DESIGN GUIDELINES FOR NATURAL VENTILATION SYSTEMS IN TERTIARY SECTOR BUILDINGS

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ABSTRACT

Parameters determining efficiency of natural ventilation systems are numerous. The most important are architecture and system design. This article get onto both but focuses on system design. Through dynamic simulations it shows that natural ventilation management has a large impact on energy saving but most of all on thermal comfort. Natural ventilation techniques are also weighted against hybrid solutions and high efficiency mechanical cooling solutions. Natural ventilation techniques show their relevance but also their limitations.

INTRODUCTION

Examples of naturally cooled buildings show that a lot of parameters have to be considered in order to ensure thermal comfort. The most important is probably the adequate combination of systems and architecture [1]. But others important elements are systems management and the possibility to bring local mechanical cooling load if needed. This paper investigates these elements to determine natural ventilation techniques performances in terms of energy savings and thermal comfort. Objective of the broader study including this paper is to develop a didactic conception tool for architects showing interest of natural cooling techniques for the most important architectural parameters.

METHOD

Dynamic simulations were performed on a typical tertiary office module (table 1) with TRNSYS16 for a typical Belgian year, depicted in figure 1. Studied outputs are energy demand and thermal comfort. Energy demand does not include technological productivity. For thermal comfort, the chosen criterion is the one considering 100 hours above 25.5°C as comfort acceptance limit [2]. Adaptative comfort criterions are of course an alternative criterion that will be used in the further steps of this study [3]. Both will be presented in the tool developed from this study, in order to give user both new and well-known reference criterions.

	Office module
Surface	19.44 m²
Façade surface	9.72 m²
Infiltration	0.2 ach
Glazing surface	6.84 m², including 18% for the frame. U window=1.23W/m²K
Orientation	South
Shadow devices	Nothing, selective glazing (g=0.42) or blinds
Mean inertia	Medium (200kg/m²) or high (375 kg/m²)
Insulation	Façade: U=0.437W/m²K, other walls are considered adiabatic
Internal gains	21W/m² or 28 W/m²
Occupation hours	8am to 18pm, including 3hours of ½ occupation

Table 1 characteristics of investigated office module

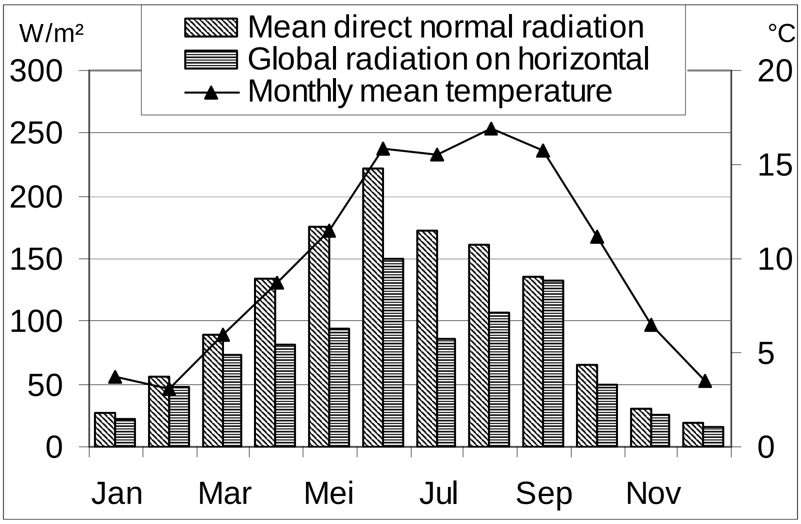

Figure 1: Weather data for a typical Belgian year: assembled representative months (monthly mean values)

IMPACT OF ARCHITECTURE ON NATURAL COOLING PERFORMANCE

It has been demonstrated that architecture has a large impact on natural cooling performance. Hybvent studies published by Delsante (2002) illustrate that efficient cases are those with high inertia, limited solar gains and limited internal gains. Figure 2 shows some combinations of these parameters for a south oriented office module with night cooling. With a mechanical cooling, this office module’s energy demand is of 99W/m². So large energy savings are available but desired comfort levels are difficult to reach. A highly energy efficient architecture is needed.

But an efficient architecture is not sufficient by it own to ensure that a natural cooling strategy will succeed. Other parameters are the natural ventilation management, and the combination with a limited mechanical cooling. Both are investigated in the following sections.

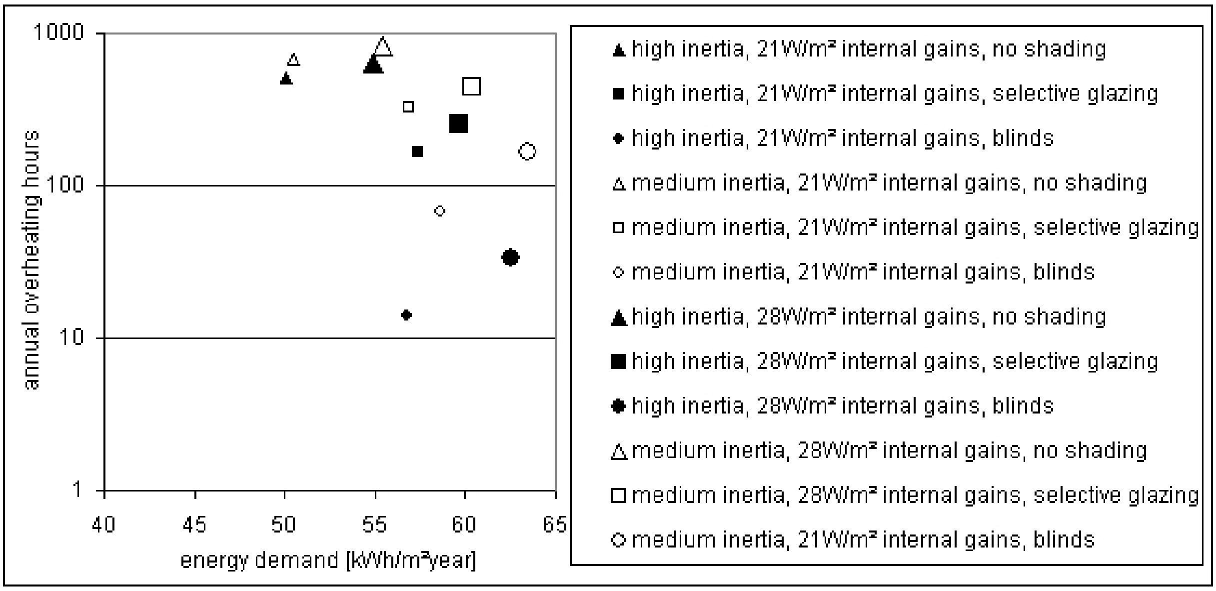

Figure 2 : Performances for a south oriented office module with 70% glazing and night cooling

IMPACT OF NATURAL VENTILATION MANAGEMENT

This impact can be studied from three points of view. The first is the choice between night cooling, day cooling and day and night cooling. Figure 3 shows difference for two architectures of a south oriented office module. All systems allow the same energy savings but impact on thermal comfort is different. Inertia reveals having a large impact especially when night cooling is organised. It is obvious that thermal inertia is particularly useful when heating and cooling loads are desynchronised.

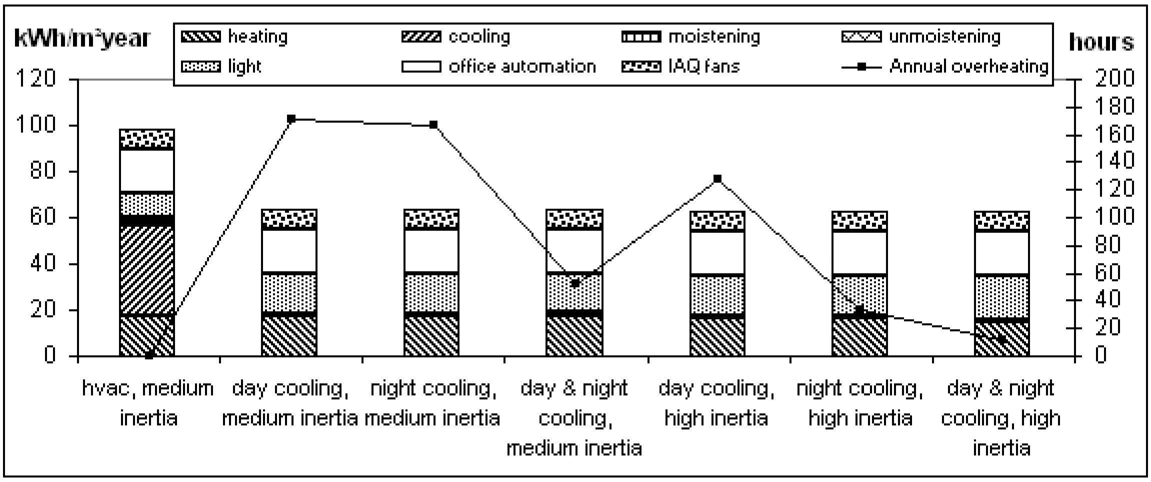

Figure 3 Performances of various natural ventilation techniques for a south oriented 70% blinded glazing office module with 28W/m² internal gains

A second point of view is natural ventilation management in terms of set points and flow rates. Figure 4 shows simulated results for different combinations. In the first case, night cooling allows 8 ach between 21h00 and 5h00 if internal temperature exceeds 22.5, with an automatic interruption if internal temperature falls under 18.5°C. This is the management rules used for previous simulations. Studied alternative are a 4 ach flow with the same set points and both flow rates with a 19h00 – 5h00 schedule. A variation in the temperature set point from 22.5°C to 23.5°C is also studied. All three parameters show impact on comfort level. Reduction of the air flow and uprising of the starting set point will reduce night cooling efficiency. A more precocious starting time however will make it more efficient.

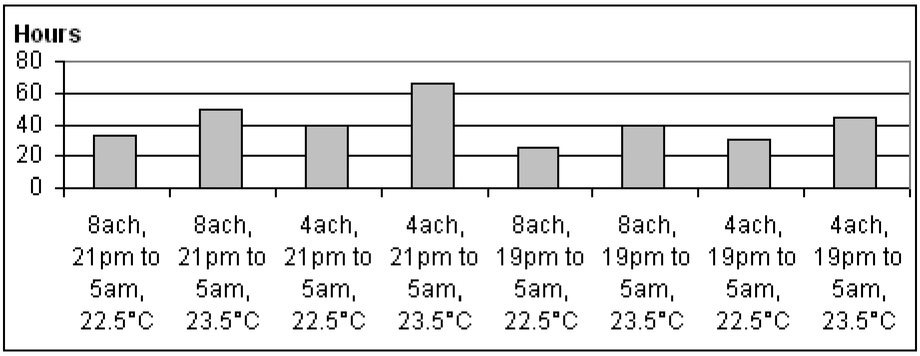

Figure 4 Overheating hours in a south office module with 70% blinded glazing, high inertia, 28W/m² internal gains, for various night cooling managements

A third parameter is the so called Rational Energy Use. This parameter may have a very large impact on energy savings. Figure 5 shows simulated results for different situations. Differences between high and poor energy efficiency strategies are resumed in table 2. All these energy efficiency parameters have a very large impact on systems performances. Looking to figure 5, it may be said that managing a highly efficient mechanical cooling allows more energy savings than managing a basic night cooling. It is obvious that all previous simulations where computed for efficient systems.

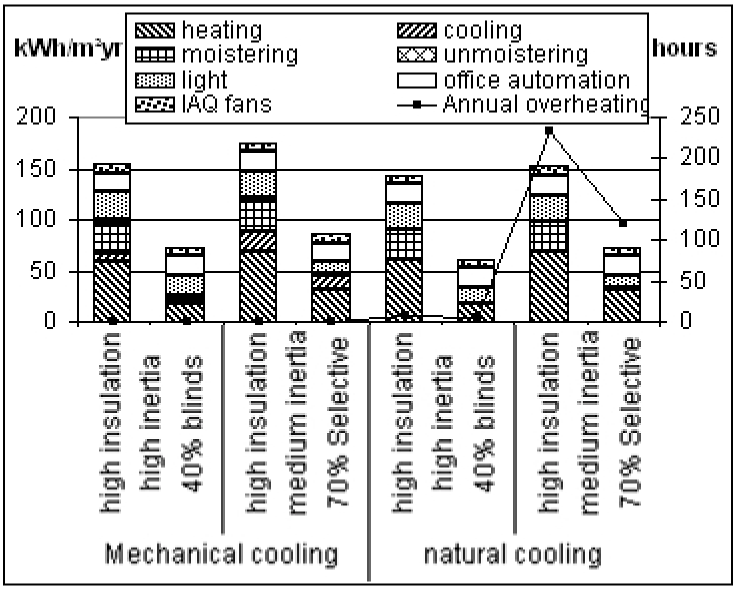

Figure 5 Energy demand and annual overheating hours for a south office module with 21W/m² internal gains, for poor (left of each couple) or high efficiency energy strategy (right of each couple)

	Low efficiency	**High efficiency**
Sanitary flow	1.15 ach	1ach
Sanitary air t°	20 or external t° if higher	14 or external t° if higher
Sanitary air schedule	8am to 20pm	8am to 18pm
Moistening	Pulsing at 55% humidity	Function of internal gains
Heating set point	21.5°C, no WE stop	20.5°C
Cooling set point	24°C, no WE stop	24°C in winter, 25°C in summer
Blinds	Down at 350W/m²	Down at 250°C and 23°C
Lighting	No dimming	Dimming

Table 2 Differences between high and poor energy efficiency strategies in figure 5

PERFORMANCES OF HYBRID SYSTEMS

When architectural choices make natural cooling unable to ensure thermal comfort, a limited mechanical cooling may be brought. This could be done different ways: by combining a classical mechanical cooling with natural night ventilation or by placing a cooling device on sanitary air ducts. In the first case, thermal comfort will always be ensured, with large energy savings compared to the so-called “mechanical cooling only” case. This case may seem ideal but major inconvenient is investment cost cumulating two systems. In the second case, overheating may happen due to the limited cooling power, but is reduced compared to the “night cooling only” case. Energy savings are larger in that case. Figure 6 shows impact of both techniques on energy savings and thermal comfort. Figure 7 illustrate impact of architectural choices when a cooling power is set on the sanitary air. Architectural choices appear to be less critic parameters since more architectural combinations allow desired comfort level to be reached, compared to figure 2.

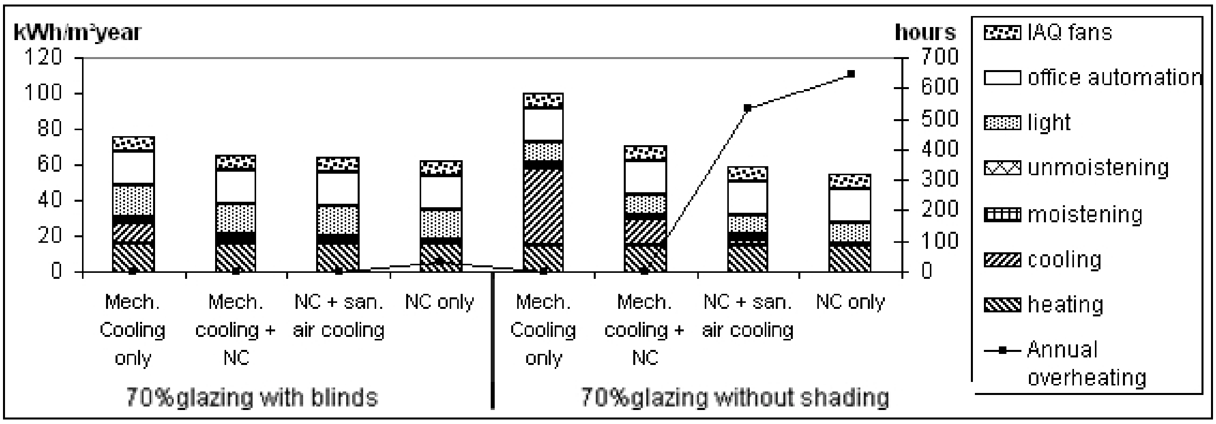

Figure 6 Performances of hybrid cooling techniques for a south oriented office. Inertia and insulations are high in both cases. Internal gains are 28W/m²K.

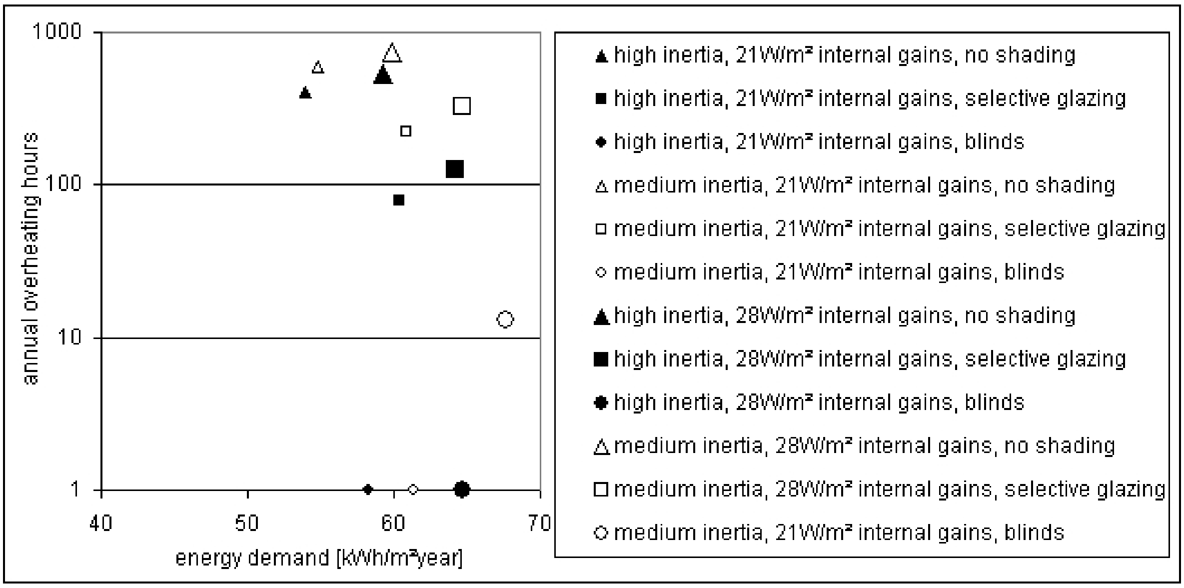

Figure 7 Performances for a south oriented office module with 70% glazing and night cooling combined with mechanical cooling on sanitary air

CONCLUSION

It has been shown that natural ventilation has to be studied for what it is: cooling systems interacting with architecture, but also technical systems with various parameters influencing energy and comfort performances. It has been illustrated that providing a highly efficient management of a mechanical cooling may be more interesting than opting for a natural cooling. Of course the ideal situation stays a well performed natural ventilation system.

When architecture does not allows natural cooling to ensure thermal comfort, hybrid systems are interesting solutions. They still manage large energy savings. For economical reasons, full mechanical cooling and sophisticated natural ventilation will scarcely be found together. Cooling power on sanitary air is therefore a good compromise, but will not ensure comfort for all architectural choice.

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