  - Researcher for Advanced Building Technology at Institute of Sustainable Energy Systems (INES), Offenburg, Germany.
- Thibault Pflug
  - Project manager, Building Systems Technology, Fraunhofer ISE, Freiburg, Germany.
- Constanze Bongs
  - Head of Group Building Systems Technology Department Energy Efficient Buildings Fraunhofer ISE, Freiburg, Germany.

2

Learning Objectives

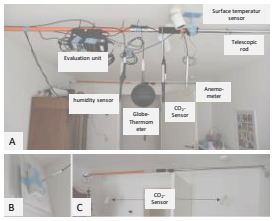
- Basics of push-pull devices = alternating façade-integrated ventilation devices
- Ventilation levels acc. to EU and German standards
- Push-pull devices provide mixing ventilation
  - ⇨ Is this statement always valid?
  - ⇨ If not: When it is valid?



3

Outline/Agenda

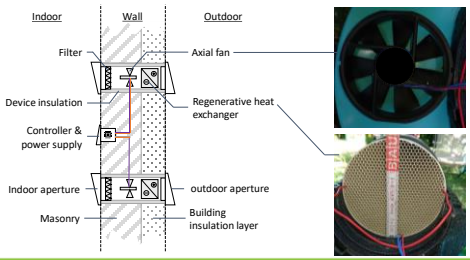
- Push-pull devices
- Theory ventilation efficiency
- Ventilation levels standards vs. measurement site
- Results
- Conclusion



4

Push-pull devices = alternating façade-integrated ventilation devices

Device structure & installation

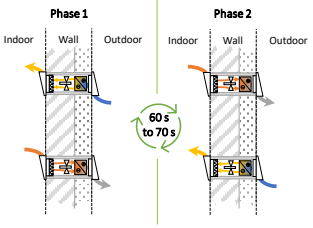


5

Push-pull devices

Operation principle & basic characteristics

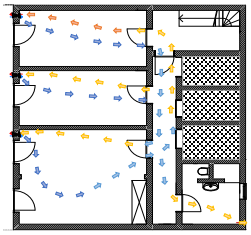
- Alternation of flow direction to activate regenerative HX
- Pairwise decentralized installation in the façade
- T-ratio: ~85 %ΔT
- Max. V-flow: ~46 $m^3 \cdot h^{-1}$
- Particularly predestined for use in refurbishments



6

Push-pull devices
Ventilation concept

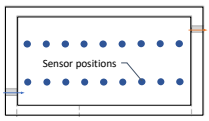
- Alternation of flow direction
- "Communication" of paired devices to:
  - Balance pressure & volume flow
  - Establish a flow pattern covering the whole indoor space
    - Not yet proven
- Ventilation characteristic: Mixed Ventilation
  - Possible but not always achieved



7

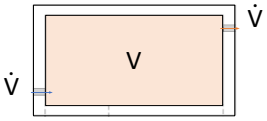
Theory: Ventilation Efficiency
Air Change Efficiency

- average air age of a room $\langle \bar{\alpha}_j \rangle$
  = reciprocal of the provided air change rate inside the room (EN 16798-1)



$$\langle \bar{\alpha}_j \rangle = \sum_{j=1}^{N} \bar{\alpha}_i(x) \cdot N^{-1} = \frac{1}{\langle \bar{n} \rangle}$$

- nominal time constant τ_{nom}
  = reciprocal of the nominal air change rate



$$\tau_{nom} = \frac{V}{\dot{V}} = \frac{1}{n_{nom}}$$

8

Theory: Ventilation Efficiency
Air Change Efficiency

- Air change efficiency: $\varepsilon^a = \frac{\langle \bar{n} \rangle}{2 \cdot n_{nom}}$

Prof. E. Skåret (1986):

„Rule no. 1 for designing effective ventilating systems is … to design for air exchange efficiencies above 50%", in the occupied zone.

$\varepsilon^a = 1$
Plug Flow*

10

Ventilation levels
standards vs. measurement site

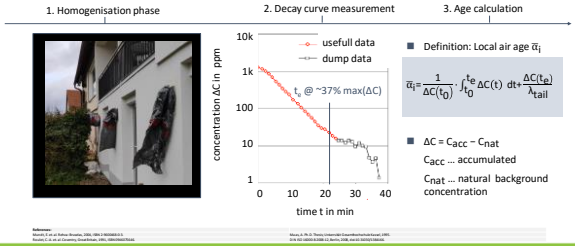
- Input: 3 Adults, total area: 88.7 m², ceiling height: 2.21 m

#	Ventilation level	DIN 1946-6 (2009) in $m^3 \cdot h^{-1}$	DIN 1946-6 (2019) in $m^3 \cdot h^{-1}$	EN 16798-1 (2021) in $m^3 \cdot h^{-1}$	#	Pre-Installed System (balanced + infiltation) in $m^3 \cdot h^{-1}$	Pre-Installed System (incl. exhaust only + infiltation) in $m^3 \cdot h^{-1}$
2	Moisture protection	20.9	6.01		2		
3	Reduced ventilation	62.5	50.5		3		
4	Nominal ventilation	93.7	77.1	117	4	39.4 ± 8.6	96 ± 12
5	Intensive ventilation	125	104		5	48 ± 12	105 ± 17

- German standards require lower ventilation rates than Europeans and have been further reduced.
- The system available for the study is an example for the assumption that existing decentralized residential ventilation systems tend to be too small.

11

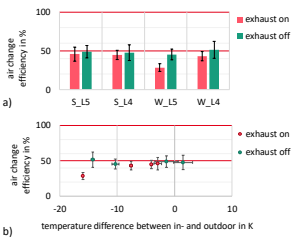
Theory: Ventilation Efficiency
Air Change Efficiency



9

Results

case	ε^a in %		$\langle \bar{n} \rangle$ in h^{-1}	
S L5 e0	49.0	±8.1	0.31	±0.01
S L4 e0	48	±10	0.24	±0.01
W L5 e0	45.4	±7.0	0.27	±0.01
W L4 e0	52	±11	0.26	±0.01
S L5 e1	45.9	±9.0	0.47	±0.01
S L4 e1	44.7	±6.0	0.1	±0.01
W L5 e1	28.4	±5.0	0.28	±0.01
W L4 e1	43.1	±6.0	0.38	±0.01



12

Conclusion

Design phase:

- German standards require lower ventilation rates than Europeans and have been further reduced.
- The system available for the study is an example for the assumption that existing decentralized residential ventilation systems tend to be too small.

Measurements:

- Very low air change rates in occupied zone due to low design volume flows
- Balanced cases slightly below mixed ventilation $\varepsilon^a = 0.48$
- Combined cases with exhaust only devices are short-circuiting $\varepsilon^a = 0.39$
- No clear impact of temperature gradients between in- and outdoors.
  - Possible reasons: mild climate conditions, good heat recovery performance or/and low ventilation flow does not penetrate the indoor space far enough

13

Bibliography

- S. Auerswald, R. Devineni, T. Pflug, C. Bongs. 2022. Ventilation Effectiveness of Alternat-ing Façade-integrated Ventilation De-vices in a Dwelling. Presented at IAQ 2020: Indoor Environmental Quality Performance Approaches Transitioning from IAQ to IEQ, Athens, Greece May 4-6.
- Mundt, Elisabeth; Mathisen, Hans Martin (2004): Ventilation effectiveness. Unter Mitarbeit von Peter Vilhelm Nielsen, Alfred Moser, Mats Prof. Ph.D (Eng) Sandberg, Dirk Prof. Dr.-Ing. Müller, Klaus Fitzner, Olli Seppänen und Derrick Braham. Bruselas: Rehva (Guidebook, 2).
- Skåret, Eimund (1986): Contaminant removal performance in terms of ventilation effectiveness. In: Environment International 12 (1-4), S. 419–427. DOI: 10.1016/0160-4120(86)90057-7.
- Roulet, Claude-Alain; Vandaele, Luk (1991): Air flow patterns within buildings. measurement techniques. Air leakage measurement methods, air flow measurement methods, measurement methods related to efficiency, measurements on ventilation systems ; [part of work of the IEA Energy Conservation in Buildings & Community Systems Programme. Annex XX: Optimization of air flow patterns within buildings, and Annex V, Air Infiltration and Ventilation Centre. Technical Note AIVC. 34. Coventry, Great Britain: Air Infiltration and Ventilation Centre (AIVC) (Technical note AIVC, 34), zuletzt geprüft am 03.04.2020.
- DIN EN 16798-1, 04.2021: Energetische Bewertung von Gebäuden – Lüftung von Gebäuden – Teil 1: Eingangsparameter für das Innenraumklima zur Auslegung und Bewertung der Energieeffizienz von Gebäuden bezüglich Raumluftqualität, Temperatur, Licht und Akustik – Modul M1-6; Deutsche Fassung EN 16798-1:2019. Online verfügbar unter https://www.beuth.de/de/normblatt-en-16798-1/296430492, zuletzt geprüft am 14.04.2021.
- DIN 1946-6, 05.2009: Raumlufttechnik – Teil 6: Lüftung von Wohnungen – Allgemeine Anforderungen, Anforderungen zur Bemessung, Ausführung und Kennzeichnung, Übergabe/Übernahme (Abnahme) und Instandhaltung. Online verfügbar unter http://fhgonline.fhg.de/bibliothek/en/list/DIN1946-6-2009.pdf, zuletzt geprüft am 29.08.2017.
- DIN 1946-6, 12.2019: Raumlufttechnik – Teil 6: Lüftung von Wohnungen – Allgemeine Anforderungen, Anforderungen an die Auslegung, Ausführung, Inbetriebnahme und Übergabe sowie Instandhaltung, zuletzt geprüft am 15.01.2020.

14

Questions?

Sven Auerswald: sven.auerswald@ise.fraunhofer.de

Fraunhofer ISE

15

Thank you!

16