Night Time Cooling of a Room with Large Internal Heat Gains.

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ABSTRACT

The aim of the investigation was to determine whether mechanically assisted night cooling could cause any useful reduction in the daytime internal temperature of a room with exposed mass walls, and with constant internal heat gains, and whether the effect could also be achieved by using only natural ventilation during the night. The results were used to validate simulations using FACET software.

KEYWORD

Buildings; Energy; Cooling; Ventilation;

INTRODUCTION

Although the UK's climate does not provide the ideal conditions for night cooling, it is widely believed (Edwards, 1994) that if harnessed effectively, it can be used to minimise or avoid air conditioning. However, through poor design and/or control, some installed systems have failed to achieve cooling - in some cases they actually heated the building.

Night cooling is best achieved by natural ventilation, but this may often provide an insufficient ventilation rate. If mechanical ventilation is needed, many factors will influence the overnight fan run in order cool the thermal mass to the optimum level. Holmes (1994) estimated that allowing temperatures to reach the limits of thermal comfort could result in substantial energy savings. People expecting external conditions to be cooler in the morning and to heat up during the day would dress accordingly. Zmeureanu (1992) and Berglund (1978) report on studies carried out which indicated that an increase of indoor temperature at a rate of 0.6^{0}C/h for eight hours to a maximum temperature of 27.2^{0}C was acceptable to 80% of the subjects wearing typical summer clothing.

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The effectiveness of the night cooling is linked to:

- the storage area and the area that comes into contact with the flowing air
- the specific heat capacity and thermal diffusivity of the storage material
- the temperature difference between the incoming air and the mass surface
- the heat transfer coefficient between the incoming air and the mass surface - approximately 3W/m^{2}K
- The effectiveness of control strategies and their underpinning technologies

CONTROL

For night cooling to be effective, openings and/or fans must be switched on and off at the appropriate times. Poor control may result in unfavourable conditions, excessive fan energy consumption or even overcooling. Control often takes the form of a simple time switch with no "safety" lock-outs or demand calculation, and in this form has seldom resulted in satisfactory comfort conditions. An optimiser algorithm may use an analysis of daily averaged building performance data by multiple regression. Since this technique is purely statistical, quantities related to thermal storage are omitted, however, the inclusion of a time-series in the regression analysis can account for thermal storage effects. One control strategy would measure the day-time heat gains in the space and then remove the equivalent amount of heat at night. Other night cooling strategies may allow the internal temperature to fall to a lower-than-acceptable value before occupancy, in order to increase the amount of "coolness" stored in the fabric.

EXPERIMENTAL DETAILS

The computer room under investigation was constructed approximately ten years ago, is located on the second floor an has exposed internal block walls. Three different scenarios were investigated:
Case 1. Fan was switched off and the windows left closed overnight. This is the normal situation within the zone, i.e. daytime ventilation only. (Figure 1).
Case 2. Data was then also collected with the fan running and an opposite window left open between non-occupational hours. (Figure 2).
Case 3. A further night cooling experiment was carried out using natural ventilation alone, i.e. windows were left open on opposite sides of the space to achieve cross-flow ventilation. (Figure 3).

RESULTS

Experimental results from the room showed that some degree of cooling was achieved using night ventilation (Figures 1-3). Parametric studies included the effect of adding 100mm layer of thermal mass, which would reduce the peak cooling load by nearly half at a 25^{0}C set point, which implies that the existing exposed block walls are not close to the optimum density. Increasing the thickness by 500mm virtually eliminated any cooling load at 25^{0}C. However, with an upper temperature limit in the room set as low as 26^{0}C, the former case would provide an acceptable level of thermal comfort.

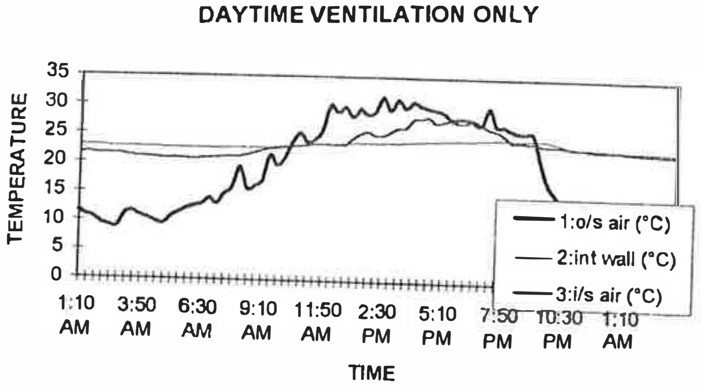

Figure 1. Daytime Ventilation Only.

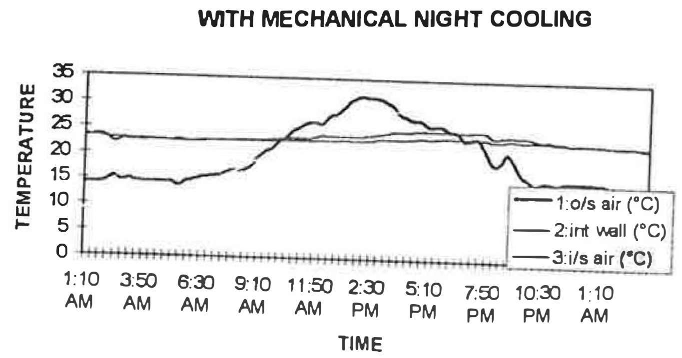

Figure 2. Mechanical Night Cooling.

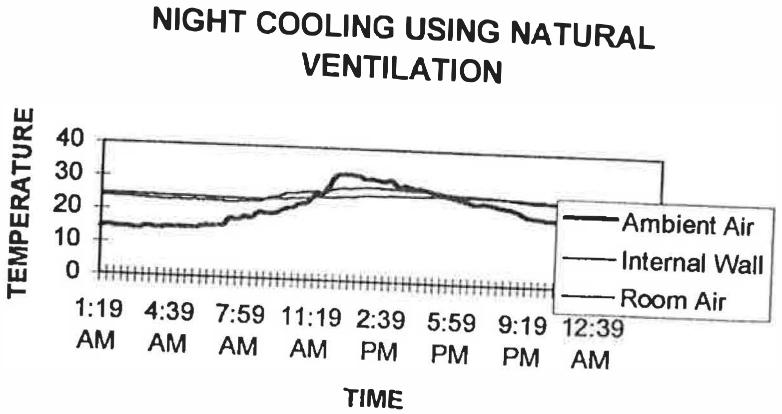

Figure 3. Night Cooling with Natural Ventilation.

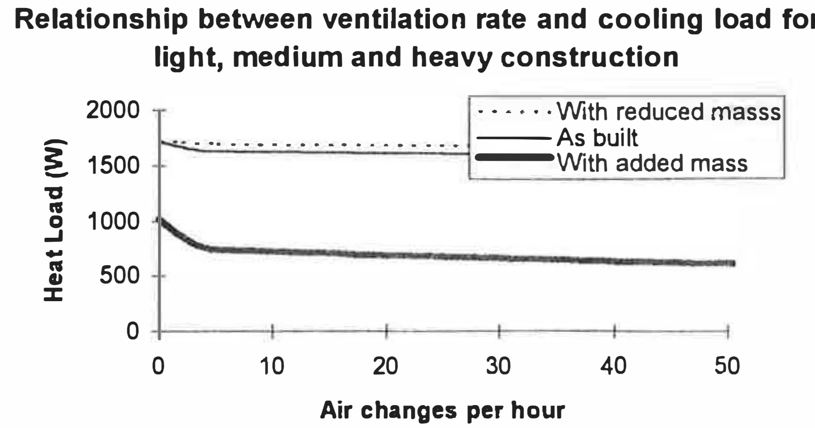

Figure 4. Limits to Useful Ventilation Rate.

CONCLUSIONS

Investigations carried out in an occupied building using simulations and measurements highlighted the benefits of night cooling, and the need for suitable control. Use of natural night ventilation only had a limited success. Simulations of the effect of changing ventilation rates showed no benefit is to be gained from increasing the nocturnal air change rate to above two air changes per hour for the room construction as it exists, or for the lightweight case, when the fan is allowed to run continuously throughout the unoccupied period. Very large air changes were simulated which emphasise this point.

To investigate this concept further, the 100mm mass wall simulation was re-run; but this time the model was revised for full occupation during normal working hours in order to increase the daytime loading. Without night cooling, temperatures of 28^{0}C were reached at peak periods, however, five nocturnal air changes reduced the peak temperature to below 27^{0}C. The air change rate was increased further but no reduction in peak internal temperature was detected. However, for the high thermal mass cases the optimum would appear to lie within two and five air changes per hour, with obvious implications for fan sizing and energy consumption. (Figure 4).

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