Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

Investigation of Different Configurations of a Ventilated Window to Optimize Both Energy Efficiency and Thermal Comfort

Liu, Mingzhe; Heiselberg, Per; Larsen, Olena Kalyanova; Mortensen, Lone Hedegaard; Rose, Jørgen

Published in:
Energy Procedia

DOI (link to publication from Publisher):
10.1016/j.egypro.2017.09.660
10.1016/j.egypro.2017.09.660

Creative Commons License
CC BY-NC-ND 4.0

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Liu, M., Heiselberg, P., Larsen, O. K., Mortensen, L. H., & Rose, J. (2017). Investigation of Different Configurations of a Ventilated Window to Optimize Both Energy Efficiency and Thermal Comfort. *Energy Procedia*, *132*(October 2017), 478-483. https://doi.org/10.1016/j.egypro.2017.09.660, https://doi.org/10.1016/j.egypro.2017.09.660

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy
If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 132 (2017) 478–483

Energy Procedia

www.elsevier.com/locate/procedia

11th Nordic Symposium on Building Physics, NSB2017, 11-14 June 2017, Trondheim, Norway

Investigation of Different Configurations of a Ventilated Window to Optimize Both Energy Efficiency and Thermal Comfort

Mingzhe Liu[a,*], Per Kvols Heiselberg[a], Olena.K. Larsen[a], Lone Mortensen[b], Jørgen Rose[b]

[a]*Department of Civil Engineering, Thomas Manns Vej 23, 9220 Aalborg Ø, Denmark*
[b]*A.C. Meyers Vænge 15, 2450 København SV, Denmark*

Abstract

The study in this article investigates 15 ventilated window typologies with different pane configurations and glazing types in climates of four European countries (United Kingdom, Denmark, France and Germany) in order to identify the optimum typology with regard to their energy balance and impact on thermal comfort. Hourly simulations of the heat balances of the windows are conducted on four days representing different typical weather conditions according to the method described in EN ISO 13790. U and g values used in the calculation method are calculated in European software tool (WIS) for the calculation of the thermal and solar properties of commercial and innovative window systems. Additionally, comfort performance is evaluated by inlet air temperature and internal surface temperature of the windows calculated by WIS software.
The results of the study show the energy and comfort performance of different ventilated window typologies and provide optimally ventilated window typologies for climates of these four European climates. The typologies with solar control or Low-emissivity (Low-e) coatings and typologies with double glazing on the outside have better performance in terms of either minimizing the energy consumption or optimizing the thermal comfort. The provided optimal window typologies can be used in residential and commercial buildings for both new constructions and renovations.

© 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics.

Keywords: ventilated window; configuration; energy consumption; thermal comfort

* Corresponding author. Tel.: +45 99407234.
E-mail address: ml@civil.aau.dk

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the organizing committee of the 11th Nordic Symposium on Building Physics
10.1016/j.egypro.2017.09.660

1. Introduction

Houses and apartments are nowadays the most energy intensive sector and their operation takes up to 40% of the total amount of energy use in Europe. Windows have a significant effect on building performance and several aspects have to be taken into account when developing new concepts for refurbishment [1]. In many existing buildings, mechanical ventilation is very difficult and expensive to provide and there is a need for the development of alternative window and ventilation solutions.

Five window typologies were simulated indicating that better energy performance can be achieved with the help of ventilated window in the subtropical and temperate climate zones [2]. Appelfeld et al. [3] conducted experimental analysis showing that a ventilated window can potentially contribute to energy savings and the ventilated window might be most suitable for a window unit with low ventilation rates. Different models and calculation methods have already been developed to investigate the performance of ventilated windows [4,5].

A comprehensive investigation needs to be implemented for different window typologies and both the energy demand and the thermal comfort of the different window typologies need to be evaluated. The study investigates 15 different window typologies (e.g. glazing type, glazing position, coating position and cavity width, etc.) under two different ventilation concepts (heating mode and cooling mode). Energy demand and thermal comfort (internal surface temperature and inlet air temperature of the window typologies) have been calculated under different weather conditions in four European countries and the most energy efficient solution providing acceptable indoor thermal comfort has been identified.

2. Description and method

The investigations were performed on the 15 different window typologies illustrated in Figure 1. Typology 3 is used as a reference case. The reference case is a closed cavity window and the others are variations of windows with different pane and glazing configurations and a ventilated cavity. In general, the samples are simulated to test the effect of:

- Coating on a single glazing
- Single glazing outside
- Single glazing inside
- Coating position (surface facing inside or surface facing outside)
- Coating type (solar control or Low-e)

The ventilation concepts shown in Figure 2 are used in the simulation. In summer the active mode is the Cooling mode while in winter the Heating mode is active.

The goal of the cooling mode is to minimize the amount of solar radiation passing through the window. For a traditional window configuration, some amount of solar radiation striking the window is absorbed in the glazing panes and then transferred to the room by convection and radiation. Natural ventilation through the air gap can cool down the glazing panes and the heated air can be expelled to the outdoors removing some amount of solar radiation. In addition, the air to the room is supplied directly from the outside in the cooling mode. The main idea behind the heating mode is minimizing the heating load from the heating system to the room by means of utilization of solar radiation for preheating of the ventilation air. Also, the energy losses from the room through the inner skin of the window will return back to the room with the ventilation air. The preheating of the ventilation air will also reduce the risk of draught.

Simulations of the window performance have been carried out for three orientations; north, south and west and for four different locations. The locations are Copenhagen (Denmark), Finningley (United Kingdom), Nice (France) and Würtzburg (Germany). The calculations are time-consuming, so only these four locations are selected to representing the northern, western, southern and eastern Europe. The results are presented for the individual orientations and discussed. The simulations are performed without solar shading systems.

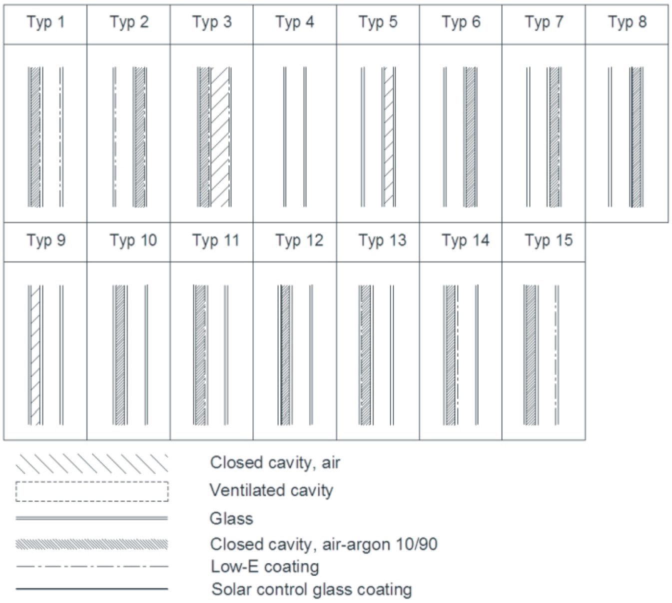

Fig. 1. The 15 different window typologies used in this study.

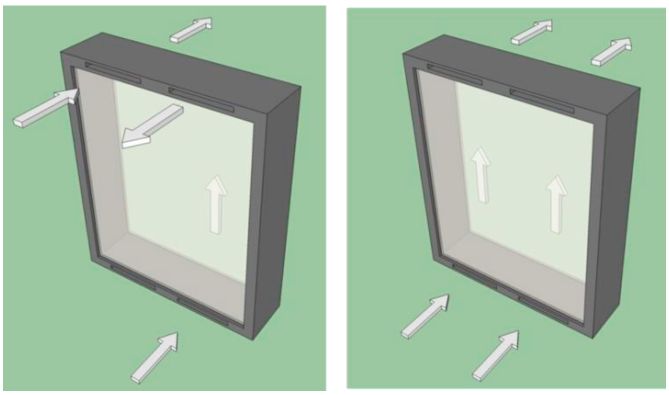

Fig. 2. Illustration of the ventilation concepts: Cooling mode (left) and Heating mode (right).

The weather data is very important for the analysis of the window design and in principle, the performance should be evaluated based on hourly values for a whole year. However, for a ventilated window both the U-value and the g-value changes hour by hour and it is a huge task to calculate these values for every hour during a whole year. Therefore, the performance evaluation in this investigation is based on calculations performed for four different typical 24 hour periods, i.e. a sunny summer, an overcast summer, a sunny winter and an overcast winter day.

The evaluation of the window typologies is based on achieving the lowest energy consumption of heating and cooling and the best thermal comfort performance in terms of internal surface temperature and inlet air temperature.

The energy demand for cooling and heating is calculated according to EN/ISO 13790 [6]. The energy balance through the windows is calculated considering heat transmittance, ventilation losses and the solar gain through the windows. Hourly calculations are implemented for all the typical days. The indoor comfort near the window is evaluated by WIS, which can calculate the average surface temperature of all the window layers and the air temperature at centre and exit position of the cavity.

3. Result and discussion

3.1. Performance of ventilated window typologies facing south in Denmark

3.1.1. Results for Low-e coating on a single pane (typologies 1 and 2)

The calculated energy performance for typologies 1 and 2 are generally better than that of the closed cavity window, and especially in the winter situation, the energy performance improves significantly. The results are very similar for typologies 1 and 2. Slightly less energy is used, when the single pane with the coating is placed internally (typology 1). For a Low-e coating, it is preferable to place the single glazing on the exterior side. The small difference in the results can emphasize that the placement can be based on best practice in the final design phase.

Regrding comfort, typologies 1 and 2 have better performance than that of the closed cavity. And typology 1 has the highest inlet air (cavity exit) temperature, while it has a lower internal surface temperature than typology 2 during the heating mode. But for typology 1 both the internal surface temperatures for a sunny winter day and for an overcast winter day are higher than 14 ^{o}C which is above the dew point temperature for normal indoor winter conditions (22 ^{o}C and 50% RH).

3.1.2. Results for single glazing on the outside (typologies 5, 6, 7 and 8)

The calculated energy performance for typologies 5 and 6 are worse than for the reference case, but neither of them has coatings on the panes. Typologies 7 and 8 have generally a better energy performance than the reference case with typology 8 as the best one. However, for the sunny summer case typology 7 with a Low-e coating needs slightly more energy for cooling than the reference case. In general, the performance of Low-e coating is best in the winter situation, whereas the solar control glass performs best during summer.

The inlet air temperature of all the four typologies is higher than the reference case, which takes air directly from outside. Typologies 7 and 8 have lower inlet air temperature but higher internal surface temperature than typologies 5 and 6 during the heating mode. For the cooling mode, typologies 7 and 8 have slightly higher internal surface temperature. The highest internal surface temperature during summer days of typology 8 is lower than the others as well as the fluctuation of the internal surface temperature is smaller.

3.1.3. Results for single glazing on the inside (typologies 9, 10, 11 and 12)

The calculated energy performance for typologies 9 and 10 are worse than for the reference case, but neither have coatings on the panes. Typologies 11 and 12 have generally better performance than the reference case with typology 12 as the best one. However, for the summer case typology 11 with a Low-e coating needs slightly more energy for cooling than the reference case. The solar control glass in typology 12 has a good effect in reducing the energy demand for cooling in the summer time, but at the same time, it increases the heating demand during winter slightly. As found for the typologies with single glazing inside the Low-e coating performs best in the winter situation, whereas the solar control glass performs best during summer.

The inlet air temperature for heating mode for all the four typologies is higher than the reference case, which takes air in directly from outside. Typologies 11 and 12 have both higher inlet air temperature and higher internal surface temperature than typologies 9 and 10 during heating mode. For the cooling mode, typologies 11 and 12 have slightly higher internal surface temperature. The highest internal surface temperature during summer days of typology 12 is lower than the others as well as the fluctuation of the internal surface temperature is smaller.

3.1.4. Results for different coating positions (typologies 13, 14 and 15)

All the results show better performance than the reference case. All results are very similar but the typologies 13 and 14 are marginally better than typology 15. The small difference in results suggests that the placement of the coating should be based on the practical experience, i.e. the coating might be best protected between the double glazing (typology 13) rather than in the ventilated air gap (typologies 14 and 15).

All the results of inlet air temperature are better than the reference case. Typologies 14 and 15 have marginally lower inlet air temperature but slightly higher internal surface temperature than typology 13 during heating mode. For the cooling mode, typologies 14 and 15 have slightly higher internal surface temperature. But the highest internal surface temperature of typology 14 is slightly lower than typologies 13 and 15.

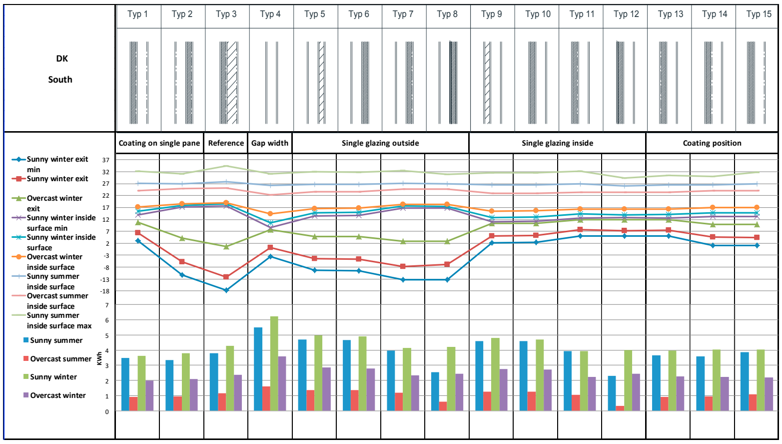

Fig. 3. Energy demand and thermal comfort results of all the window typologies for south facing orientation in Denmark.

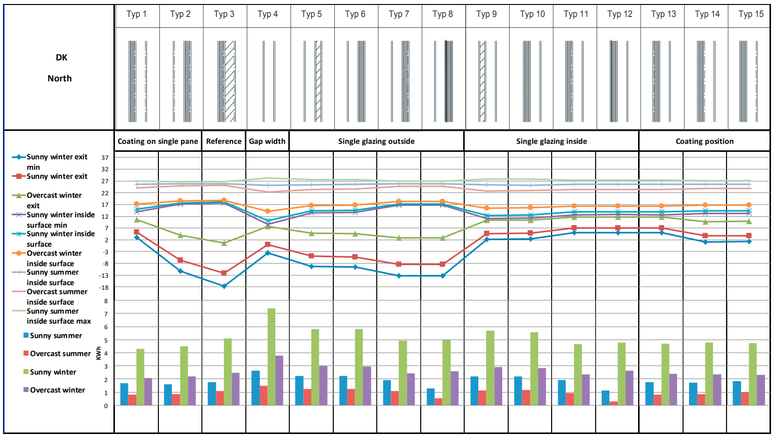

Fig. 4. Energy demand and thermal comfort results of all the window typologies for north facing orientation in Denmark.

3.2. Comparison of performance of window typologies facing south and north in Denmark and facing south in France

Shown in figures 3 and 4, south-facing typologies in Denmark have higher cooling energy demand than north-facing typologies in Denmark because of the higher solar radiation in sunny summer. Furthermore, the internal surface temperature of all the south-facing typologies is approximately 5 °C higher than that of the north-facing typologies also resulted by the higher solar radiation.

According to figures 3 and 5, the cooling energy demand and the internal surface temperature of the south-facing typologies in both Denmark and France are high in sunny summer because of the higher value of the solar radiation. The cooling energy demand of south-facing typologies in France, however, is higher than that in Denmark in overcast summer because of the higher outdoor temperature in France. Furthermore, the heating energy demand of south-facing typologies in Denmark is much higher than that in France on sunny winter days, which is because of the lower outdoor temperature in sunny winter in Denmark.

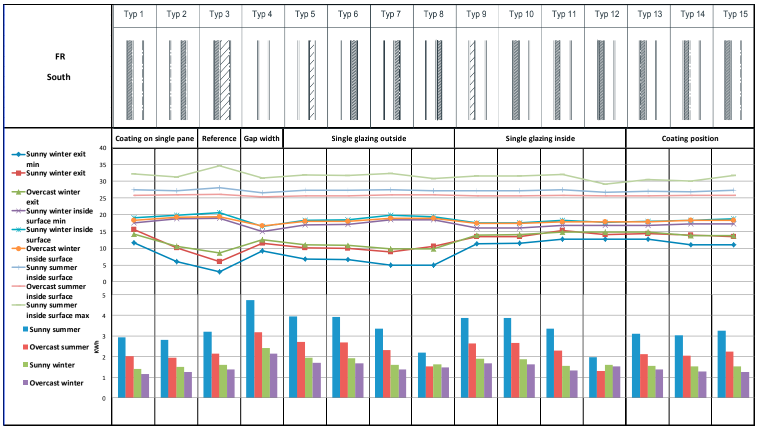

Fig. 5. Energy demand and thermal comfort results of all the window typologies for south facing orientation in France.

4. Conclusion

Based on the different sets of calculations with varying typologies for the windows it can be concluded that ventilated windows can be used to reduce the energy demand for cooling and/or heating and improve the indoor comfort performance depending on the season.

The position of the single glazing is preferably on the internal side. In terms of energy consumption, it is only slightly better than when the glazing is placed externally, but the single glazing at the internal side performs much better in terms of the inlet air temperature.

It is recommended to use a window typology like either typology 12 with an air-argon filled double pane with solar control glass combined with an interior single pane where the gap between them acts as a ventilated cavity or like typology 1 with an air-argon filled double pane with a Low-e coating combined with an interior single pane also coated where the gap between them acts as a ventilated cavity. The main strength of typology 12 is the superior summer performance, while typology 1 is recommended because of its better indoor comfort performance. However, typology 13 is also recommended considering its lower cost than typology 1. With only one pane of Low-e coating, its energy performance is slightly worse than typology 1, while the comfort performance of typology 1 and 13 are almost the same.

Acknowledgements

The research work presented in this article was carried out in the EU FP7-SME supported project CLIMAWIN— An intelligent window for optimal ventilation and minimum thermal loss, Project number 262262.

References

[1] Häkkinen T. (ed.), Sustainable refurbishment of exterior walls and building facades, Final report, Part A – Methods and recommendations, Espoo 2012. VTT Technology 30. 303 p. + app. 40 p.

[2] Chow T., Lin Z., Fong K., Chan L., He M. Thermal performance of natural airflow window in subtropical and temperate climate zones – A comparative study. Energy Conversion and Management 2009; 50: 1884-1890.

[3] Appelfeld D., Svendsen S. Experimental analysis of energy performance of a ventilated window for heat recovery under controlled conditions. Energy and Buildings 2011; 43: 3200-3207.

[4] Carlos J. S., Corvacho H., Silva P. D., Castro-Gomes J.P. Real climate experimental study of two double window systems with preheating of ventilation air. Energy and Buildings 2010; 42: 928-934.

[5] EN 15099, November 2003. Thermal performance of windows, doors and shading devices-Detailed calculations.

[6] EN ISO 13790, Energy performance of buildings-Calculation of energy use for space heating and cooling (2008).