NATURAL VENTILATION

Experience and results in office buildings

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ABSTRACT

This paper is divided into tree main sections, 'Introduction to natural ventilation', 'Examples, strategies and results' and 'Energy consumption'.

In the first section a general introduction to natural ventilation is given, including the three main principles for natural ventilation. It is also described what the author's understanding of natural ventilation is – for example the difference between opening windows or just opening grills or trickle vents.

In the second section three major building projects are mentioned and described. The projects are situated in three different countries across Europe – from Denmark in the north to Switzerland in the middle and Hungary in Eastern Europe.

The three chosen project cases are: Aston IT Group headquarters, Denmark and Bodum headquarters, Switzerland and an office and training building, Hungary.

For each project the chosen ventilation strategies will be explained. Furthermore the actual measurements of the indoor climate in the buildings are shown together with the relevant weather data.

In the third section the results of analysing a model building with either natural ventilation or mechanical ventilation are shown. The results include analysis of the indoor climate, the energy consumption and the total cost over a 25 years period for the two ventilation solutions.

KEYWORDS

Natural ventilation, Night cooling, Energy consumption, Total cost.

INTRODUCTION

What is Natural Ventilation? Is it only manual opening of a window/grill or is it a window/grill with a motor built on it? When Natural Ventilation is mentioned in the following the meaning is *Controlled Natural Ventilation*. The basic principles are

Single sided ventilation

Means that the ventilation of a room/an area can only be done through opening(s) in one facade.

Cross ventilation

Means that ventilation of a room/an area can be done through opening(s) in two or more facades.

Stack ventilation

Means that a room/ building can be ventilated through opening(s) at different levels, so that it is possible to use the thermal effect (air change driven by differences in temperature).

EXAMPLES, STRATEGIES AND RESULTS

In this part a number of different office buildings with natural ventilation are described, including the ventilation strategy and solution for controlling the indoor climate.

All buildings have been in use for at least one year, and the indoor climate has been monitored in this period. For each building the measurements of a selected summer period are shown to prove the cooling effect of natural ventilation and night cooling.

ASTON

The Aston building is an office building and headquarters of the IT company called ASTON GROUP. The building is situated in the middle of Copenhagen near the harbour and constructed in year 2000.

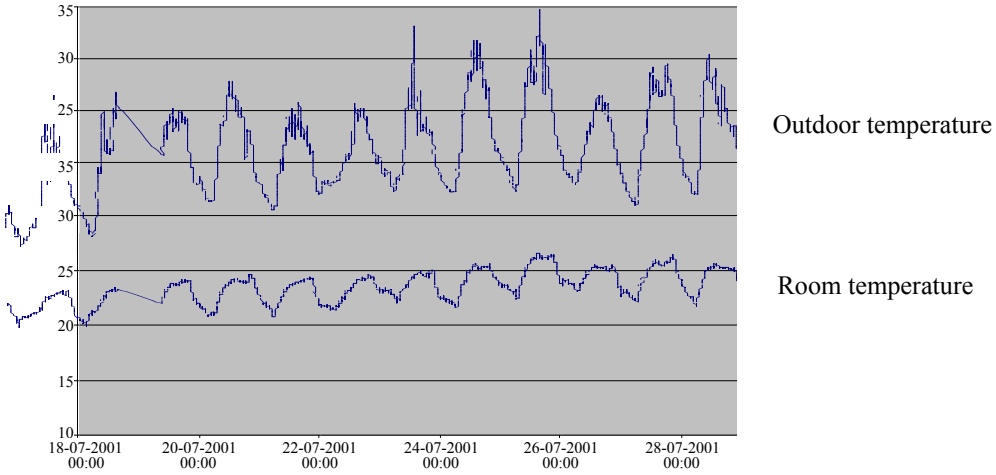
The interior part is divided into modern open plan office areas, which contain 15-25 people each, and in the middle of the building there is an atrium through all 5 levels.

Figure 1: Interior from the Aston building.

The total area of the building is 12.000 m^2 divided into 5 levels and of this area approximately 10.000 m^2 is naturally ventilated.

The natural ventilation principle in the building is 'stack ventilation' based on air inlet through highly placed windows (height 0.35 m) in the facades on each floor and outlet through the glass roof above the atrium. To control the indoor climate an NV Control System™ from WindowMaster has been installed, which controls the window openings depending on room temperature and data from a weather station placed on the roof (outdoor temperature, wind speed, wind direction and rain). The control strategy used is optimal night cooling together with a combination of automatically and manually controlled day ventilation.

Figure 2: Indoor and outdoor temperature during a summer week.



The indoor temperature in the period was maximum 26 ^{o}C when the outdoor temperature was up to 33 ^{o}C. The measurement of the indoor climate shows that it is possible to lower the indoor temperature by up to 7 ^{o}C by using effective night cooling by natural ventilation.

BODUM

The Bodum buildings are situated in Triengen, Switzerland and are headquarters of the Bodum Company which produces designer kitchenware. The buildings consist of 2 square units, the new one built in year 2000 and the other refurbished the same year. The interior parts of the buildings are divided into open plan office areas containing 3 - 10 people each, and some cellular offices.

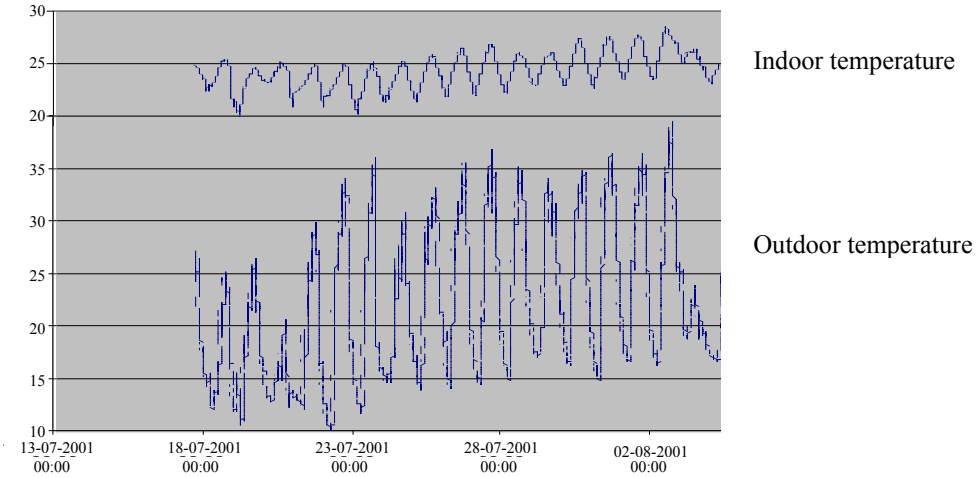
Figure 3: Bodum office buildings.

The natural ventilation principle in the buildings is 'cross ventilation' at each level combined with 'stack ventilation' through staircases. The air inlet and outlet passes through highly placed windows in the facades on each floor. On the roof above the staircases windows are also placed, which are used as outlet in the 'stack ventilation' situation. If the effect of the

natural ventilation is not high enough, small exhaust fans are installed on the roof. The fans exhaust through pipes from each floor.

To control the indoor climate the NV Control System™ from WindowMaster is installed, which controls the window openings and the fans dependent on room temperature and data from a weather station placed on the roof (outdoor temperature, wind speed, wind direction and rain). The control strategy used is optimal night cooling together with a combination of automatically and manually controlled day ventilation.

Figure 4: Indoor and outdoor temperature during a summer week.



The indoor temperature in the summer period was maximum 28 ^{o}C when the outdoor temperature was up to 38 ^{o}C in peak. The measurement of the indoor climate shows that it is possible to lower the indoor temperature by up to 10 ^{o}C by using efficient night cooling by natural ventilation and in this case combined with a mechanical exhaust.

BUDAPEST

The Budapest building is a combined office and training building. The building has three levels, 2 normal levels and one level under a ‘slanting roof’.

The natural ventilation principal in the buildings is ‘cross ventilation’ on each level combined with ‘stack ventilation’ through the staircase. The air inlet and outlet passes through highly placed windows in the facades on each floor. In the roof above the third floor (and the staircase) a number of windows in all four directions are placed which can also be used as outlet in the ‘stack ventilation’ situation.

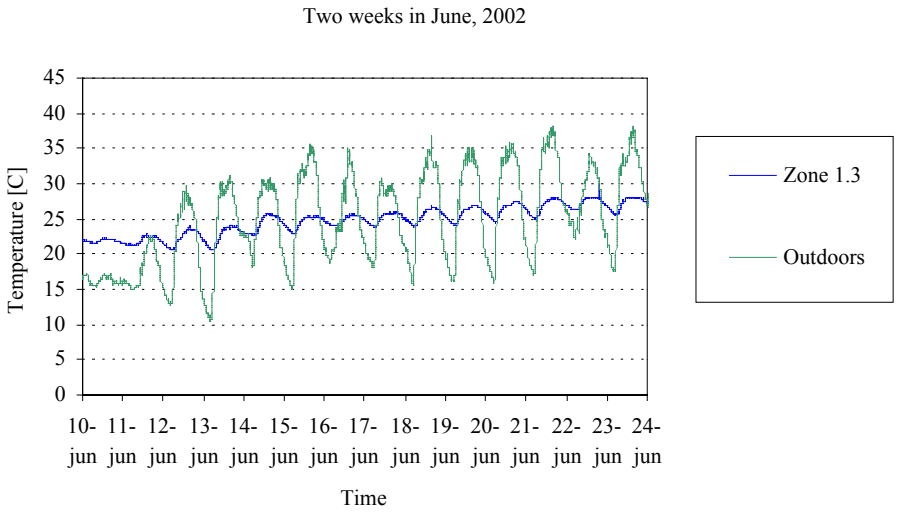


Figure 5: Indoor and outdoor temperature during a summer week.

The indoor temperature in the summer period was maximum 29 °C when the outdoor temperature was up to 38 °C in peak. The measurement of the indoor climate shows that it is possible to lower the indoor temperature by up to 9 °C by using efficient night cooling by natural ventilation.

ENERGY CONSUMPTION AND ECONOMY

The Engineering College of Aarhus, Denmark has together with WindowMaster made an analysis of the total energy consumption in a standard office building with mechanical ventilation or natural ventilation. The analyses are based on results from the software program BSIM2000, developed by the Danish Building Research Institute. The BSIM2000 program is used by consultants and institutes in a number of countries all over Europe.

The calculation model for the office building is a 3000 m^2 building in three levels with a ground area of 79.2 x 12.7 meter. The building is a medium heavy building with windows in all four facades, and the ventilation principle for natural ventilation is cross ventilation at each level.

As weather data standard weather data were used – the so-called TRY-reference year developed by the Danish building research institute.

Figure 6: Maximum operative temperatures for the working hours 8-18 and hour quantiles for 24 hours on workdays in the summer period week 20-39 (middle of May – end of September).

	Natural Ventilation	Mechanical Ventilation
Max. operative room temperature	**25.4**	**28.7**
No. of hours with room temperature above 26 °C	**0**	**60**
No. of hours with room temperature above 27 °C	**0**	**120**

The analysis of the two models ’Natural ventilation’ and ’Mechanical ventilation’ shows that it is possible to achieve lower maximum temperatures in the summer period as well as a reduced number of hours in which the shown temperature limits are exceeded. By comparison

of a naturally ventilated office building with a corresponding mechanically ventilated office building model calculations will show:

- That the naturally ventilated building has lower maximum temperatures during the time in use.
- That the reduction of the maximum temperatures is a consequence of the possibility of more efficient night cooling of the building, and reduced air change on warm days, when the outdoor temperature is higher than the indoor temperature.
- That energy-saving and environmental improvements are possible when using natural ventilation.
- That it may be considered combining mechanical ventilation with natural night cooling in connection with hybrid ventilation solutions.

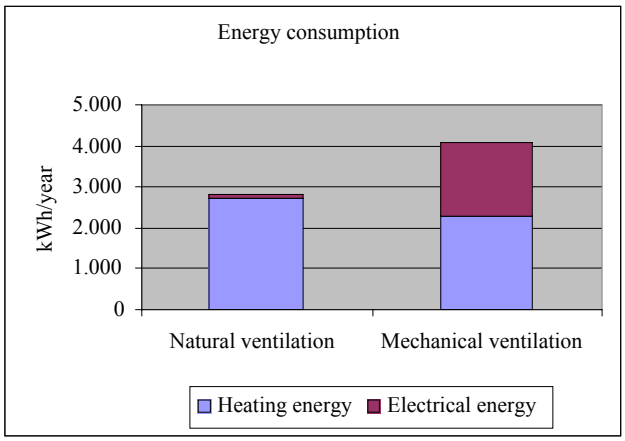


Figure 7: Total energy consumption of the reference office building with natural ventilation and mechanical ventilation, respectively. The energy consumption of the naturally ventilated building is 46% lower than for the mechanically ventilated building. The figures mentioned are net energy consumption.

In office buildings with considerable internal heat loads and where the natural ventilation is provided without preheating, the results show, that the lacking heat recovery results only in a modest increase in the energy consumption for heating, compared with a standard mechanical ventilation plant.

The naturally ventilated solutions result in considerable electricity saving, and if the total energy consumption is converted into gross energy, which can be regarded as an indicator of the total environmental impact, it can be seen that considerable reductions can be achieved by changing from mechanical to natural ventilation.

The calculations for mechanical solutions show that there is a considerably increased electricity consumption in connection with night cooling. The consumption for night cooling is of the same magnitude as the daily consumption in a summer period.

Figure 8: Maximum operative temperatures for the working hours 8-18 and hour quantiles for 24 hours on workdays in the summer period week 20-39 (middle of May – end of September).

	Natural Ventilation (no ceiling)	Natural Ventilation (suspended ceiling)
Max. operative room temperature	**25.4**	**26.8**
No. of hours with room temperature above 26 °C	**0**	**30**
No. of hours with room temperature above 27 °C	**0**	**0**

In the model with lowered ceiling it is assumed that there is a loose, false ceiling with a free air-filled space of 30 cm between the concrete floor and the false ceiling. The air in the space is regarded as stagnant. All other building data, ventilation principles and periods are identical for the two models.

It can be seen that the maximum operative room temperature is only increased by 1.4 ^{o}C in the model as a consequence of the false ceiling. The increased temperature can only be caused by a reduction of the impact of night cooling.

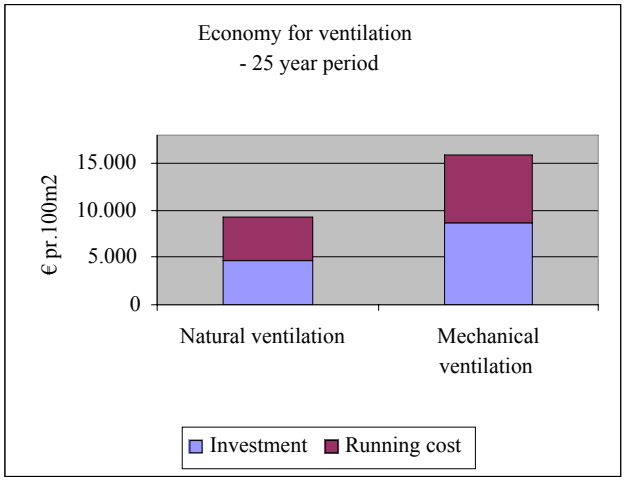


Figure 9: Total economy of the office building provided with natural ventilation or mechanical ventilation, respectively. The costs for energy as well as maintenance of the plants are included in the figures.

For the two types of ventilation, costs have been calculated with regard to investment and running costs. The results show that over the lifetime of a ventilation system – 25 years – the total costs are 72% higher for the building with the mechanical system compared to natural ventilation.

The conclusion concerning the work done by The Engineering College of Aarhus, Denmark was that when comparing a naturally ventilated office building with a corresponding mechanically ventilated building, model calculations show:

- The naturally ventilated building has lower maximum temperatures during the time in use.
- That the reduction of the maximum temperatures is a consequence of the possibility of more efficient night cooling of the building and a reduced air change on warm days when the outdoor temperature is higher than the indoor temperature.
- That energy-saving and environmental improvements are possible when using natural ventilation.
- That the yearly operation costs when using natural ventilation are lower than for mechanical ventilation.
- That the total costs over a 25 years period are lowest for natural ventilation, and there is room for considerable extra costs for the building without changing this fact.
- That it may be considered combining mechanical ventilation with natural night cooling in connection with hybrid ventilation solutions.

References

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