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Can a naturally ventilated office outperform a mixed mode office? Pilot study on occupants' comfort

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ABSTRACT

It is established that a mixed mode indoor environment provides the best for occupant comfort by augmenting the passive system with a mechanical system when and where required. However, the recent desperation for near zero energy environments, of which natural ventilation provides, warrants the need to explore the possibility of achieving this without sacrificing occupants' comfort. The purpose of this study was to investigate if a naturally ventilated building can outperform a mixed mode building in providing comfort for occupants. The Building in Use (BUS) questionnaire was used to carry out this survey on occupants' comfort in two office buildings in Auckland, New Zealand. The findings showed that occupants of the naturally ventilated office building were slightly more satisfied and comfortable than their counterparts in the mixed-mode office building for almost all the variables of comfort investigated. Thus, the results indicate that naturally ventilated office spaces can provide more comfort than mixed-mode office spaces, if well-designed. This finding suggests that the use of natural ventilation in office environments by designers and building owners should be encouraged. A limitation of this study is that it was carried out in the winter season. The winter season could have affected the results obtained. Also, the study was carried out on only two office buildings. As such, the results cannot be generalised to all office buildings in New Zealand. More surveys on ventilated systems are required for results to be generalisable.

1. Introduction

Mixed-mode buildings have been reported to provide better environmental comfort and occupant satisfaction than naturally ventilated buildings [1,4,19]. The basic benefit of mixed-mode ventilation over natural ventilation is the maintenance a satisfactory indoor environment by alternating between and combining natural and mechanical systems (air-conditioners) to avoid the cost, energy penalty and consequential environmental effects of full year-round air conditioning [3]. The implication is that air conditioners are used only when the indoor comfort conditions are outside the acceptable range for occupants. According to Ward et al.,[24]; whereas naturally ventilated buildings (in most cases) offer near zero-energy at the expense of occupant comfort, mixed mode buildings achieve both by combining actual and predicted conditions in a dynamic building model to allow pre-emptive actions – not just responding to conditions, but actively controlling towards an optimal outcome.

However, buildings are nowadays expected to be more environmentally sustainable – using lesser energy throughout its lifespan and sustaining itself in the event of unfavourable climatic conditions. As pointed out by Kwok and Rajkovich [11]; it is important that we begin to future-proof our buildings with adaptive opportunities for passive, low energy buildings in response to the unprecedented climatic variability presented to us by climate change. As such, there is the desperation for near zero energy indoor environments, of which natural ventilation provides. Studies have shown significant savings in energy use with natural ventilation in cities across the globe. For example , Brittle et al.,[5] found that yearly ventilation and cooling energy savings ranging between 21% and 39% could be achieved with natural ventilation in Abu Dhabi . Tong et al., [22] observed that 8–78% of the cooling energy consumption could be potentially reduced by natural ventilation depending on local weather and air quality. The authors estimated the natural ventilation potential of all the major Chinese cities . Cardinale et al.,[7] showed potentialities of natural ventilation in the reduction of cooling loads and energy consumptions need for the summer in Italy . Tong et al.,[23] estimated 7258 NV potential hours annually at ground level for Los Angeles.

Naturally ventilated spaces depend on passive strategies for heating,

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cooling and the ventilation of the indoor environment. Based on the adaptive models of comfort [16], naturally ventilated spaces allow for wider range of comfort temperature that is more compatible with outdoor conditions. This is because it depends on factors such as the pressure differences that are generated by the effects of wind (speed and direction), indoor and outdoor temperature and a combination of both across the façade openings to achieve thermal comfort. They also require high thermal mass to retain the heat and an appropriate ventilation system that is well-suited to the overall building design.

Despite the potential to achieve net-zero energy indoor environments, naturally ventilated office spaces are often not the preferred ventilation option amongst designers for office spaces. For instance in New Zealand, they have been shown to be unpopular when compared with mixed mode and air-conditioned buildings [6,19]. Buildings within Auckland, New Zealand are likely to obtain air conditioning systems of some sort to achieve the required occupants' comfort [20]. A study carried out by Rasheed et al., [19] showed that even though they took less sick leaves per year, office workers in New Zealand, preferred working in Mixed-mode office buildings to naturally ventilated office buildings.

As such, this paper investigates whether naturally ventilated office spaces can provide more comfort than mixed mode ventilated office spaces. Based on the findings of Rasheed et al.,[19] that occupants have less sick leaves in naturally ventilated office spaces, the study reported in this paper is a step towards exploring the possibility of achieving environmental sustainability without sacrificing occupants' comfort in naturally ventilated buildings. It aims at identifying perceived comfort differences across a range of variables such as lighting, noise and temperature between naturally ventilation and mixed-mode ventilation systems.

2. Method

This pilot study contributes to a rich narrative of building performance by employing a post-occupancy evaluation framework. Post-occupancy evaluation (POE) is the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time [18]. Its major focus is on the needs of the occupants and how the study building is satisfying those needs. From its inception, POE has provided significant information on the performance of buildings, providing information from occupants on how buildings function and how they can be improved to cater to present and future occupants. This is true for any ventilation system as its success depends extensively on the results of POE that depict the ability to provide comfort and environmental satisfaction for occupants especially in commercial buildings. The results presented in this paper highlight the importance of appropriate environmental design to achieving environmental sustainability and occupant comfort.

The study buildings are located in Auckland, New Zealand – a temperature climate characterised by warm summers and not so cold winters. The aim of selecting buildings within the same location is to provide a common basis for comparison between buildings. As it is only a pilot study, two buildings were investigated consisting of a naturally ventilated building (Building A), and a mixed-mode ventilated office building (Building B). It is expected that the findings will lead on to a main study comprising of more office buildings. The sample population included all the occupants of the two office buildings. The identity of the sample buildings had to be kept secret for ethical reasons. To gain sufficient information about both buildings' environmental control systems, interviews with the buildings' managers, site visits and review of project information were carried out.

The Building in Use Studies (BUS) questionnaire was used to survey the building occupants. This questionnaire is a self-reporting method of POE which captures the perceptions of occupants on the conditions of their workspace. This questionnaire is a popular method, and its results have been used extensively in this area of research [2,13,14,17,21] etc.). The questionnaire contains questions which are concerned with office environmental performance and operational matters. It uses a structured Likert scale of 1–7 over 45 key variables evaluated in the questionnaire. For both buildings, the questionnaires were administered by hand on the first day of the survey week (Monday). The collection of filled out questionnaires was carried out in the afternoons and took between two and three days of the week following the requirements of the questionnaire licence.

3. Findings

This section provides the results of the questionnaire survey as analysed by the licensing company – BUS Ltd.

Building A is a series of sub-let speculative offices providing no heating or cooling. Building B is owner-occupied with heating/cooling system provided. As a naturally ventilated buildings, Building A has openable windows with smaller upper windows on each side elevation intended for night-time cooling. Their use is solely dependent on occupants awareness. Being largely open-plan spaces, it enables cross-ventilation across the indoor space. It was noted that some occupants seated away from the openings in the offices had some small fans on their work desks etc. They acknowledged that the fans were rarely used for circulation. Building B has a mixed mode ventilation system with Low E laminated double glazing employed in the facades. The benefits of low E glass are potential energy efficiency and comfort by transmission of visible light into the offices while blocking heat transfer [9]. Laminated double glazing should be effective in reducing noise (i.e. providing sound insulation) and heat transmission (thermal insulation and the reduction of solar heat gains) [15]. Table 1 below shows the characteristics of the surveyed buildings.

3.1. Background information

Background statistical information on the respondents is given in Table 2. The New Zealand BUS benchmark was used as a comparison. The position of the study building amongst all studied buildings in New Zealand is represented by a building percentile. This shows how well the building has performed in comparison with other buildings that have been studied.

It is worth mentioning here that the NZ BUS benchmarks used for the study buildings are different. Both the buildings were surveyed during the winter season (1 month apart), but the results of the two buildings were processed at different times (5 months apart). As such, different BUS benchmarks were produced for the study buildings. This development was expected as there might have been more buildings surveyed; thus the difference in benchmarks. However, it does not affect the results of the comparison carried out on the study buildings significantly because the buildings were compared based on their respective benchmarks and response rates. The background information on data gathered is shown in the table below.

Table 1
Building characteristics of the study buildings.

Building Properties	Building A	Building B
Year of completion	2009	2008
Size	9,600m^2	60,000 m^2
No. of floors	Five (5)	Eleven (11)
Type of spaces	Office spaces	Office spaces, Training rooms, Cafeteria, Banking facility
Air-conditioning system	100% Natural (Passive)	Mixed mode with sun-shading to control heat gain.
Glazing system	About 50%	Extensive (about 80%)
Sample Population	All occupants (75% of responses received)	All occupants (58% of responses received)