Comparative analysis of control strategies for passive cooling

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ABSTRACT

Natural ventilation can be successfully applied for passive cooling in order to reduce cooling loads of buildings. Several parameters may have a significant impact on the performance of such a cooling technique, among others: climate, ventilation configuration, thermal mass, control parameters, etc. Within the frame of the PHACES project, a comparative analysis of control strategies in different configurations has been conducted, to underline and to quantify the relative impact of these various parameters. Some of these configurations have been experimentally tested.

HybCell is a test cell implemented at LASH, DGCB, ENTPE, dedicated to the design, test and validation of control strategies for hybrid ventilation and passive cooling. The façade of this one-zone cell is equipped with six windows (tilt, top hung, vertically pivoted and sliding openings). The cell can also be ventilated using an extracting fan, and up to three virtual occupants can be experimentally simulated through sensible heat and CO_2 production. A numerical model of this test cell has been validated, to be used as a numerical platform for such control strategies.

Three European climates, seven ventilation configurations (up to three windows used for natural ventilation), various control strategies (including manual – automatic combination) and control parameters (dead band and set point values) have been implemented. Relevant results are presented in terms of performance evaluated through the definition of performance criteria, dealing with thermal comfort, indoor air quality and maintenance of actuators.

1. THE PHACES PROJECT

The passive cooling of a building is based on the cooling power of the outside air to decrease the indoor temperature of the building. Improvement of the thermal comfort has to be reached through the decrease of the indoor temperature during occupation hours and the reduction of discomfort periods during the hottest periods of the year (Allard, 1998; Geros, 1999).

However, while implementing passive cooling in a building, other constraints, parameters and/or objectives have to be taken into account as soon as possible in the design of the building: indoor air quality, noise, occupancy, physical phenomena, climate, ventilation configuration, maintenance, control parameters, sensors and actuators… (Heiselberg, 2002; Liddament, 1996; Michel, 2003).

Within the frame of the PHACES project, a comparative analysis of control strategies in different configurations has been conducted, to underline and to quantify the relative impact of these various parameters. Some of these configurations have been experimentally tested using the HybCell test cell (Elmankibi, 2003; Nicol and McCartney, 2000).

2. THE HYBCELL TOOL

HybCell is presented in Figures 1 and 2. Its unique façade is equipped with two series of three openings controlled by actuators, a heating system, lighting sources and a ventilation fan. All actuators are controlled by a supervisor, which ensures the acquisition of all physical parameters. Up to three virtual bodies may simulate the occupation of the cell. A numerical model of the cell has been validated in various

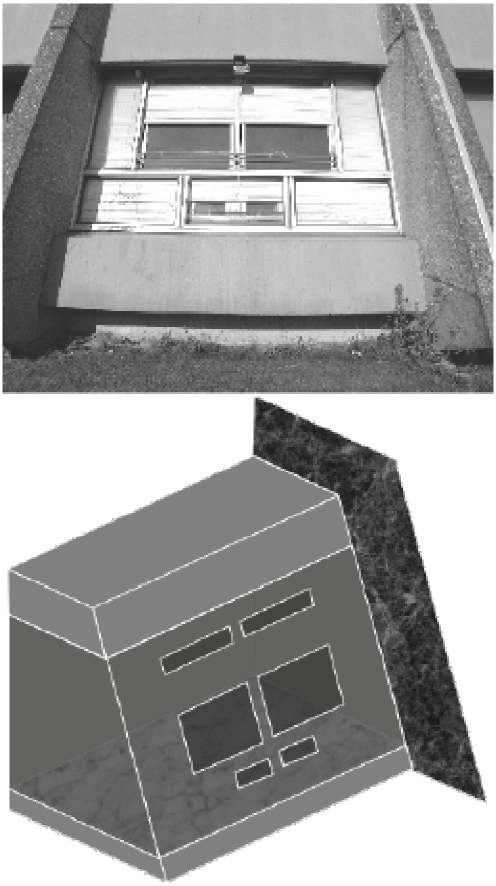

Figure 1: Outside and schematic views of HybCell.

Figure 2: Openings implemented in HybCell.

configurations (season, ventilation, occupancy).

3. CONTROL STRATEGIES FOR COOLING

Four different types of passive cooling strategies have been defined and numerically evaluated through a sensitivity analysis on various parameters such as dead bands, ventilation configuration…

Type A strategies use natural ventilation as soon as a cooling power of the outside air exists, through an On-Off controller with a ΔSV_n (upper) - ΔIV_n (lower) dead band.

Type B strategies are On-Off controllers based both on cooling power (type A) and cooling needs, introducing a second ΔSR_p (upper) - ΔIR_p (lower) dead band.

Type C strategies are based on type B strategiess, introducing supplementary control for indoor air quality (using time control, occupancy sensor or CO_2 sensor), solar shading or manual control.

Type D strategies combine indoor air quality control during occupation and passive cooling control during unoccupied periods, using natural, assisted or mechanical ventilation, and based on On-Off or PI control.

4. A SELECTION OF RESULTS

In Figure 3 is illustrated the influence of the ventilation configuration on the ratio of hot discomfort time during occupation period. Evaluated using an adaptive comfort temperature, P7T ratio varies from 90% for CV1 (small upper opening) to less than 50 % for CV7 (three

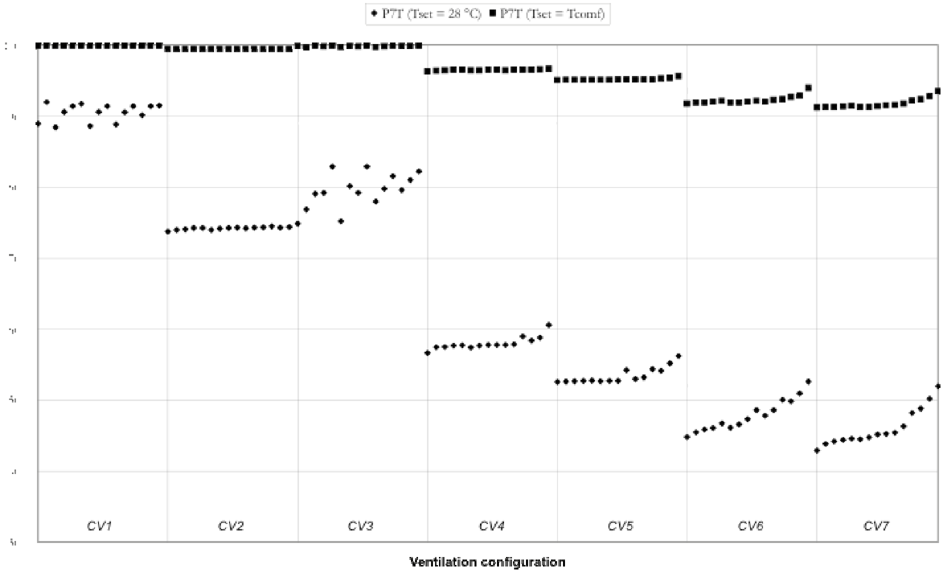

Figure 3: Ratio of hot discomfort duration during occupation for type A strategies and various ventilation configurations.

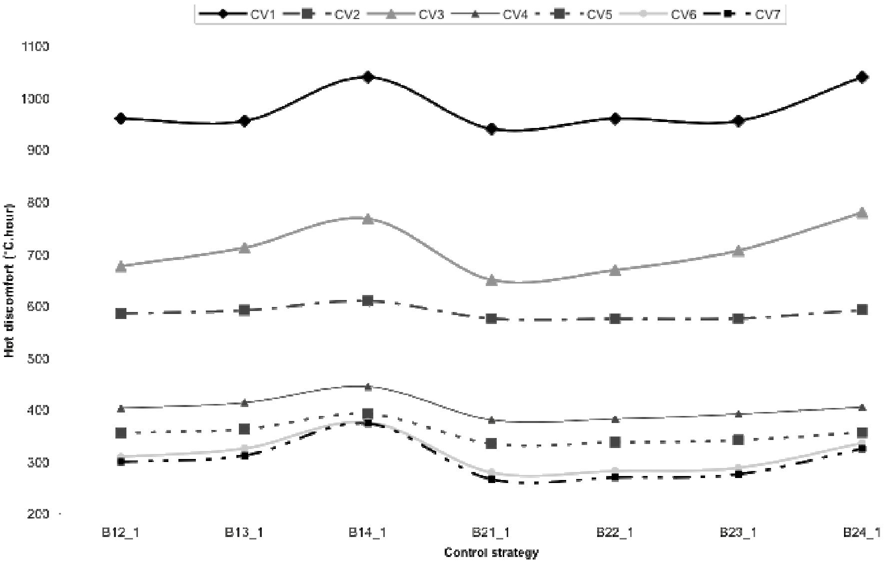

Figure 4: Influence of dead band and ventilation configuration on hot discomfort for type B's (Lyon climate)

openings used).

Figures 4 and 5 illustrate the influence of the ventilation configuration (openings used) on hot and cold discomforts for different type B strategies (Lyon and Copenhagen climates). Hot discomfort (for Lyon climate) is basically and highly influenced by ventilation configuration, while cold discomfort in Copenhagen climate is also influenced by dead band of the On-Off controller.

On Figure 6 are compared results for type C strategies with and without solar shading control. Decrease of the maximum temperature is close or even over 3°C according to ventilation

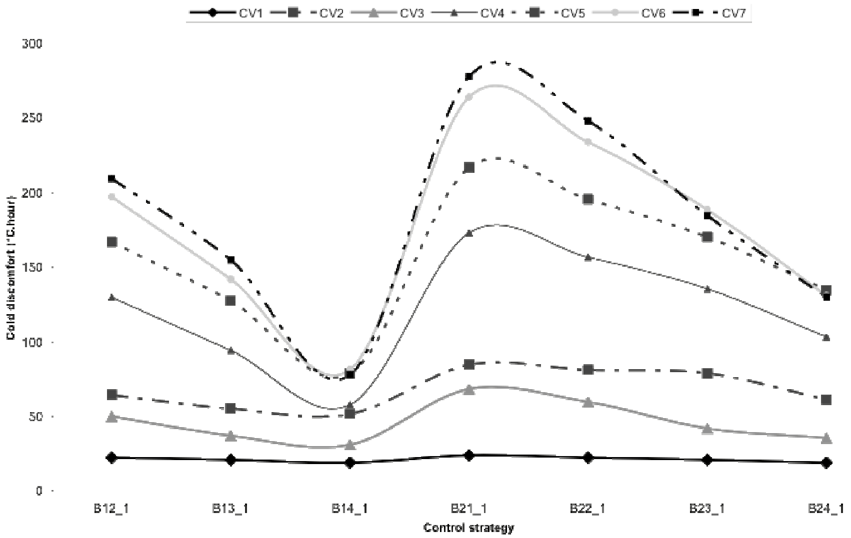

Figure 5: Influence of dead band and ventilation configuration on cold discomfort for type B's (Copenhagen climate).

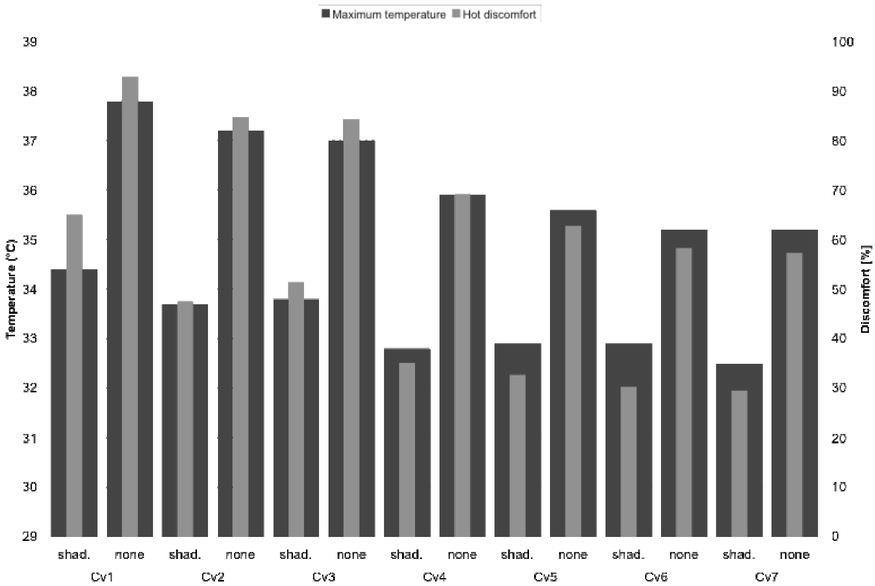

Figure 6: Influence of ventilation configuration and shading control on maximum temperature and hot discomfort.

configuration. Hot discomfort is in the same way strongly reduced while combining the two passive techniques (from one third up to divided by 2).

Figure 7 illustrates experimental results obtained with type D strategies based on a 5-level On-Off CO_2 control of different openings. The different results are comparable, except for sequence SE6 which corresponds to the control of indoor air quality using a small lower opening. While other strategies maintain the quality of the indoor air, the type D strategy implemented in SE6 sequence is unable to avoid high CO_2 concentration peaks.

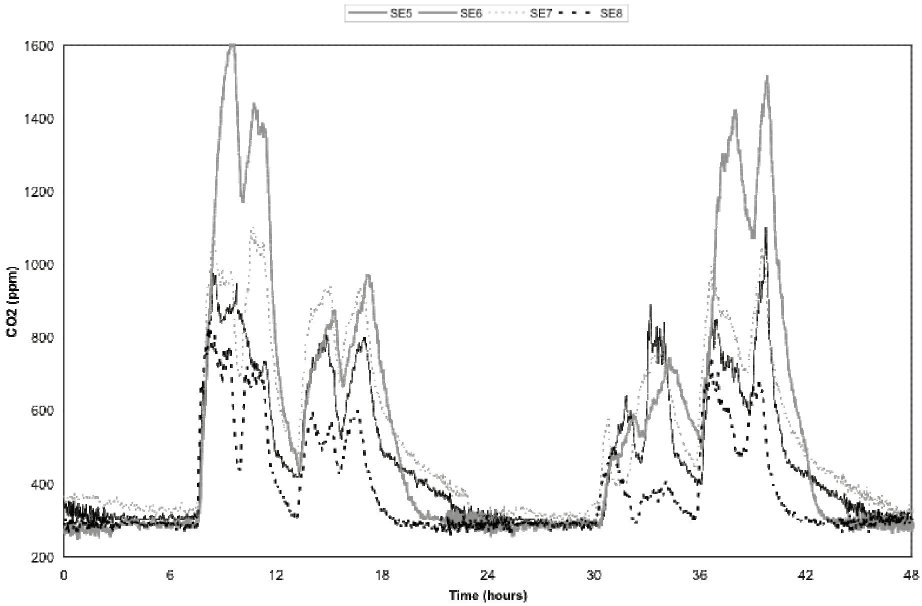

Figure 7: Comparison of experimental resultats for type D strategies (CO_2 concentration).

ACKNOWLEDGEMENT

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