

DEVELOPMENT OF DESIGN GUIDELINES FOR TERTIARY SECTOR BUILDINGS EQUIPPED WITH NATURAL VENTILATION SYSTEMS

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ABSTRACT

This study considers the link between tertiary buildings design and equipments known as natural and hybrid ventilation or cooling. It focuses on the case of cross ventilated buildings and the envelope choices able to ensure comfort along with energy savings. This link is studied by simulating with TRNSYS various cross ventilation systems: by night, day or both. These are applied to typical situations as individual office, open-plan office, or meeting rooms. Studied rooms are chosen south oriented and subjected to medium internal gains. Thermal behaviour of these rooms is analysed and compared when architectural characteristics vary: insulation level, shading strategy, glassed surface and thermal inertia. These results will be used to develop feasibility criteria for low energy cooling and design guidelines for these rooms for both typical year and heat wave. The case of a complementary mechanical cooling is also studied.

KEYWORDS

Natural ventilation, comfort, energy savings, design

INTRODUCTION

Thinking about natural cooling by ventilation can not be done without talking about architecture. Usually building and HVAC design are made by different teams with few interactions. But to determine architecture from energy efficiency point of view may lead to high performance buildings, as illustrated by Breesh et al (2005) and other authors. A promising technique is natural ventilation. But for this one to ensure thermal comfort some architectural choices have to be made. This paper tries to give design guidelines for architects and HVAC designers in order create efficient buildings with natural cooling systems. Four parameters are investigated here: inertia, insulation, glazing surface and shadow devices. Other parameters are important to consider, like internal gains, control modes, orientations, dimming strategies for example. These will be part of further studies.

ENERGY SAVINGS BY NATURAL COOLING

Dynamic simulations were performed on typical tertiary rooms (depicted in table 1) with TRNSYS16 for a typical Belgian year and the measured heat wave of July 1976, depicted in figure 1.

TABLE 1 : Main characteristics of investigated rooms

	Office module	Landscape office (2 opposite facades)	Meeting room
Surface	19.44 m ²	142.6 m ²	58.3 m ²
Facade surface	9.72 m ²	64.8 m ²	32.4 m ²
Infiltration	0.2 air change by hour		
Glazing surface	6.84 m ² , including 18% for the frame.	45.36 m ² , including 18% for the frame.	22.68 m ² , including 18% for the frame.
Orientation	South	North-south	South
Shadow devices	Low-emissive selective glazing. Solar factor=0.42, U=1.23W/M ² K		
Mean inertia	200 kg/m ²		
Insulation	Façade: U=0.437 W/m ² K, other walls are considered adiabatic		
Internal gains	28 W/m ²	40 W/m ²	46.9 W/m ²
Occupation hours	From 8h00 to 18h00, including 3 hours of ½ occupation		

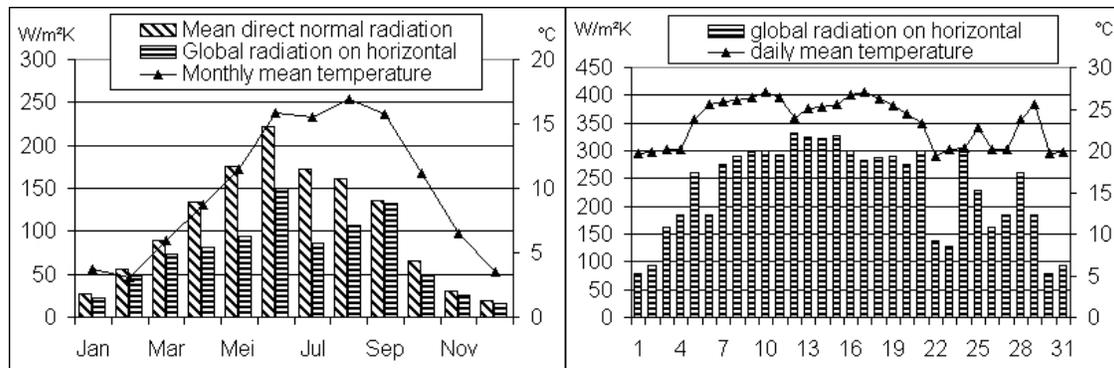


Figure 1 Weather data used for the simulations: a typical Belgian year made of assembled representative month (monthly mean values, left) and the measured heat wave of July 1976 (daily mean values, right)

Investigated outputs are energy demand and thermal comfort. No technological productivity is considered for energy demand. Although Brager et al. (2002) showed adaptive comfort criteria are suited for naturally ventilated rooms, the first steps of this study use a well established among practitioners criterion considering 100 hours above 25.5°C as comfort acceptance limit, as defined by ISSO (1994). Adaptive criteria will be used in parallel in the next steps of this study.

For each office, four systems are modelled: traditional mechanical cooling, and 3 natural ventilation modes (Figure 2). These are defined with constant air flow rate. Such efficient control may be obtained by fan assisted ventilation. For the mechanical case, cooling set point is set to 24°C in winter and spring and 25°C in summer and fall. Heating set point is of 20.5°C with night interruption. Night cooling consists of 8 air changes by hour between 21pm and 5am. Night cooling begins if internal temperature exceeds 22.5°C with an automatic stop if inside temperature falls under 18.5°C. For day cooling, lower inside temperature limit is 21°C. Air change by hour is modulated following outside temperature, from 0.5 ach below

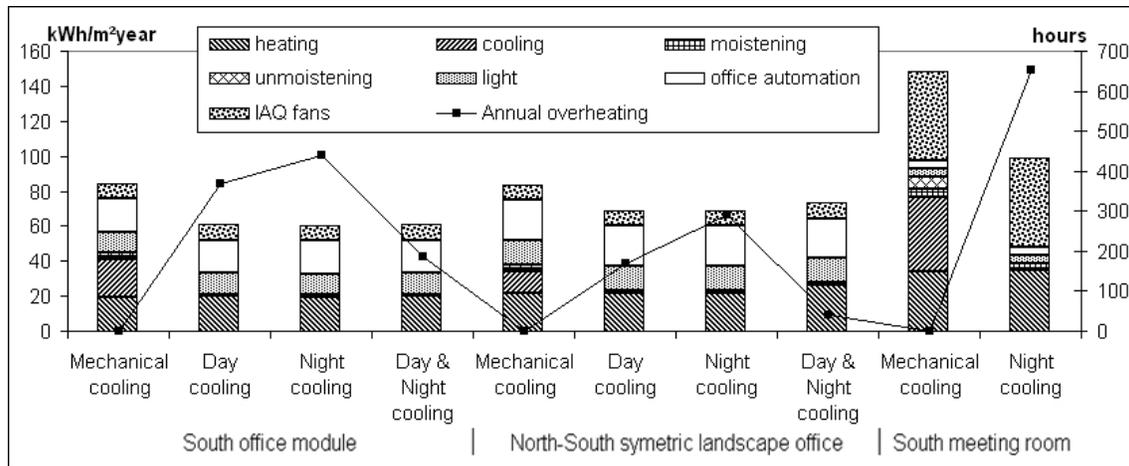


Figure 2 : Energy demand and overheating hours for rooms depicted in table 1. Neither light dimming nor internal gain reduction modelled.

11°C to 3 ach above 15°C. For the meeting room, only night cooling is modelled in addition to mechanical cooling. Indeed, natural day ventilation makes no sense as hygienic ventilation brings already a high air change rate.

Results may seem quite low compared to monitored situations, for example in the HYBVENT state-of-the-art report, Delsante (2002). It can be justified by many favourable management hypotheses. Choice has been made to modelled highly efficient cases. Natural cooling techniques allow important energy savings: 28% in an office module, 13% in a landscape office and 35% in a meeting room, but for the chosen example these seem unable to ensure comfort during a typical year, especially in the meeting room. These poor performances may dissuade designer interested in natural ventilation.

IMPACT OF ARCHITECTURAL CHOICES ON COMFORT

By modifying building design choices like insulation, inertia, glazing surface and shading, it is possible to reach a satisfactory comfort level, both with larger energy savings. But some building design choices may also make things worse. Choices presented in figure 3 varies from the best (40% glazing surface with $g=0.82$ blinds, high insulation, high inertia: 375kg/m² for office module and 430kg/m² for the meeting room) to the worst (100% glazing without shading, low inertia and low insulation: $U_{wall}=1.46W/m^2K$ and 0.5ach infiltration rate) from the energy point of view. Results for the office module shows good insulation allows lower energy demand. Comfort level of maximum 100 hours can not be reached without shading, whatever the glazing surface. Blinds always give sufficient comfort. Chosen management is closing when irradiation exceeds 250W/m² simultaneously with internal temperature above 23°C. Selective glazing may or not be efficient following other choices. Also low inertia is not favourable for comfort.

Comfort criterion is always met in the landscape office because solar gains are relatively smaller (higher floor area for the same façade) and thanks to the north façade losses. Design parameters nevertheless bring to different energy demands. In a meeting room, high internal

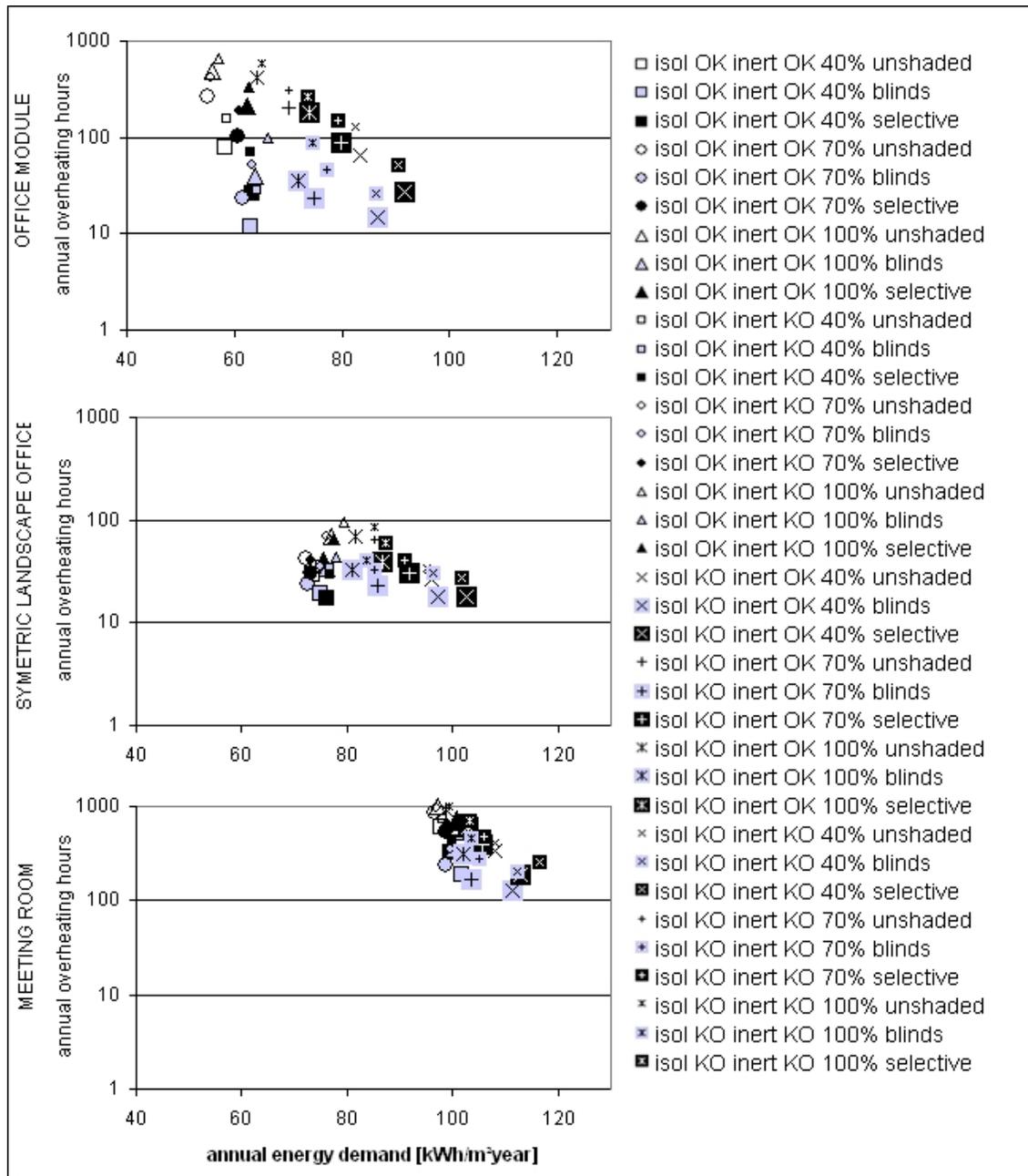


Figure 3 Impact of architectural choices on overheating hours and energy demand for an office module, a landscape office and a meeting room, day and night natural ventilation

gains always make overheating too large.

Considering a heat wave, comfort is more difficult to reach. Figure 4 shows internal temperatures for two cases considered comfortable for a typical year. The optimal solution maintains comfort conditions without mechanical cooling, internal temperature being around 5°C lower than outside. But replacing a 40% glazing surface with blinds by a 70% selective glazing leads to too high internal temperatures during day, even with an efficient night cooling. Internal temperature may even rise above outside temperature because of inadequate shadow device. It shows natural cooling may ensure thermal comfort, even for a heat wave, but all architectural choices must be considered with this objective in mind.

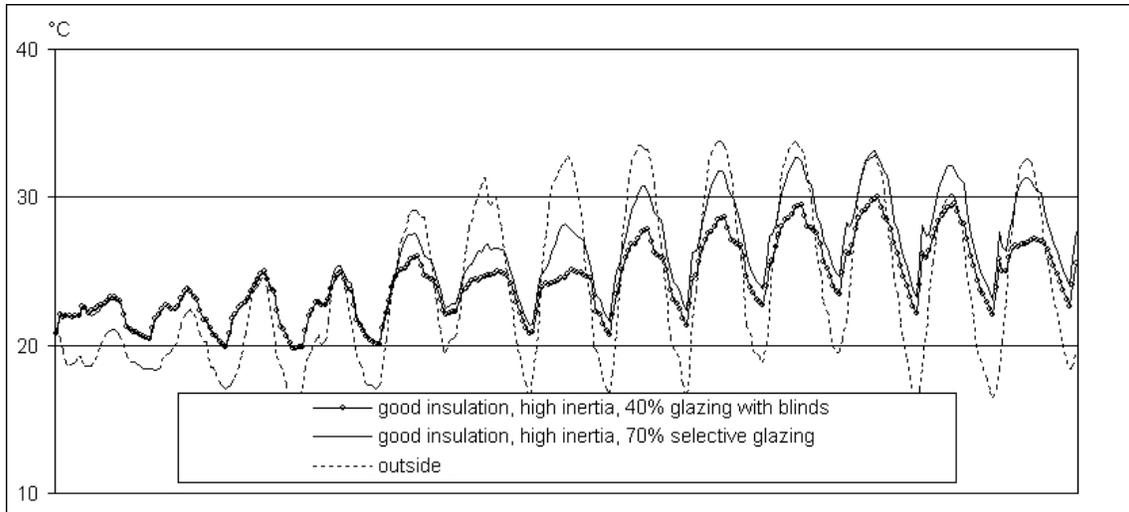


Figure 4 Internal temperature for a high and a medium energy efficiency design during a heat wave. Simulated case: south oriented office module with 0.2 ach infiltration rate, 28W/m² internal gains

HYBRID COOLING

When architectural choices are so that natural cooling is insufficient to create satisfactory indoor conditions, a mechanical device may be installed to give a complementary cooling. Figure 5 illustrates energy saving reached with natural cooling when mechanical cooling maintains a 25°C set point.

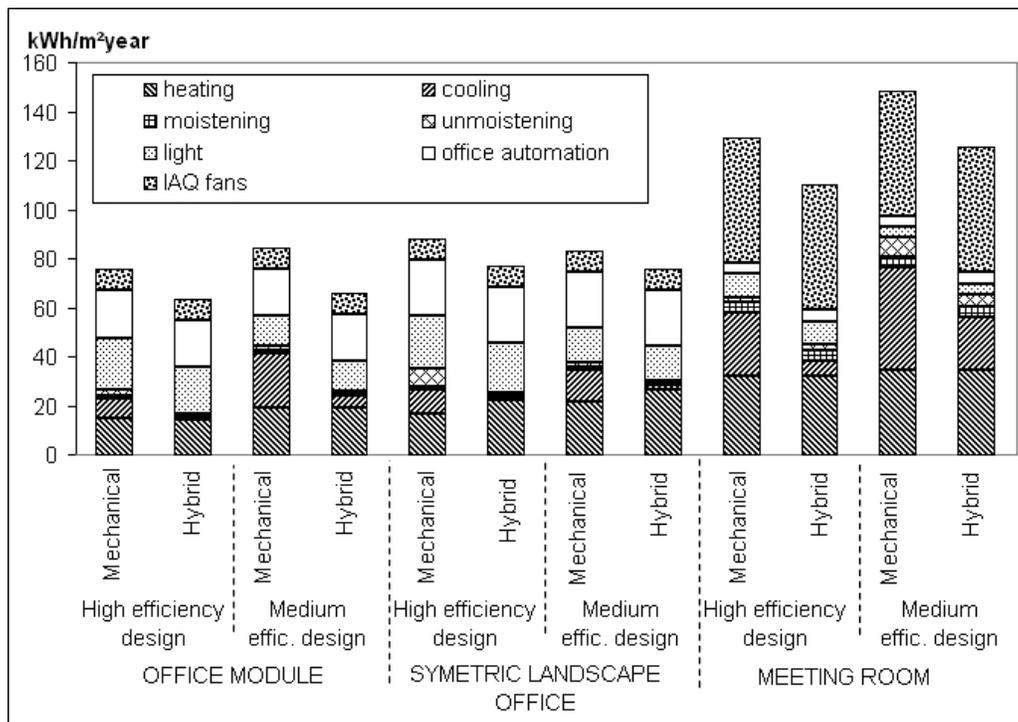


Figure 5 Energy demand for an office module, a landscape office and a meeting room. Impact of natural ventilation used in combination with mechanical cooling. High efficiency: 40% blinded glazing, high inertia and high insulation. Medium efficiency: 70% selective glazing, high insulation and medium inertia

Combination of mechanical and natural cooling allows substantial energy savings in the modelled situations: 16 to 22% for an office module, 10 to 13% for a landscape office and 15% in a meeting room. Complementary mechanical cooling is not very energy costing. The only arguments against it are investment cost and the risk of too large use of the mechanical cooling once it is installed.

Savings are only a few smaller than without mechanical cooling in the case of office modules or landscape offices. For the meeting room, reduction in savings is larger but natural ventilation used alone was never capable to ensure thermal comfort.

CONCLUSIONS

This paper shows free cooling strategies have to be considered both with architectural choices. Best performances are reached when efficient natural cooling is managed in massive, well insulated and efficiently shaded buildings. All parameters must be met to reach comfort in a heat wave. If not possible, as for retrofitting cases, a complementary mechanical cooling can be added. Free cooling is then still very useful, allowing large energy savings.

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