

190: Overheating Analysis of a Naturally Ventilated Office Building in a Temperate Climate

H. Altan ^{1*}, I. Ward ¹, J. Mohelnikova ² and F. Vajkay ²

School of Architecture, University of Sheffield, Sheffield, United Kingdom ^{1}*

h.altan@sheffield.ac.uk

Faculty of Civil Engineering, Brno University of Technology, Brno, Czech Republic ²

Abstract

The paper discusses the analysis of an overheating issues occurred in a naturally ventilated office building in Sheffield, England. The building is designed with a south facing fully glazed facade where solar energy is utilised to provide cooling within the building. The ventilation strategy is based on passive cooling strategy where the heated air is driven upwards by passive stack ventilation effect and extracted through louvres on the top level. In this study, indoor thermal conditions have been measured in order to determine the overheating periods during warm spring and summer months and the findings of thermal discomfort levels are examined on each floor level including open plan floor spaces. The overheating periods are determined in a duration where indoor air temperatures reach to 27°C or above for more than two consecutive hours between 9:00 am and 6:00 pm, and the results of the analysis are presented together with series of overheating studies.

Keywords: thermal condition, natural ventilation, overheating, office buildings

1. Introduction

With the increasing demand for building cooling in temperate climates due to increased outdoor air temperatures as a result of global warming, overheating has become a real issue considering thermal comfort conditions of work environments, particularly in naturally ventilated office buildings. Climate change is a known fact and adapting buildings for climate change is the only survival guide for such buildings due to their climate sensitive designs [1].

Passive solar design techniques likely to be simple and inexpensive and night time ventilation is one of the known techniques used to cool the exposed thermal mass of a building as a passive cooling strategy [2]. Night time ventilation again is a significant potential for energy savings and therefore naturally ventilated office buildings in particular can benefit from this technique whenever outdoor air temperatures are low enough to provide sufficient cooling into the building.

Although there isn't a very clear definition of overheating in office buildings, all buildings do overheat to some extent depending on the definition of thermal comfort conditions [3].

The building investigated is a naturally ventilated office building in Sheffield, England where passive solar design techniques share a crucial part of the building design, and the use of solar energy as a means of ventilation strategy to drive passive cooling within the building as well as night time ventilation to minimise potential overheating throughout warm summer periods (see figure 1).

The building was constructed in 2004 as a new interdisciplinary research facility for the Social Sciences faculty in the university campus. It is

approximately 1850 m² of new-build on 5 floors with is iconic design that forms a landmark. The open space is animated by an elevated, sculptural conference room, which opens views across the site and forms a dramatic marker for the building's entrance. The laboratory floors are to be aligned against a south-facing atrium which contains the primary vertical and horizontal circulation, and acts as a thermal collector to drive the passive stack natural ventilation [4]. The building was internationally recognised at the Green Apple Awards 2006 and won an environmental and architectural award [5].

Main building characteristics:

- Built up area is approx. 550 m².
- Area of glazed facades are; North approx. 240 m² and South approx. 280 m².

Description of building envelopes constructions:

- Both southern and northern facades are fully glazed in aluminium frames with a U-value of 1.8 Wm⁻²K⁻¹; both facades glazing is with a U-value of 1.5 Wm⁻²K⁻¹. The southern windows have white roller blind solar shadings.
- Eastern and western walls are masonry cavity walls with full fill cavity insulation and metal studs.
- Flat roof is incorporated as a green roof with benefits to building insulation and rainwater run-off control.

A research-oriented investigation of thermal comfort during the initial years was conducted by the Building Energy Analysis Unit (BEAU) in the School of Architecture and the University of Sheffield, where the building indoor temperatures were monitored in selected parts. The most important part monitored was the internal open space vertical shaft close to the southern glazed facade. Measurements of the vertical thermal profile provided information about the winter

building regime and the summer overheating periods in the building. From previous studies conducted, the findings were suggesting concerns related to overheating periods and thermal discomfort conditions in the building and therefore in this study, the focus is on investigating overheating over the past three years (post-occupancy evaluation) on open plan office floors [6], [7].

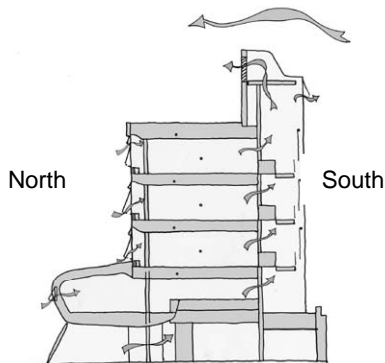


Fig 1. The investigated building and the natural ventilation strategy used

2. Overheating Studies

In the study, the overheating periods are calculated with a simple Excel based tool developed and the overheating is determined in a duration where indoor air temperatures reach to 27°C or above for more than two consecutive hours between 9:00 am and 6:00 pm.

Below, there are the results of the analysis carried out in such an office building, throughout the first three years of its post-occupancy (May 2006 - May 2008).

The overheating time was investigated on the basis of measured air temperatures inside the building in the central area of open plan office floors. There is a scheme with the positions of temperature sensors located inside of the investigated building.

Indoor air temperatures were measured by HOBO and HOG logger apparatuses; about 16 thermal sensors were distributed inside the building. To investigate the overheating periods, the following sensors were selected from the whole measurement data obtained (see figure 2):

- HOBO/07 on the ground floor entrance hall,
- HOBO/11 on the first floor meeting room and conference hall,

- HOG/08 on the second floor, HOG/12 on the third floor and HOG/09 on the fourth floor open plan administrative offices.

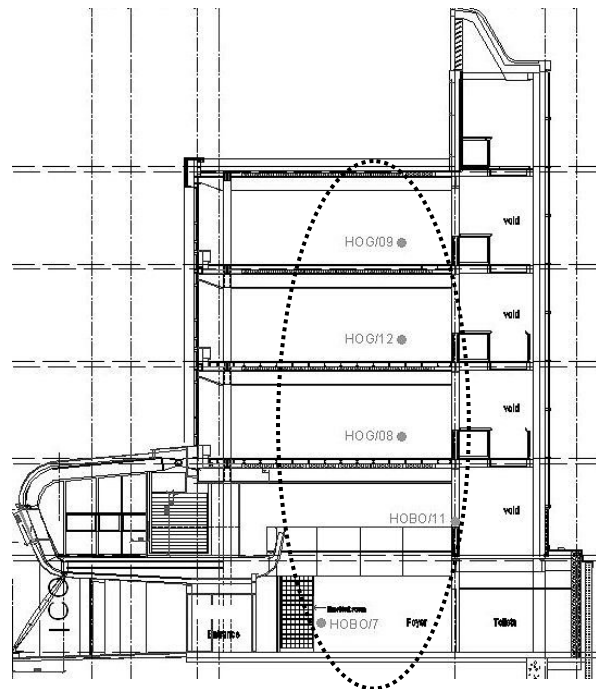


Fig 2. Position of air temperature measurements

3. Results of Measurements

On the basis of the monitoring of indoor air temperatures, the results were completed in histograms summarising the time of temperature intervals during a monitored season and the thermal profiles in characteristic days.

Examples of the results are presented in figures 3 to 9. The figures present thermal profiles monitored within the open plan offices close to the glazed ventilated façade. Temperature profiles are completed with histograms which gave information about indoor air temperatures during the monitored seasons.

Figure 3 is showing a histogram of the indoor air temperature profiles recorded during summer 2006.

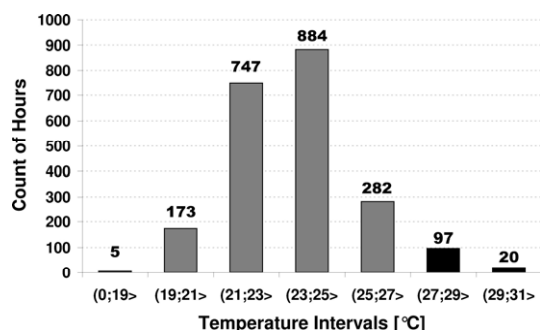


Fig 3. Temperature histogram for summer 2006

Figure 4 is showing a period of indoor air temperature profile with a slight overheating snap shot between 11.07.2006 - 17.07.2006.

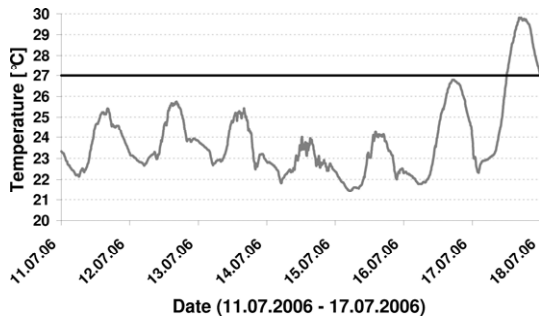


Fig 4. Temperature profile over a period where overheating was recorded during summer 2006

Figure 5 is showing a histogram of the indoor air temperature profiles recorded during summer 2007.

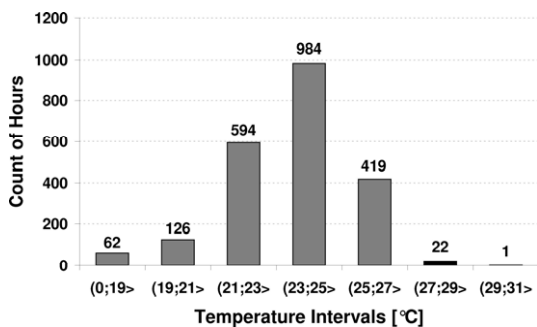


Fig 5. Temperature histogram for summer 2007

Figure 6 is showing a period of indoor air temperature profile with a slight overheating snap shot between 11.07.2007 - 17.07.2007.

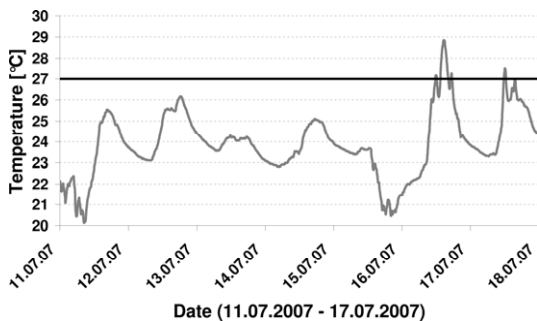


Fig 6. Temperature profile over a period where overheating was recorded during summer 2007

Figure 7 is showing a histogram of the indoor air temperature profiles recorded during May 2008.

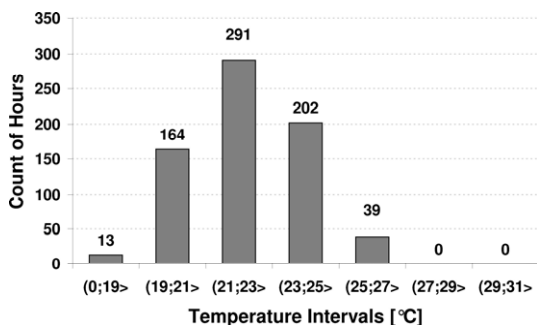


Fig 7. Temperature histogram for May 2008

Figure 8 is showing a period of indoor air temperature profile with no overheating conditions recorded during May 2008.

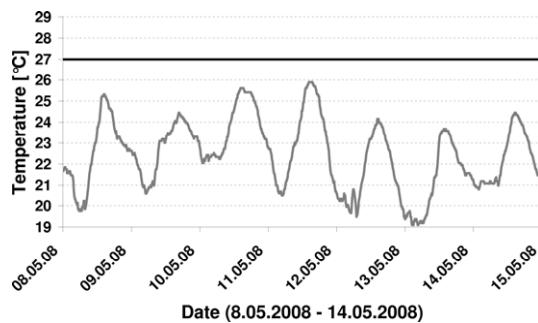


Fig 8. Temperature profile over a period where no overheating was recorded during May 2008

Figure 9 is showing a comparison graph where snap shots of overheating occurred during summers of 2006 and 2007.

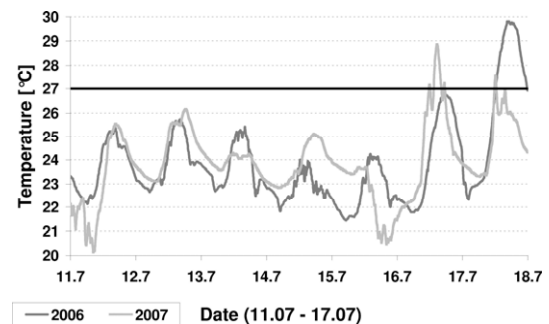


Fig 9. Temperature profiles during summers of 2006 and 2007, and during May 2008

4. Discussion

As it can be seen from the above analysis, overheating periods were recorded both in summer 2006 and summer 2007 with a slight correlation. This is because of the outdoor air temperatures had been relatively different in summer 2006 and 2007; as well as the operation strategy set for opening louvres on the top floor for night time ventilation in the building (see figure 8 for weather statistics recorded for 2006 and 2007).

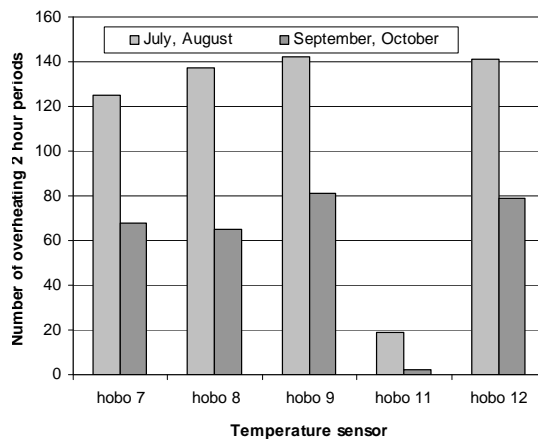


Fig 11. Example of overheating periods monitored in the building from July to October 2006

From previous studies [6], it was also determined that the overheating periods were much higher in year 2006 due to extreme outdoor weather conditions during summer periods, and in addition louvres were not operated in a way to provide night time ventilation, which was caused by the building energy management system (BEMS) in place at the time. However in 2007 after certain adjustment to the BEMS this was avoided and although the conditions were not as extreme as the year 2006 in summer periods of 2007, overheating was reduced substantially.

Figure 10 is showing the Met Office mean outdoor temperature statistics for years 2006, 2007 and the first 5 months of 2008.

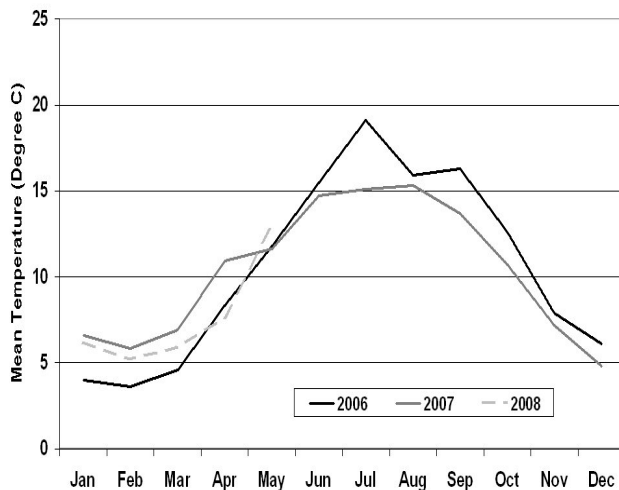


Fig 10. The Met Office temperature statistics

The Met Office statistics are the mean outdoor temperatures for England [8], and as it can be seen on above graph, there is a significant variation on temperatures recorded during summer of 2006 and 2007 (approximately up to 5°C difference), which is again consistent within the indoor temperature profiles recorded in the naturally ventilated office building investigated.

5. Conclusion

There are obvious advantages of passive solar designs with various techniques such as using a fully glazed facade to both drive the natural ventilation and maximise the daylighting with high indoor illuminance in buildings. However in contrast, high intensity of solar radiation transmitting through the glazed areas can also cause unwanted interior overheating during warm and sunny days, and therefore the efficient shading system should be in permanent operation.

The architectural concept behind this building design in terms of its ventilation strategy was to construct a building that would operate naturally ventilated where indoor air temperatures are maintained at temperature levels between 20°C to 22°C. In reality, excessive solar gains through the southern glazed facade causes unwanted overheating which then leads to thermal

discomfort and are not easily eliminated by the natural ventilation effect. The building is currently under ongoing monitoring of indoor air quality (in addition to indoor air temperatures and relative humidity levels in selected parts) which should help to modify the design strategy used as means of ventilation system in the building and to suggest a more efficient solar shading system for the glazed active facade.

To conclude, the investigation of indoor air temperatures in such buildings with glazed facades is very important for the building design and operation, particularly for solar shadings and efficient ventilation systems, which will decrease summer overheating and its unwanted effects.

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