Design of a hybrid ventilation system: the Cli'Nat project

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ABSTRACT

Ventilation has a major impact on the global performance of buildings, in terms of energy consumption as well as regarding indoor climate: thermal comfort, indoor air quality, acoustics.

The objective of the Cli'Nat project is to design, within a systemic approach, and to evaluate, by simulations and experiments, the performance of a ventilation and passive cooling system including a dedicated building envelope component and specific control strategies. Such a hybrid ventilation component has to be designed to be used as a ventilation opening for indoor air quality and as a passive cooling opening for night ventilation. Control strategies will allow maintaining satisfactory indoor environment while avoiding energy penalties. Three industrial partners and a university R&D laboratory constitute the team in charge of this project.

A first step of the project has shown the feasibility of the Cli'Nat system. A two-zone educational building model has been developed and used to test basic control strategies of the Cli'Nat ventilation system. Simulations have been conducted to evaluate the performance of this system in terms of thermal comfort, indoor air quality and energy consumption.

During the second step of this project, prototypes will be designed and tested using laboratory test facilities, to be characterized as a building envelope component, regarding thermal performance, acoustics, air flow… A detailed model of these prototypes will then be validated to test advanced control strategies of the whole ventilation and cooling system.

1. THE CLI'NAT PROJECT

Three industrial partners and a university R&D laboratory constitute the team in charge of the Cli'Nat project which aims at developing, within the frame of a systemic analysis, a IAQ ventilation and passive cooling system, notably based on a specific building envelope component and related control strategies (Elmankibi, 2003; Michel, 2003).

Such an active specific component has to be designed both as a ventilation opening for indoor air quality and as an aperture for passive cooling by night natural ventilation. The implementation of control strategies for the management of the actuators of this component should provide good indoor climate conditions.

The overall architecture of the system consists in a supply mechanical ventilation, envelope components – playing both the role of ventilation openings and passive cooling openings – and indoor openings allowing air flow between adjacent zones. All these elements are controlled in order to obtain good indoor air quality during the day whilst not exceeding a defined limit for the pressure difference between the inside and the outside, and to cool the building by night ventilation whilst maintaining a comfortable temperature at the beginning of the occupation period (Allard, 1998; Heiselberg, 2002; Liddament, 1996).

During the first step of the project, a feasibility study has been conducted through simulations based on a temperature and air flow model of a two-zone educational building (12 x 6 x 3 m^3 each). A selection of the results in presented below, showing the impact of the control strategy: control of the indoor component, management of the occupation breaks, occupation evaluation mode (Chéron et al., 2004).

2. A SELECTION OF RESULTS

Figures 1 and 2 present two of the basic control strategies, which have been implemented and tested. In both cases, air flow supplied by the mechanical ventilation system depends on the occupation level of each zone. Ventilation openings are then controlled in order to maintain the inside-outside pressure difference below a defined limit.

S_d strategy consists of a distinct control of the two zones: south-oriented and north oriented openings are managed separately, depending on the occupation and the pressure difference. In case the north zone is unoccupied, a S_c strategy keeps the south-oriented opening closed. The air of the south zone goes through the indoor component (between the two zones) and the north-oriented envelope component. Such a strategy can be interesting for example in case of a noisy environment for the south façade. Figure 3 illustrates outdoor conditions used for the two-day simulations presented below. The building is supposed to be occupied during four periods of two hours during the day, with half an hour

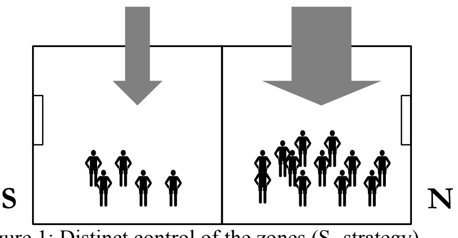

Figure 1: Distinct control of the zones (S_d strategy).

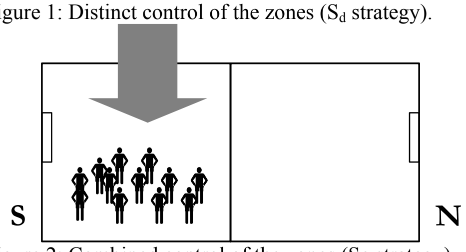

Figure 2: Combined control of the zones (Sc strategy).

breaks in the morning and in the afternoon and a one hour and a half lunch break.

During the night, large openings are used to cool the building (6 m x 0,5 m for the façade components and 6 m x 0,1 m for the indoor component between the two zones). They are open above 26 °C and closed below 22 °C, and controlled by a cooling potential of 2 °C.

During the day, the air flow supplied by the mechanical ventilation system is 28 m^3/h per person. The whole system is controlled so that the pressure difference stays below 20 Pa.

Figures 4 and 5 present the temperature and the CO_2 level in the two zones. The south zone is occupied by 9 persons, while the north zone is occupied by 25 people. Figure 4 illustrates the various impacts of the occupation level, very different in the two zones, of the unoccupied periods during the day (with temperature drops especially during the second day), and of the night cooling. As shown on Figure 5, when the supplied air flow is defined at a correct level, the control of the opening size for a ΔP lower than 20 Pa allows a good indoor air quality, even in case of an important occupancy (north zone).

Figures 6 and 7 present the same results, when applying a Sc control strategy with the configuration illustrated by Figure 2. Temperatures are strongly influenced by the occupation level and the occupation scenario. As previously mentioned, a ΔP control strategy gives a good result in terms of indoor air quality. The CO_2 concentration in the more occupied zone (south in this case) hardly exceeds 1000 ppm.

Figures 8 and 9 present the CO_2 concentration in configuration as shown in Figure 1, for a one day simulation. On Figure 8 are compared two different way to evaluate the occupation level: occupation sensor (or occupation scenario) and CO_2 sensor. In the latter case, the number of occupants is calculated at the beginning of each period through the CO_2 concentration trend, and the CO_2 is used as a control parameter in a 1000-1200 ppm dead band control strategy. The global strategy gives thus good results both in terms of indoor air quality and regarding ΔP.

On Figure 9 are compared, for a zone occupied by 25 persons, different strategies for the ventilation of the zone during breaks. In the case of natural ventilation are compared two opening

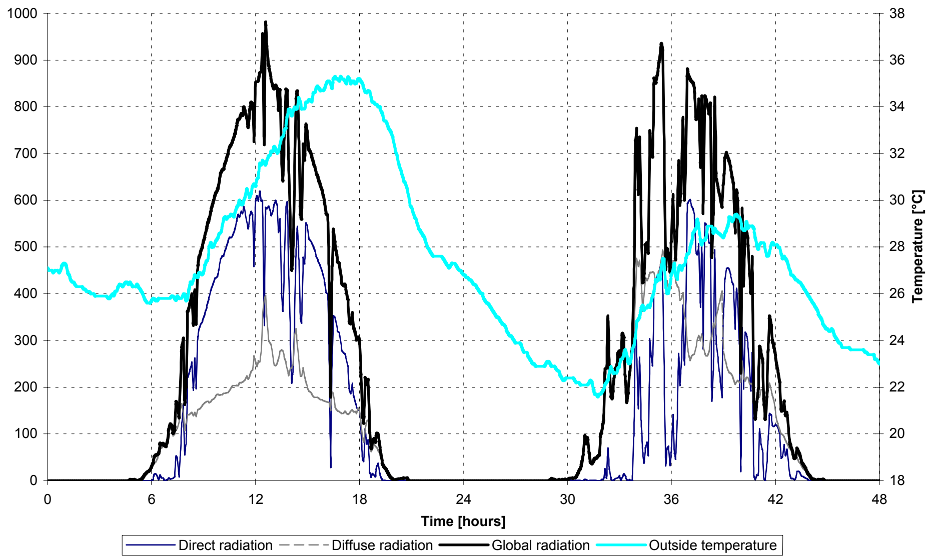

Figure 3: Outdoor summer conditions used for the simulations.

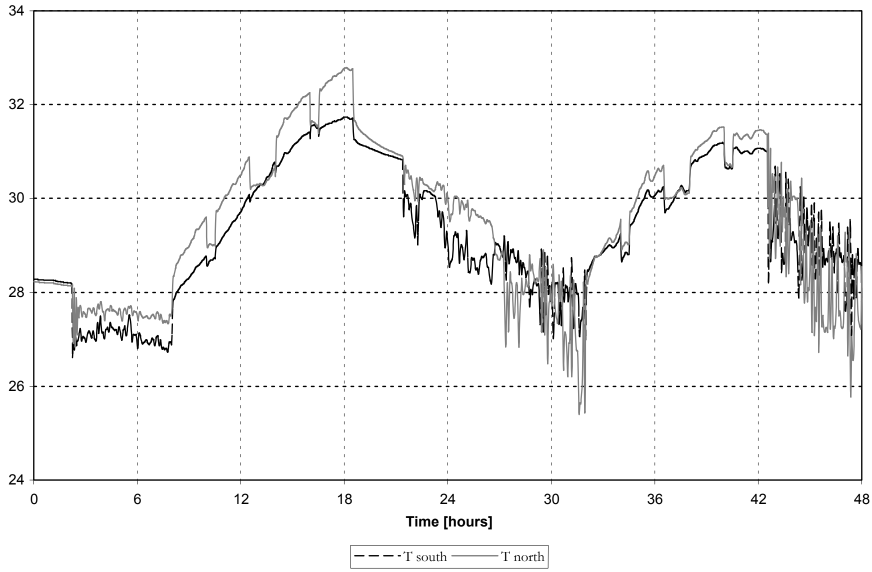

Figure 4: Temperature of the two zones when implementing the S_d control strategy.

sizes, the larger corresponding to the maximum size of the ventilation daytime opening, the smaller to the night time passive cooling opening.

3. FURTHER DEVELOPMENTS

The objective of the second step of the Cli'Nat project, planned to start at spring 2005, is to validate, by simulations and by experiments, the Cli'Nat concept and to design the building enve-

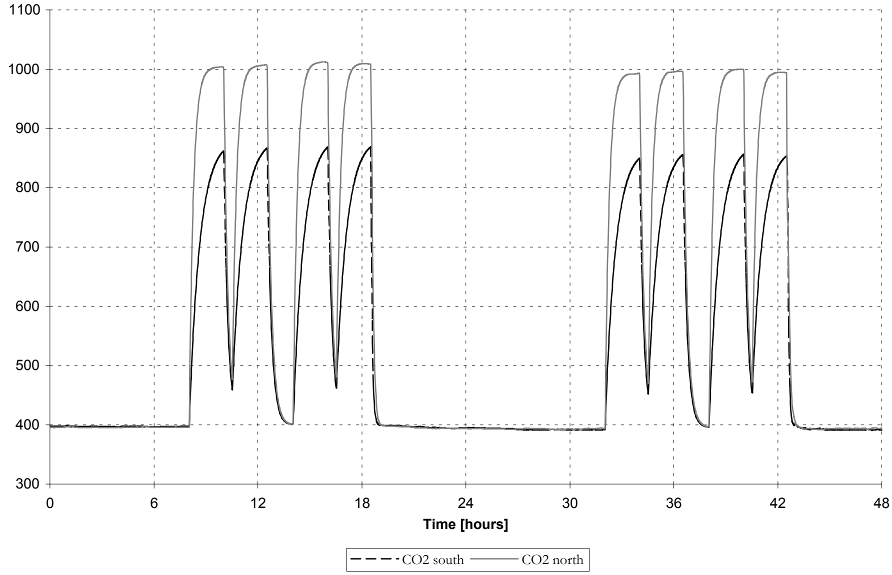

Figure 5: Indoor air quality (CO_2) in the two zones when implementing the S_d control strategy.

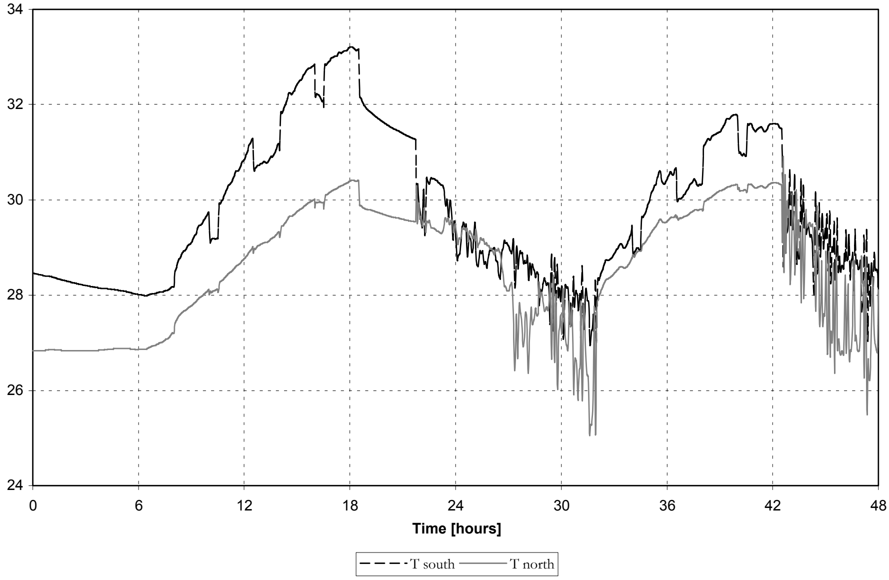

Figure 6: Temperature of the two zones when implementing the S_c control strategy.

lope active ventilation component.

Prototypes will be designed, in order to reach the objectives defined within the systemic analysis and taking into account the various technical and industrial constraints which have been identified during the first step. These prototypes will be implemented in a test cell, to be characterised as a building component (thermal performance, acoustics, air flux through the openings…).

A detailed model of these components will be developed and validated. This model will be used for simulations of the overall performance of the ventilation and passive cooling system.

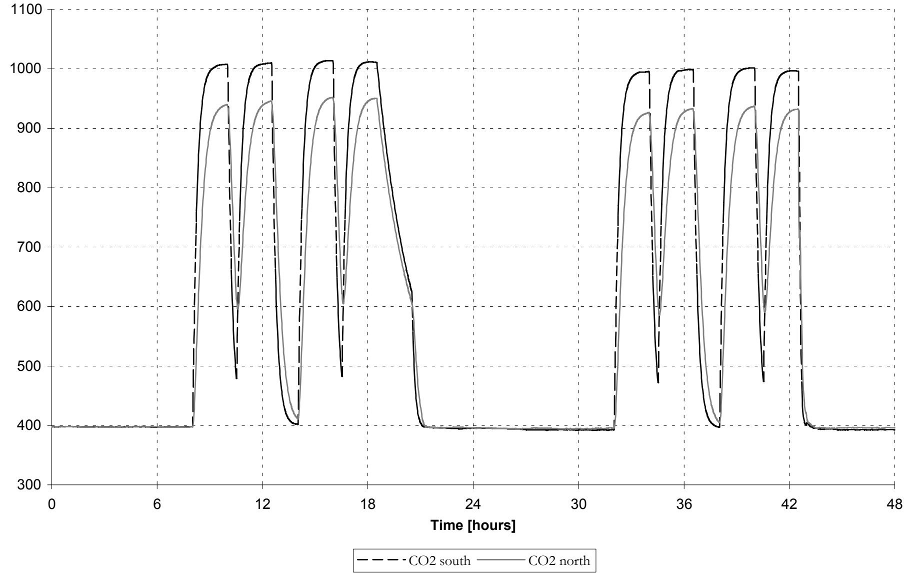

Figure 7: Indoor air quality (CO_2) in the two zones when implementing the S_c control strategy.

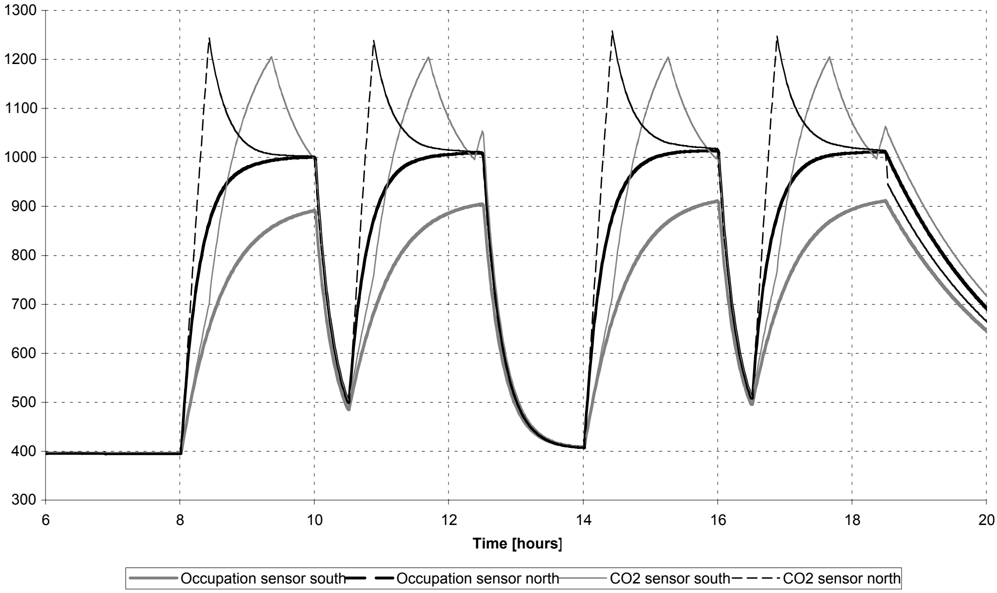

Figure 8: Indoor air quality (CO2) using the Sd control strategy and two different occupation evaluation modes

Simulations and experiments will also be performed in order to develop advanced control strategies of the whole system (supply ventilation system, envelope components, indoor components).

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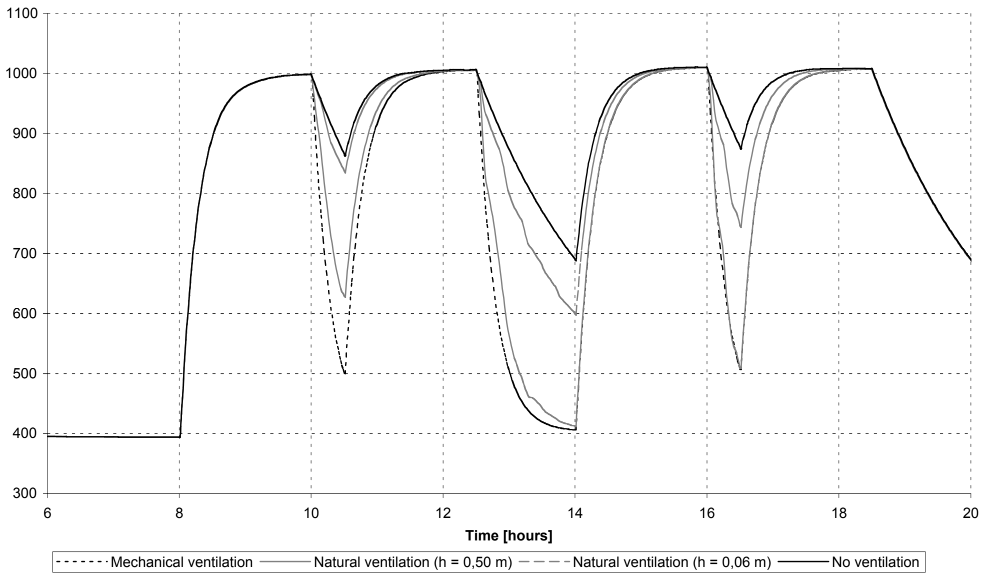

Figure 9: Impact of the ventilation mode during the breaks on the indoor air quality (CO_2), using a S_d control strategy.

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