London-
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The indoor air quality of a Victorian school with a post-1968 extension

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Figure 1: Classroom A (post-1968)

Figure 2: Classroom B (Victorian)

MRes Dissertation Background:

One third of all energy use within developed countries is consumed in buildings and over the next fifty years around one half of this total energy use may be dissipated through ventilation and air infiltration [1]. Conversely, previous research has shown that recommended ventilation rates are not being met in schools [2]. This can have a detrimental effect on pupil's health [3][4]. Children spend almost 12% of their time in classrooms [5]. The occupant density of teaching spaces is on average around 1.8 – 2.4m^2 per person [3]. The main source of Carbon Dioxide (CO_2) within these spaces is the occupants [6]. The current guideline for the internal levels of CO_2, which used as an indicator to the overall indoor air quality (IAQ), is that the average quantity should be below 1500 parts per million (ppm) during occupied hours [6]. However, at any one time, the occupant should have the ability to reduce the level of CO_2 to below 1000ppm [6]. Recent studies have shown that relatively new, naturally ventilated, schools have average internal levels close to 1420ppm [2]. There has been little research on the IAQ of naturally ventilated Victorian schools. The challenge for these buildings is to minimise heat loss whilst providing an adequate fresh air supply; optimising the internal environment to facilitate learning.

Aim:

Quantify the indoor air quality and energy consumption density of a Victorian school with a post 1968 extension.


Figure 3: HOBOware CO2 sensor & data logger

Objectives:

1. Quantify the levels of CO_2 and temperature within a sample of five school classrooms. (An example of a post-1968 classroom is shown in figure 1 and the only Victorian classroom monitored in figure 2. The sensor and data logger models used are shown in figure 3.)
2. Compare the data with current guidelines [6] and average quantities recorded within newly built school data.
3. Add an intervention to the study to establish the impact of maximum window opening for a week.
4. Model additional window opening using Integrated Environmental Solutions software.
5. Calculate the energy consumption density and carbon dioxide emissions of the school over the last year.
6. Engage with the pupils through assemblies, worksheets and discussions in addition to thermal comfort questionnaires.

Results:

Figure 4. shows classroom B during week one. It is clear to see that the recorded levels often rise above 1500ppm CO2. The collected data was filtered to the occupied hours of 09:00 to 15:00.

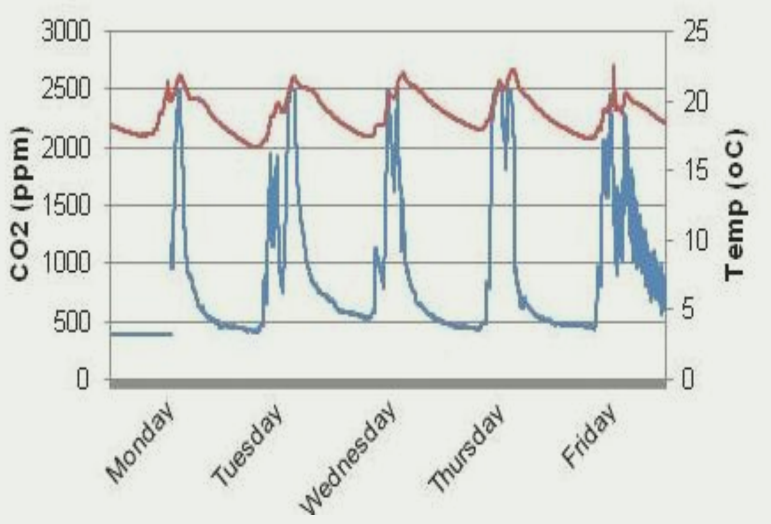

Figure 4: Classroom B week one data

The occupied averages for each classroom were calculated. Figure 5 shows all five classrooms over a six week period. The blue line is the Victorian classroom. The average here is mostly above 1500ppm.

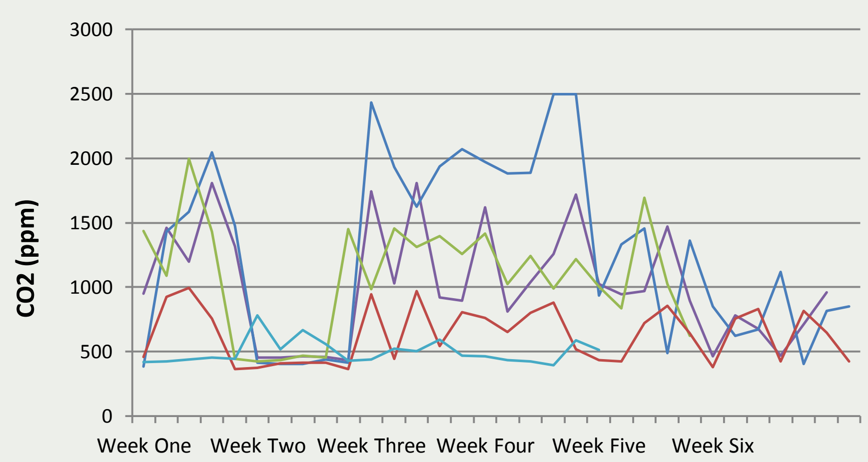

Figure 5: Average CO2 quantities of all five classes

To realise the benefits of occupant behaviour change an intervention was added during week six; maximum window opening. The average CO2 level (ppm) during the intervention period of the Victorian and post-1968 classrooms were compared with the previous average and the new school average as shown in figure 6:

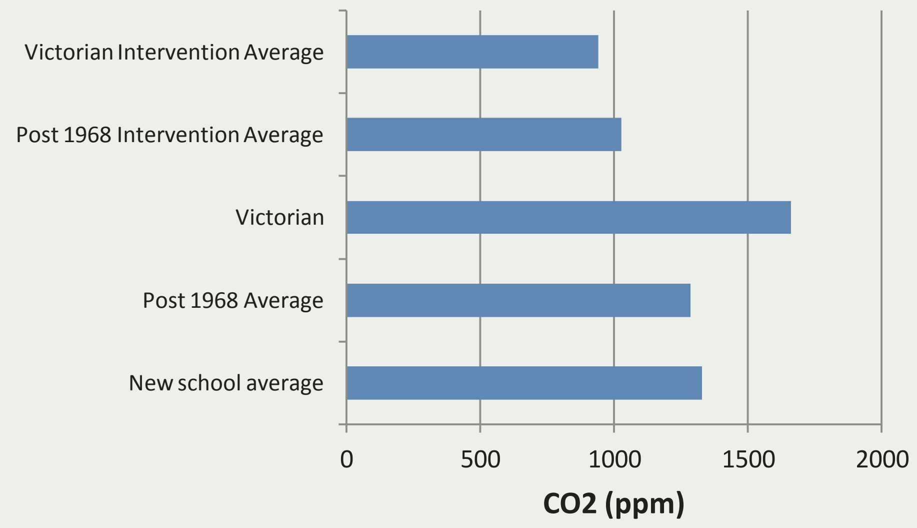

Figure 6: A comparison of average CO2 levels

The main factors leading to the higher quantities of CO2 within the Victorian classroom were found to be the small floor area per person and the small window opening area. Figure 7 begins to explain this:

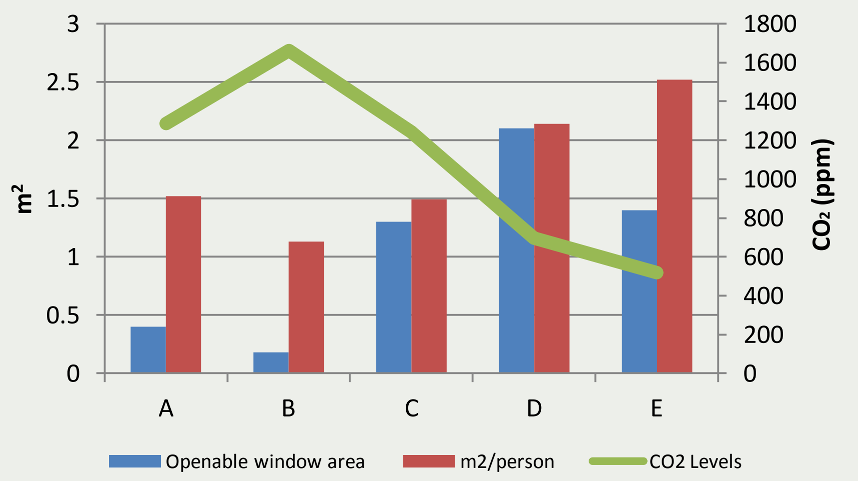

Figure 7: Openable window area, floor area per person and average CO2 levels

To establish the strength of correlation between the floor area per person and window opening area against the measured CO2 quantity, Spearman's rank correlation coefficient was used. As shown in figure 8, a score of -0.6 indicated a strong negative correlation.

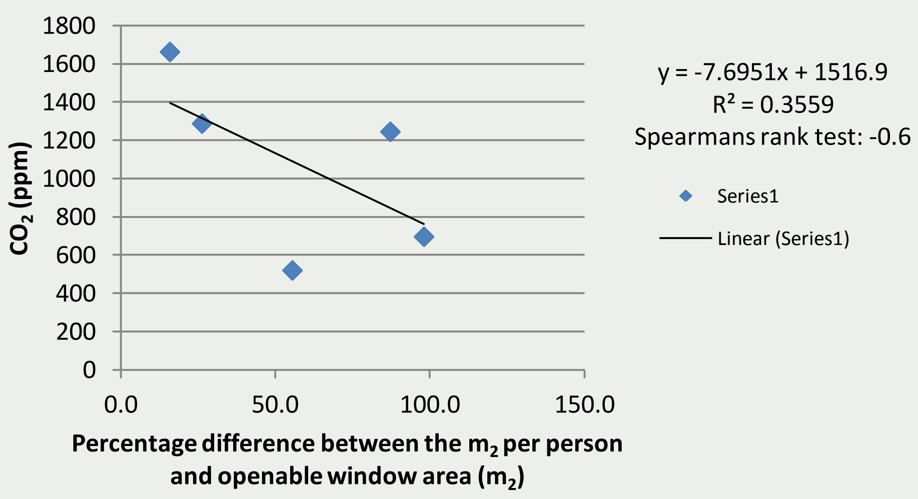

Figure 8: Classroom B week one data

Main Conclusions:

The key factors affecting the CO2 quantities within the classrooms was size of the room in relation to the occupant density and the openable window area. This highlights the retro-fit challenges for typical Victorian classrooms. The window opening time depends on occupant behaviour and thermal comfort. It is possible to meet the guideline upper average level of 1500ppm [6] with maximum window opening in the summer. Further monitoring during the winter months would be beneficial. The post-1968 classrooms performed well in terms of IAQ during the summer but the lack of thermal fabric insulation indicates high heat loss. The display energy certificate has an 'F' rating.

PhD Proposal

Supervisors: Victoria Haines and David Allinson
Web profile: http://www.lolo.ac.uk/project/view/project/21

'A holistic approach to housing retro-fit investigating the wider benefits or detriments experienced by the occupants'

Aim:

To take a holistic approach by measuring and recording the wider implications of housing retro-fit to the occupants; focusing on the affects of indoor air quality and thermal comfort.

Objectives:

1. Broaden the paradigm of 'low-income housing' retro-fit
2. Attempt to draw relationships between IAQ and occupant health in dwellings.
3. Quantify the broader outcomes such as socio-economic benefits or cultural changes.
4. Obtain case studies of similar construction, size and occupants with a variety of retro-fit stages.
5. Analyse and compare pre and post-retro-fit dwellings.

References:
[1] Liddament, Martin. W. "A Guide to Energy Efficient Ventilation." Coventry: Air Infiltration and Ventilation Centre, 1996.
[2] Santamouris, M, et al. "Experimental investigation of the air flow and indoor carbon dioxide concentration in classrooms with intermittent natural ventilation." *Energy and Buildings*, 2008: 1833 - 1843.
[3] Fisk, William. J. *Health and productivity gains from better indoor environments and their relationship with building energy efficiency.* Annual Review, California: Energy Environment, 2000.
[4] Clements-Croome, D J, H B Awbi, Zs Bako-Biro, N Kocchar, and M Williams. "Ventilation Rates in Schools." *Building and Environment*, 2008: 362 - 367.
[5] D. Grimsrud, B. Bridges and R. Schulte. Continuous measurements of air quality parameters in schools. Building Research and Information 34 (5) (2006), 447–458.
[6] DFEE. "Building Bulletin 101." Guidance Document, London, 2006.

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