# Effect of Occupant Environmental Issues on the Passive Design Strategy of a Naturally Ventilated Building

**Yufan Zhang and I.C.Ward**

Building Energy Analysis Unit, School of Architecture, University of Sheffield, Sheffield, UK.

ABSTRACT: Architectural passive design strategies play an important role in improving the indoor environment. However, in reality the way occupants interact with passive control systems is poorly understood. This paper based on a naturally ventilated office building examines the occupant's perception and response to indoor the environment, highlighting aspects of practical performance of the south/north facing glazing with internal blinds. Also the effect of the south facing passive stack on air movement is analyzed by onsite observation, physical data collection and a questionnaire survey. The results provide quantitative and qualitative information on built environment impacts that affect and/or are affected by occupant satisfaction, behaviour and interaction with passive control systems.

Keywords: passive design, environment, glazing, blinds, occupant

## 1. INTRODUCTION

At present, the impact of passive design strategies in architecture has been tested both on the energy use and physical environment during the design stage [1]. These technical design decisions are very often assumed to be used by the occupants to improve the internal environment [2]. However, in reality the way occupants interact with these control system is poorly understood [3]. This study is designed to contribute to and to increase the understanding of the concept of passive design in architecture, especially in terms of occupant control system. The study is based on an existing naturally ventilated building and aims to investigate the effects of occupant issues on the passive design strategy. Based on onsite observation, physical data collection and questionnaire a survey, the results will provide quantitative and qualitative information from the strongest to the weakest link which affect or are affected by occupant satisfaction and interaction with passive control system.

## 2. METHODOLOGY OF STUDY

*2.1 Building identification*

The ICOSS Building is a 5-story office building with around 50 occupants who work in it at present. It is 34m long and 17.5m wide with about 2900 $m^2$ of usable floor space. Figure 1 shows a typical floor plan of the Building. This building has large area windows with manually controlled internal blinds on both the north and south elevations. The building was designed to be naturally ventilated with the 100% glazed south façade providing a natural ventilation shaft, drawing air across the floors from the north elevation. A building management system controls the operation of the windows opening and closing them in accordance with prevailing internal and external conditions. The exposed concrete structure provides a high level of thermal mass which is again cooled by night ventilation. The building is heated by a radiator convective system. In this study, the open plan offices space was investigated.

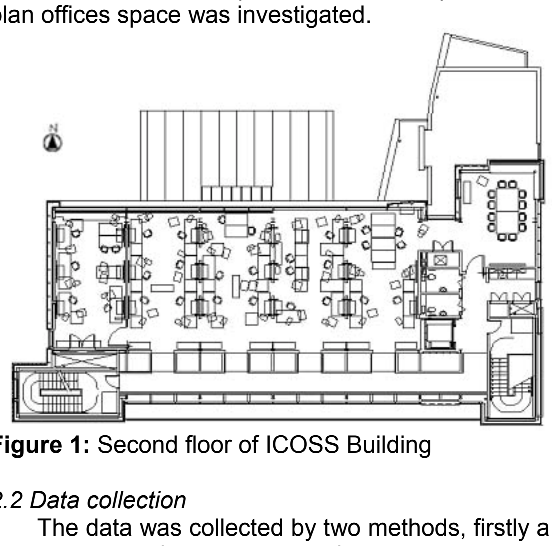


**Figure 1:** Second floor of ICOSS Building

*2.2 Data collection*

The data was collected by two methods, firstly a : photo record of the position of the blinds and the weather information. The photo record was aimed at recording the position of each blind on the south and north façades of the building twice per day (10:00 hrs and 15:00hrs). This photo record was carried out from Dec. 2004 and will continue until April 2006.

The main climatic data, hourly: air temperature; relative humidity; solar radiation; wind speed/direction; total cloud cover; daily: mean air temperature; rainfall totals; sunshine hours; and relative humidity were also collected from a local weather station.

*2.3 Questionnaire collection*

The questionnaire was designed using plain, concise language. It was divided into two parts: observation and survey sheet. The observation sheet was focused on the interviewee information, including gender, age, and clothing level. The survey sheet was focused on the interview's response and opinion on the indoor environment which they are in, including:

- the perception of individual indoor environment at the moment of the survey
- the comfort level of individual indoor environment at the moment of the survey
- the opinion on the physical indoor environment seasonally
- the response to the working environment

A total of 35 sets of valid records (19 female and 16 male) were obtained which accounted for about 70% of total occupants who worked in this building. Data were collected primarily in the morning and afternoon when a high concentration of people could be found in the building.

*2.4 Physical measurement*

In order to obtain the basic indoor environmental information in association with the occupants' response, some physical parameters were measured when the interviewee answered the survey sheet. These parameters included sound level; luminance; relative humidity and temperature.

*2.5 Data processing*

The photo survey concentrated on identifying the position of the blinds and each photo was analysed using the positional information as shown in Figure 2. The window position either open or closed was also recorded. The blinds based on their up/down position ranged from 0 to 7 respectively. This value was further divided by its maximum values to obtain the proportion of occlusion [4].

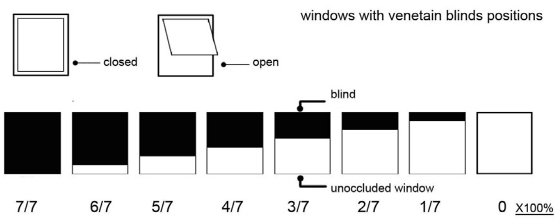



**Figure 2:** Value of window and blind's position

## 3. RESULTS

*3.1 Visual environment at the user's workplace*

In the open plan area of the building, the glazing area is about 100% for the south façade and 70% for the north façade. All glazing has internal blinds. The working area near the north façade was found to have no serious problems from glare or overheating. However, those working near the south façade did experience some problems and it was not until about 4m away from the façade did the problems seem to reduce. [See figure 3]

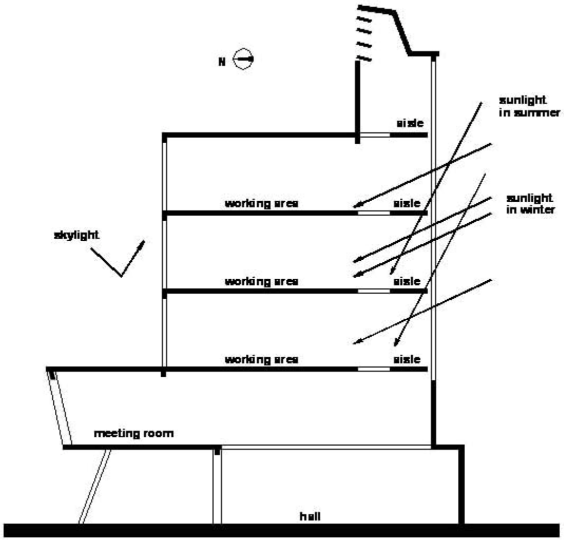



**Figure 3:** Sunlight penetration in summer and winter

This observation indicates that the blinds were always up during summer time. Figure 4a shows the percentage of occluded window area on the south façade in May and June, 2005. The windows are seen primarily for daylight and glare did not seem to be a major problem. This could be attributed to the fact that the solar angle in summer is high and at about 4m from the façade the penetration of sunlight was minimal.

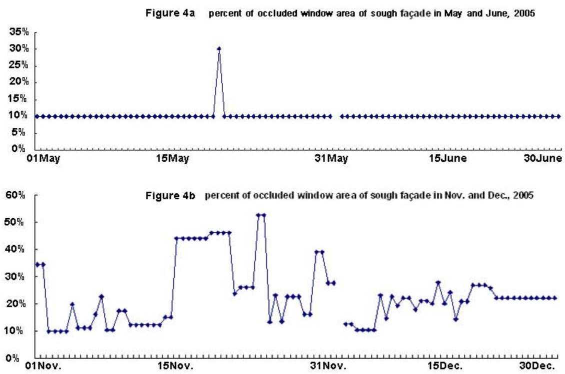
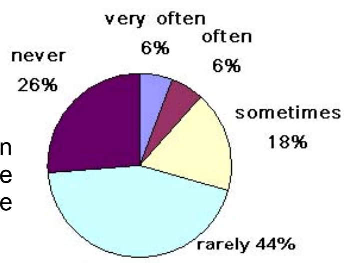



**Figure 4:** Occluded window area of south façade in May/ June and Nov./Dec.2005

However, in Nov. and Dec., the solar angle is lower which means that there is greater penetration and the blinds on south façade are used to prevent the glare problem. Figure 4b indicates that the blinds were used frequently and diversely to fit the occupants needs.

**Figure 5:** Breakdown of the discomfort glare affection to the occupant



Even with the blinds to control the sunlight, from the survey it appeared that still 6% of occupants reported that discomfort glare occurred "very often" with a further 6% reporting discomfort glare "often". (See figure 5)

Furthermore, from the survey responses for the lighting level, 50% of people felt neutral (neither dull or bright) and 20% of people felt that the light level to be 'very bright' in all seasons. (See figure 6)

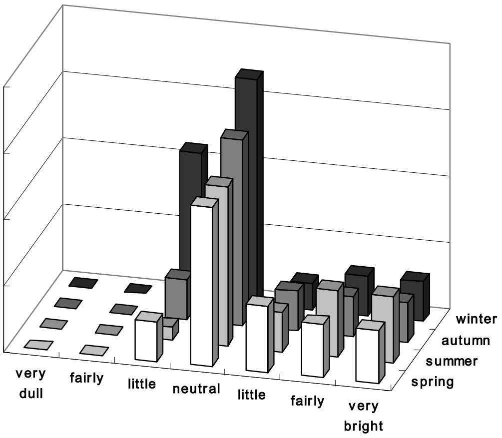



**Figure 6:** Distribution of responses to the lighting level in the four seasons

In this case, both discomfort glare and lighting level could be helped by encouraging occupants to use internal blinds to maximize their visual comfort and lighting quality.

*3.2 Thermal environment at the user's workplace*

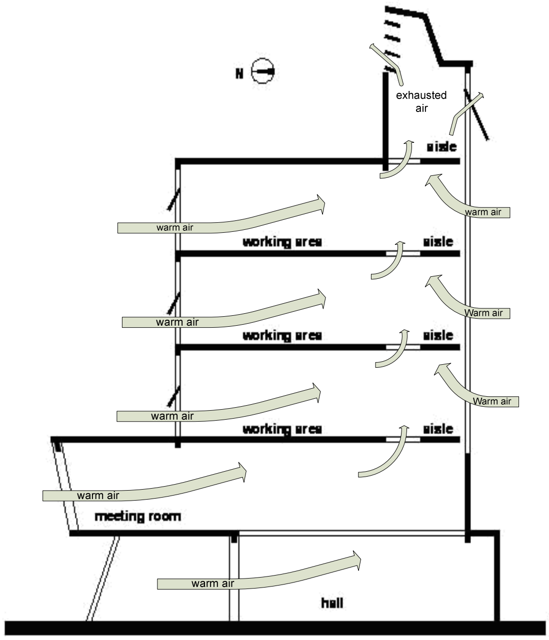



**Figure 7:** How natural-ventilated clerestory works

As mentioned above, the building has large glazing area both in south and north facades, however in the south side; most of the windows are fixed except in the fifth floor (clerestory floor) where a row of small windows can be opened. On the north façade, 70% of the glazing area is fixed and 30% can be opened. A clerestory on the top floor is designed to provide a means of increasing natural ventilation to all floors.

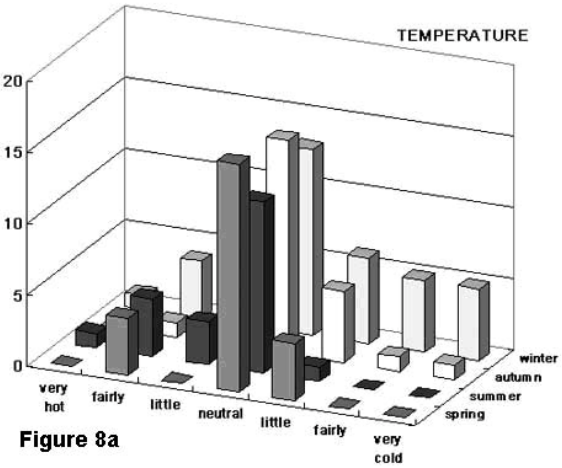



**Figure 8a**

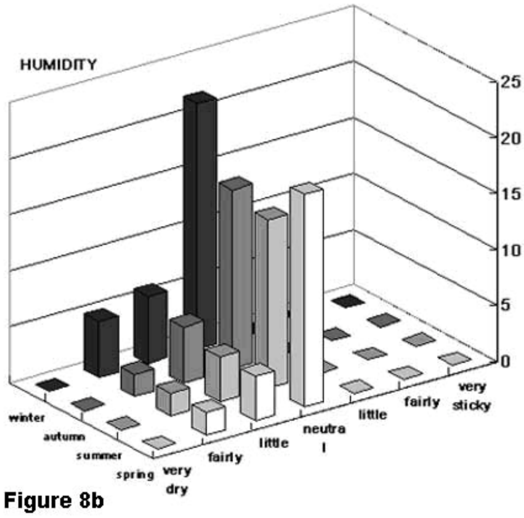



**Figure 8b**

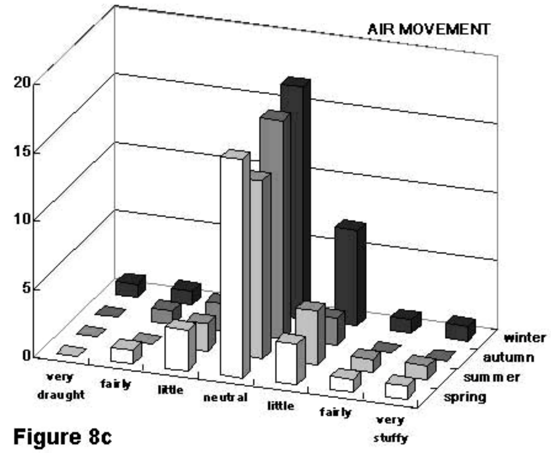



**Figure 8c**

**Figure 8:** Distribution of responses to the temperature, humidity and air movement in the four seasons

Figure 7 shows how the passive stack ventilation system was designed to promote the flow of air from the north to the south. The clerestory windows provide further openings to vent the warm air out of the building in warm days during summer periods.

Figure 8 shows the distribution of survey responses to the temperature, humidity and air movement for the four seasons. In each diagram, the axis X presents the different levels perception from very hot to cold for temperature; very dry to sticky for humidity and very draught to stuffy for air movement. The axis Y presents four seasons respectively and axis Z indicates the total numbers of responses received.

Figure 8a shows the occupants perception of temperature seasonally. The main conclusions to be found from this data were that in summer 57% felt neutral while the rest felt slightly hot to hot. In winter 36% felt neutral, 21% slightly hot to very hot and 43% slightly cool to very cold. These results indicate that in summer the building tends to be on the warm side while in winter there is a slight tendency for the building to be cool.

Figure 8b shows little difference between the four seasons for occupant perception of humidity. Average 71% occupant felt neutral, while 18% felt a little dry and 11% fairly dry.

Figure 8c shows a broad consistency in the perception of air movement over the four seasons. 62% of occupants felt neutral in summer which dropped to 51% in winter. Also in winter 21% occupant felt a little or fairly draughty while 27% felt very, fairly and a little stuffy.

### *3.3 Acoustic environment of the user's workplace*

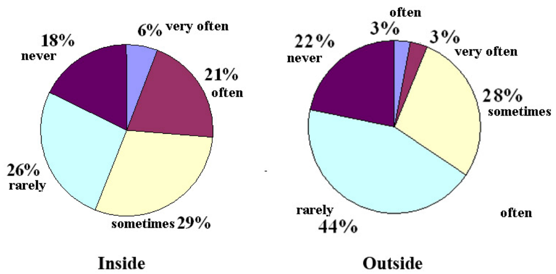



**Figure 9:** Breakdown of the noise affection to the occupant from outside and inside the building

This building has a significant amount of exposed thermal mass which can have the tendency to cause reverberations'. Some effort has been taken by the designers to reduce this by including soft furnishings and acoustic baffles.

Figure 9, indicates that only 6% of the occupants felt that external noise affected their work either often or fairly often.

On the other hand, the open plan nature of the building means that many occupants working together lead to potential acoustic problems. These factors lead to more than half of the occupants (56%) being affected by the noise inside of the building ranging from sometime (29%) to often (21%) and very often (6%).

## 4. CONCLUSION

This study has led to the following conclusions:

1. It appeared that the blinds (which were designed to limit solar penetration) were not operated by the occupants.
2. This led to certain areas suffering form glare problems on the computer screens and to overheating in the warm periods.
3. Acoustically there did seem to be some problems with the transmission of internal noise which needs to be addressed by the designers.
4. Another conclusion found was that the occupants were not informed of the way to control the blinds and therefore an education programme should be implemented to ensure that they knew how the control the blinds.

## ACKNOWLEDGEMENT

The authors would like to thank Angie Maskrey for kindly arranging interview time and all the occupants in ICOSS building for their assistance in data collection.

## REFERENCES

[1] Lebens, Ralph M., Passive solar heating design, London : Applied Science Publishers, 1980
[2] Bansal, Narenda K., Passive building design, London ; Amsterdam : Elsevier, 1994
[3] Inoue T, Kawase T, Ibamoto T., The development of an optimal control system for window shading devices based on investigations in office buildings, ASHRAE Transactions 1988;94(2):1034-49
[4] Michelle Foster and Tadj Oreszczyn, Occupant control of passive systems; the use of Venetian blinds, Building and Environment 36 (2001) 149-155