Proceedings of 2nd Conference: ***People and Buildings*** held at Graduate Centre, London Metropolitan University, London, UK, 18th September 2012. Network for Comfort and Energy Use in Buildings: http://www.nceub.org.uk

An investigation of potential natural ventilation strategies for thermal comfort in the Howell building at Brunel University

Yazhini Chandrasekaran

School of Engineering and Design, Brunel University, Uxbridge, UB8 3PH, UK

Abstract

The main objective of the current project is to identify suitable sustainable natural ventilation strategies to achieve appropriate thermal comfort in a naturally ventilated Howell building located in Brunel University, Uxbridge. Dynamic thermal simulation using IES<VE> thermal modelling software was carried to assess the effectiveness of the different proposed strategies. The ventilation profile for the building during summer was analysed and overheating calculations were performed. Results have shown that overheating was drastically reduced by adoption of a strategy which combined night ventilation, open plan office and the central shaded atrium. The percentage of yearly occupied hours above 28°C, it would drop from 7% to about 2%. The night ventilation rates in the building were about 6 ACH, and it is also demonstrated that night ventilation was effective in bringing down the peak day temperatures in the building.

Key words: passive ventilation strategies, dynamic thermal simulation, IES.

1 Introduction

People in European countries and North America spend on an average 80% to 90% of time inside buildings. Consequently, indoor environmental quality is a major concern. It must satisfy two basic requirements – first, the indoor environmental health risk should be negligible and second, the indoor environment must be comfortable and pleasant (Huynh, 2010). Indoor air quality and thermal comfort are significant factors to maintain healthy indoor environmental quality. The need for good indoor air quality and the goal of energy efficiency often conflict each other. However, with proper design, installation and operation good indoor air quality can be maintained with energy efficiency.

In this study, an attempt at identifying a passive sustainable and effective ventilation system for the Howell building located on Brunel University campus has been carried out. It was built in 1968 and accommodates the cellular offices of the academic staff. The building also comprises of meeting rooms, classrooms, PC rooms, lecture theatres, staff rooms, kitchen, pantry, IT rooms, toilets and other ancillary areas. The total gross floor area of the building is about 4800 m^2, spread over four storeys. The plan depth of the building is about 10 m and the floor-to-ceiling height of the building varies from 2.56m to 3.75m on the different floors. The building is located in a sub-urban location in a university campus with low noise levels and is exposed to the wind. The building has a good natural ventilation potential and good indoor conditions can be achieved in an energy efficient manner by using natural ventilation techniques. Currently, the main issues with the Howell building are the significant overheating and low ventilation rates during the summer season. The objective is to achieve good thermal conditions against all the resistances to air flow, in order to obtain appropriate room conditions to satisfy occupants' expectations.

2 Methodology

Feasible sustainable passive strategies to improve the ventilation in the building were identified and modelled using IES VE version 6.4.0.1. Dynamic thermal analysis was used to obtain results on the ventilation effectiveness of different strategies. Based on the initial results, the strategies were fine tuned to optimize the design.

Three different cases were investigated on the IES <VE> platform. These are listed in Table 1. In Case 1, the cellular offices on the first, second and third floors were converted to open plan offices; in Case 2, a central glazed atrium was constructed and connected to the open plan offices; in Case 3, instead of a completely glazed atrium a shaded atrium was used. The potential of night cooling was also investigated.

Table 1: Proposed cases for investigation

Case 1	Open Office
Case 2	Glazed Roof Atrium
Case 3	Shaded Roof Atrium

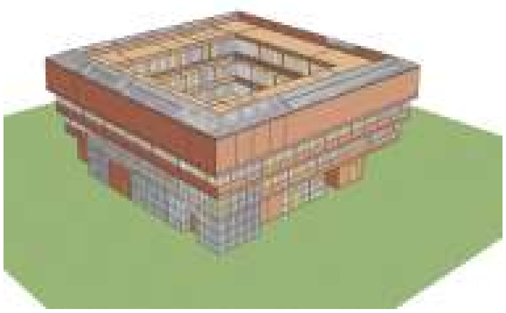

Figure 1: Snapshot of the Howell building model

Figure 2: Snapshot of the Howell building with glazed Atrium.

In Case1, the space currently occupied by the cellular offices on the first, second and third floor of the building can be converted to open plan offices to have cross ventilation. In Case 2, a central atrium is constructed to increase the ventilation rates by using stack effect. For the ventilation to be effectively driven by stack effect, CIBSE Guide B recommends that the opening in the atrium should be about 5% to 10% of the roof glazing area (CIBSE, 2005a). In order to prevent back draught of air, the openings of the atrium top should be modelled such that it is above the Neutral Pressure level i.e., the level at which the outside air pressure equals the internal pressure within the building. The neutral pressure line is set at about 0.5m above the top floor ceiling (CIBSE, 1997). The thermal response factor of the Howell building was calculated and the building was found to have high thermal capacity. This high thermal capacity of the building can be utilised to create better comfort conditions during the summer period. One of the critical issues with night cooling is the possibility of the temperatures falling too low that it might cause discomfort during the initial hours the following day. Hence, an appropriate control strategy of the night ventilation needs to be investigated.

3 IES Model Setup

Dynamic thermal analysis has been performed on representative occupied spaces in order to assess the resulting conditions in the building during the course of a design year. The analysis accounts for the characteristics of each space including the internal gains, type of glazing, building fabric details, building orientation and external weather conditions. The model geometry and construction details were based on building plans drawings and information provided by the Estate department at Brunel University. The weather file 'LondonDSY05.fwt' was used for the simulation.

Modulating ventilation profiles have been set up in the software using MacroFlo module of IES. The window opening profiles were setup such that the windows will be open as long as the air temperature of the indoor is higher than outside air temperature. And the degree of opening is modulated such that below 19°C the openings will remain closed but as temperature goes higher the degree of opening increases and would be fully open at temperatures above 27°C to have higher rates of air flow. For night time ventilation during summer, the windows are setup to be open as long as the temperature of the air indoor is higher than outside air temperature and the room air temperature is above 16°C. This is to ensure that the temperature of the building does not fall too low by night cooling. If the temperature of the building falls too low, additional heating would be required in the mornings to ensure thermal comfort. The profile was derived upon by running a series of simulations and optimizing to attain adequate level of ventilation and thermal comfort. The temperature in the morning during the initial hours of the occupied period on an average rises by 2°C by internal and solar gains. This ensures adequate thermal comfort in the building.

4 Results and Discussion

4.1 Ventilation Rates

The ventilation rates in the building were analysed for each floor. The ventilation profile for different floors in the building, for a day in the month of July, is depicted in Figures 3 to 4. It can be seen that during the day the ventilation rates vary from 2 ACH to 5 ACH and during the night the ventilation rates are about 6ACH. The ventilation flow rates are lower in the earlier in the day and go higher as the temperature of the building increases. It can also be seen that the ventilation flow rates are lower in the third floor as compared to the other floors. This could be attributed to the fact that the top most floors would have the least stack effect compared to the lower floors.

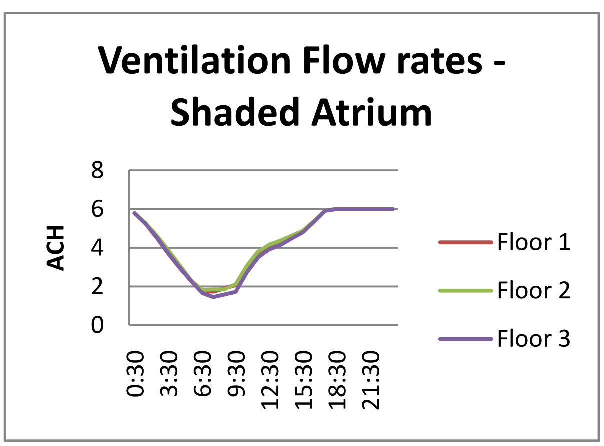

Figure 3: Ventilation Flow Rates in July – Shaded Atrium

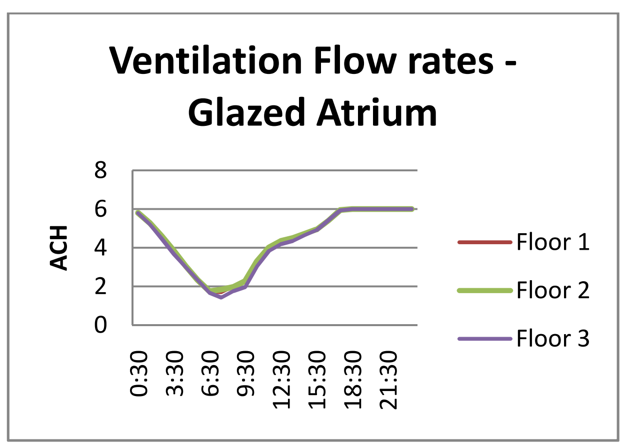

Figure 4: Ventilation Flow Rates in July- Glazed Atrium

The yearly mean airflow rates for each floor have been summarised in Figures 5 to 7. This is done in order to compare the trend of the air flow rates of the different strategies throughout the year. The mean air flow rates in the summer with the central atrium reach about 4.5 ACH. During winter, the mean air flow rates were about 1-2 ACH through the trickle ventilators. However, it can be observed that the mean air flow rates for the open offices without an atrium were about 2-3 ACH which were far below the mean air flow rates with the central atrium. The air flow rates for the glazed atrium were slightly higher than the shaded Atrium. It is also interesting to note that air flow rates are highest during the month of July.

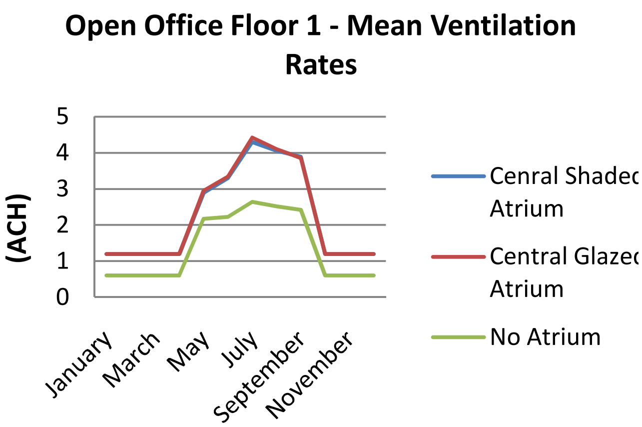

Figure 5: Mean Ventilation Rates in Open office on Floor 1

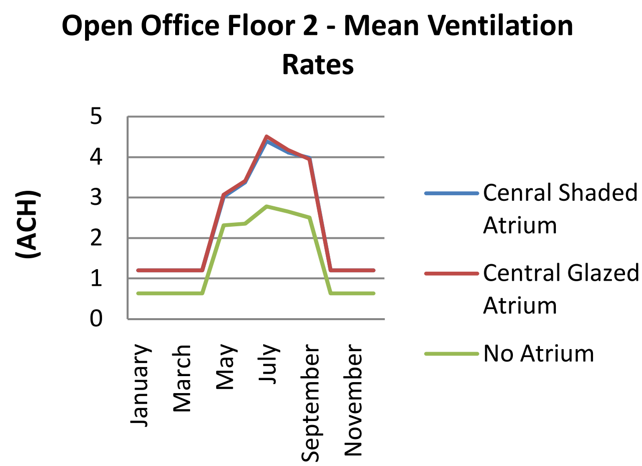

Figure 6: Mean Ventilation Rates in Open office on Floor 2

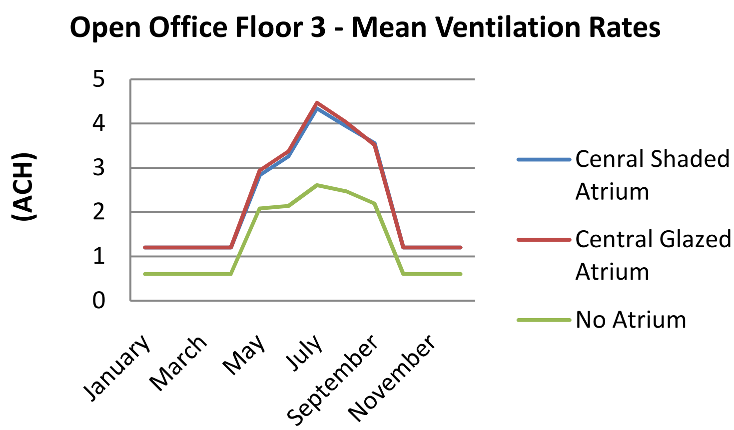

Figure 7: Mean Ventilation Rates in Open office on Floor 3

4.2 Cooling Potential of Night Ventilation:

Night ventilation helps cool down the thermal mass of the building and offset the high temperature gains in the building. Night cooling resulted in a drop in the peak temperature in the summer months by 1°C - 3°C, depending on the set up of the building. Higher impact of night cooling was measured in the atrium set up as compared with the cellular office or open plan office design. The peak indoor air temperatures for the different cases are summarised in Table 2.

Table 2: Peak indoor air temperatures of the different investigated cases

Case	Peak indoor air temperature
Initial layout without night cooling	36.4°C
Initial layout with night cooling	35.3°C
Open office	34.5°C
Open office with glazed Atrium	33.5°C
Open office with shaded Atrium	33.1°C

4.3 Overheating:

The total yearly office hours during which the indoor temperatures exceeded 25 in the naturally ventilated open-plan office were analysed for each case and comparisons were made. The occupied period was taken as between 9am to 5pm on weekdays. A summary of the analysis have been provided in Table 3.

It can be seen from results that in the case of the open plan office without the atrium, the number of hours above 28°C were about 7% and with the construction of a central atrium in the building, there is a drastic reduction in the percentage of occupied hours above 28°C. However, the number of overheated hours is higher in the glazed atrium as compared to the shaded atrium. In the case of the shaded atrium, the percentage of occupied hours above 28°C is about 1-2% whereas with the glazed atrium it's just above 2%.

Table 3: Yearly office hours during which the indoor temperatures exceeded 25 to 30 °C in the naturally cooled open-plan office, Floor 1-3

First Floor	>25°C	>26°C	>27°C	>28°C	>29°C	>30°C
No Atrium	17.40%	13.37%	9.38%	6.49%	3.61%	1.73%
Central Glazed Atrium	10.34%	7.36%	4.18%	2.02%	1.25%	0.87%
Central Shaded Atrium	9.38%	6.15%	3.56%	1.35%	1.01%	0.67%

Second Floor	>25°C	>26°C	>27°C	>28°C	>29°C	>30°C
No Atrium	17.26%	13.46%	9.76%	6.78%	3.94%	2.12%
Central Glazed Atrium	10.82%	7.60%	4.47%	2.26%	1.30%	0.87%
Central Shaded Atrium	9.62%	6.25%	3.70%	1.88%	1.01%	0.77%

Third Floor	>25°C	>26°C	>27°C	>28°C	>29°C	>30°C
No Atrium	15.91%	12.16%	9.04%	6.68%	3.94%	2.31%
Central Glazed Atrium	10.00%	6.97%	4.23%	2.21%	1.49%	0.91%
Central Shaded Atrium	8.56%	5.63%	3.32%	1.78%	1.11%	0.82%

5 Discussion of Result:

Overheating was drastically reduced by adoption of a strategy which combined night ventilation, open plan office and the central shaded atrium. It can also observed that the even though an open plan office would increase the ventilation air changes in the building, the yearly overheated occupied hours above 28°C were still about 6.8%. The yearly occupied hours above 28°C were down to about 1-2% with the shaded atrium. This can be attributed to the combined effect of night cooling and stack effect of the atrium. The overheated hours were higher in the case of the glazed atrium even though it resulted in high ventilation rates. This is probably due to the increased solar gains through the glazing.

The results also indicate that night ventilation is efficient in bringing down the peak indoor air temperatures, by cooling down the thermal mass of the building. This is because the cool thermal mass of the building is capable of offsetting the thermal gains in the building the following day. The drops in peak indoor air temperature were higher with higher night ventilation rates in the building. This is because more heat from the building is driven out by higher rates of air flow in the building. Hence, it can be stated that night cooling is an effective passive cooling measure to improve the thermal comfort in the building.

6 Conclusion

From the study, it can be concluded that a natural ventilation strategy with an open plan office, central shaded atrium and night ventilation can significantly improve the indoor conditions in the Howell building. This would improve the working conditions for the employees. However, the design criterion of limiting the working hours to only 1% above 28°C, which equates to about 21 hours, is not attained. It is difficult to attain this criterion as the LondonDSY weather file has the external dry bulb temperature 71 hours above 28°C.

Reference

Avgelis Aristotelis and Papadopoulos Agis M.. (2004). Indoor Air Quality Guidelines and Standards - A State of the Art Review. *International Journal of Ventilation*. 3 (3), pp. 267-278.

Barnard Nick. (2002). International Journal of Ventilation. *Thermal Mass and Night Ventilation – Utilising "Hidden" Thermal Mass*. 1 (2), pp. 81-90.

Chartered Institution of Building Services. (2007). *Environmental design: CIBSE Guide A*. Great Britain: Page Bros. (Norwich) Ltd.

Chartered Institution of Building Services. (2005). *Heating, ventilating, air conditioning and refrigeration: CIBSE Guide B*. Great Britain: Page Bros. (Norwich) Ltd. [a]

CIBSE (2005). *Natural Ventilation in non-domestic buildings*. Great Britain: Page Bros. (Norwich) Ltd.

Huynh CK. (2010). Building Energy Saving Techniques and Indoor Air Quality - A Dilemma. *International Journal of Ventilation*. 9 (1), pp. 93-98.