THERMAL COMFORT SIMULATIONS FOR DIFFERENT STRUCTURED NATURALLY VENTILATED ROOM

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ABSTRACT

The objective of this research was to investigate thermal comfort with respect to the mass of the building inside a test room which is naturally ventilated. The room is an existing portable cabin of light mass, located at Loughborough University. The comfort parameters for different mass of the cabin were predicted. For this purpose a simulation package, is used to calculate the thermal parameters defined by Fanger. Medium and high thermal masses were added to the test room and their effects on thermal comfort were investigated. The results predicted that thermal mass has significant effect on thermal comfort parameters. It also demonstrated that to achieve the possible thermal comfort, the control strategy for the months of April, May and October is to close the louvres and for the months of June, July, August and September to have maximum opening.

Keywords: -Natural ventilation, impact of wall material, thermal comfort

INTRODUCTION

The distribution of fresh air and effectiveness of the depth of a room for single-sided natural ventilation assessed by Walker and White [1], demonstrated that comfortable temperatures can be maintained in deep offices. A series of air velocity and temperature measurements were carried out in an environmental chamber over the summer using single-sided natural ventilation by Eftekhari [2]. The measured and predicted thermal comfort analyses showed that thermal comfort can be achieved in small offices for most days during the summer.

The objective of this research was to investigate the impact of thermal mass on thermal comfort for a naturally ventilated office. An existing portable cabin is used to represent a typical office. For this purpose, a computer program is used to calculate the thermal parameters defined by Fanger [3]. The comfort parameters for different mass of the cabin were predicted. This information will then be used to modify the existing test room.

After the louvres were installed the air infiltration into the test room was measured using a tracer gas technique. Initially all the gaps and louvres were covered and SF6 tracer gas was released into the room. After uniform readings at eight points inside the room were achieved, the covers were removed and from the concentration decay, the total leakage was calculated. The tracer gas measurements demonstrated that the air change per hour was 1.3. This value was then used in the simulation program.

Simulated test room: the standard portable cabin

The simulated room was a standard off the shelf portable cabin. The external walls are of composite construction having an external skin of plastisol-coated galvanised steel sheet, timber studs and peripheral frame, a galvanised steel bottom rail and an internal lining of 0.6 mm thick polyester-coated steel. The 85 mm cavity between the external skin and internal lining is filled with injected, rigid polyurethane insulation. The thermal conductivity coefficient, λ measured for the external wall is 0.45 $Wm^{-2} K^{-1}$ [5]. The floor comprises an 18 mm thick moisture resistant wood chipboard fixed to the steel joists and covered by carpet. A profiled steel under drawing is fixed to the underside of the steel joists. Thermal insulation is provided by injected, rigid polyurethane insulation. The U value for the floor is 0.34 $Wm^{-2} K^{-1}$.

The roof is of composite construction having an external profiled skin of plastisol-coated galvanised steel sheet, rigid polyurethane/plywood composite inserts, softwood peripheral frame, and a ceiling of polyester-coated steel. The 110 mm cavity thickness is filled with rigid polyurethane insulation. The U value supplied by the manufacturer is 0.32 $Wm^{-2} K^{-1}$.

Combination of louvres

Simulations were carried out for 5 damper positions shown in Table 1. Louvres 1 and 3 are placed at low level and louvres 2 and 4 are high level openings (see Figure 1).

Table 1 The simulated opening size of the louvres

Louvres Positions	Low level area (m)	High level area (m)	Space between openings (m)
Case 1: Closed	0	0	1.5
Case 2: Louvres 1&2 Mid-position	0.4	0.4	0.8
Case 3: Louvres 1&2 fully open	0.805	0.805	0.1
Case 4: All Louvres Mid-position	0.805	0.805	0.8
Case 5: All Louvres Fully open	1.61	1.61	0.1

SIMULATION PROCEDURES

To assess thermal comfort inside the test room, a series of comfort analyses were carried out. These analyses were based on Fanger's theory and the simulation program was used to predict the average Predicted Percentage of Dissatisfied (PPD) and the Predicted Mean Vote (PMV) in the office [4]. The simulation program is intended to assess detailed environmental conditions within a single space. The numerical model is based on an explicit finite difference formulation for unsteady heat flows within the building fabric.

Natural ventilation due to the stack effect is calculated within the program from open areas at high and low levels and the vertical separation between them. In general, the simulation program is useful in determining the environmental conditions in single spaces with a low level of servicing, such as naturally ventilated buildings.

The software uses a set of typical climatic conditions provided for UK, which defines the minimum and maximum dry and wet bulb temperatures for each month of the year, the direct and diffuse radiation factors and cloud cover. The predicted average PPD values for a naturally ventilated room using the default weather data, and a seated person with light office wear and light office activity and a total internal heat gain of 150 W were calculated.

Test Room

An existing portable cabin of light mass which is used as a test room for natural ventilation at Loughborough university, is simulated [5]. The test room is of light mass so that a quick response to the effect of openings can be detected. There are four sets of metal louvres fitted in the room (see Figure 1). Each unit has the overall dimensions of 125 cm wide, 80 cm high and 20 cm deep and contains 5 of 12 cm wide adjustable louvre blades. The louvres were fitted to the test room so that the air flow measurements can be carried out for different size of opening at high and low levels.

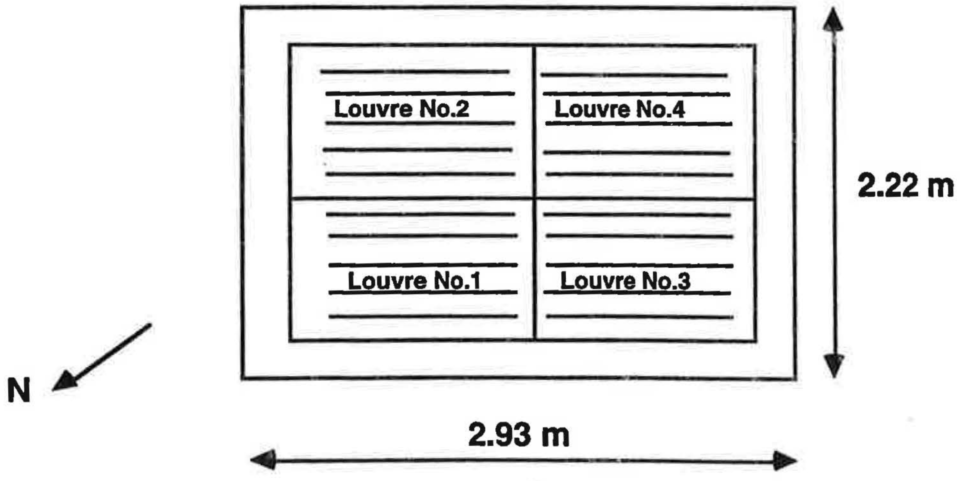

Figure 1. Schematic diagram of the louvre's arrangement in the test room

THE SIMULATION RESULTS

Light weight test room

The comfort results for the standard portable cabin and cases 1,3, and 5 are shown in Figure 2.

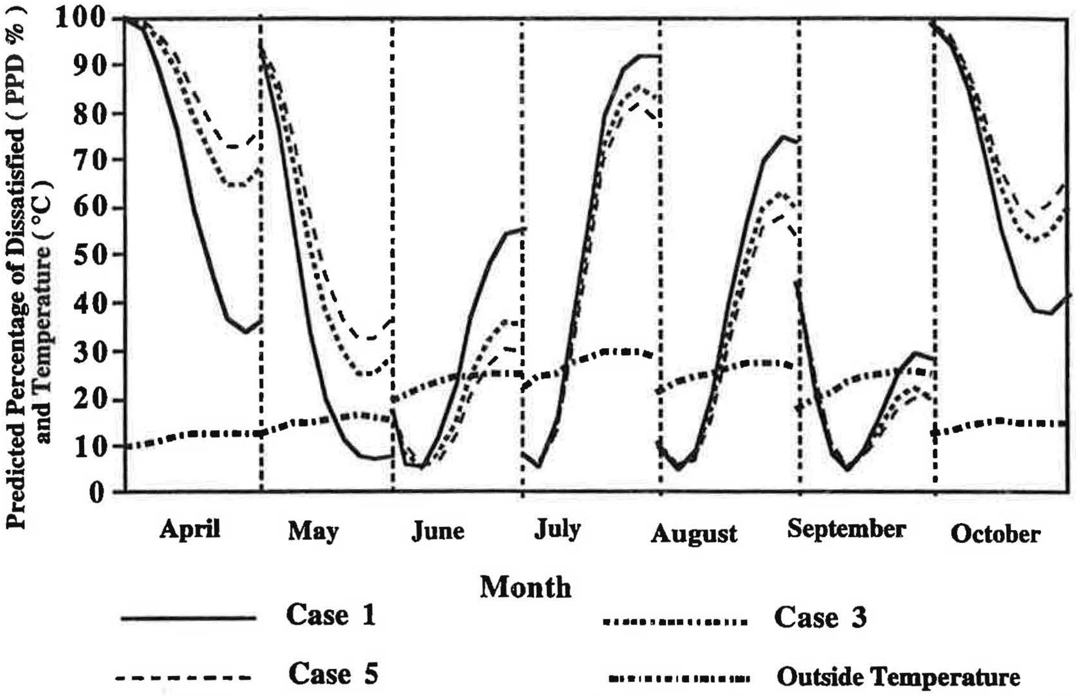

Figure 2. The PPD values for light weight test room and different louvre's position

It can be seen that for the months of April, May and October the best ventilation strategy is to close the louvres. This is mainly due to the lack of any heating input and the average PMV value was about -2.0. However, for the months of June, July, August and September maximum opening will provide better comfort inside the room. Despite maximum opening the PPD values for the months of July and August were very high about 80% and 58% respectively.

Medium thermal capacity test room

In this case a layer of medium concrete block of 200 mm thickness was added to the walls. Simulations were carried out for the same cases as before and the results are shown in Figure 3. A similar louvre control strategy as the above was observed. However for the months of June and September the PPD values were lowered by as much as 50% and for July and August the PPD values were reduced by 40%. For April, May and October, with the louvres closed, the PPD values were increased by 25%. The main reason for this increase is the thermal capacity of the building as it takes longer to heat the room temperature.

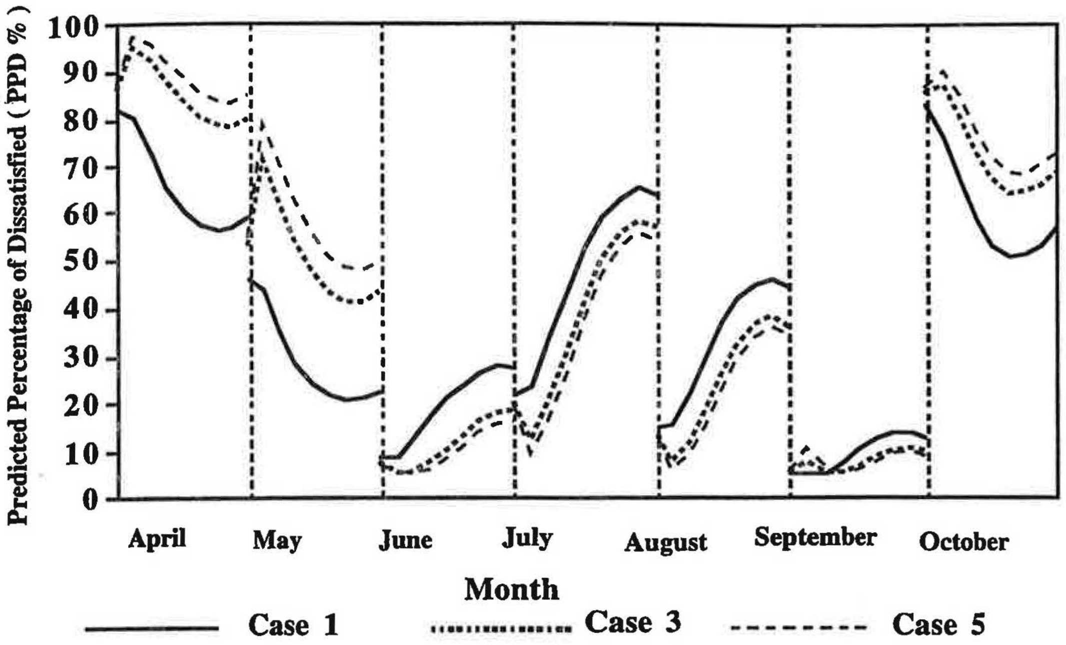

Figure 3. The PPD values for Medium weight test room

High thermal capacity test room

The additional mass to the original light weight walls were a layer of medium concrete block of 200 mm thickness, an 85 mm cavity thickness filled with rigid polyurethane insulation and a layer of inner brick of thickness 100mm.

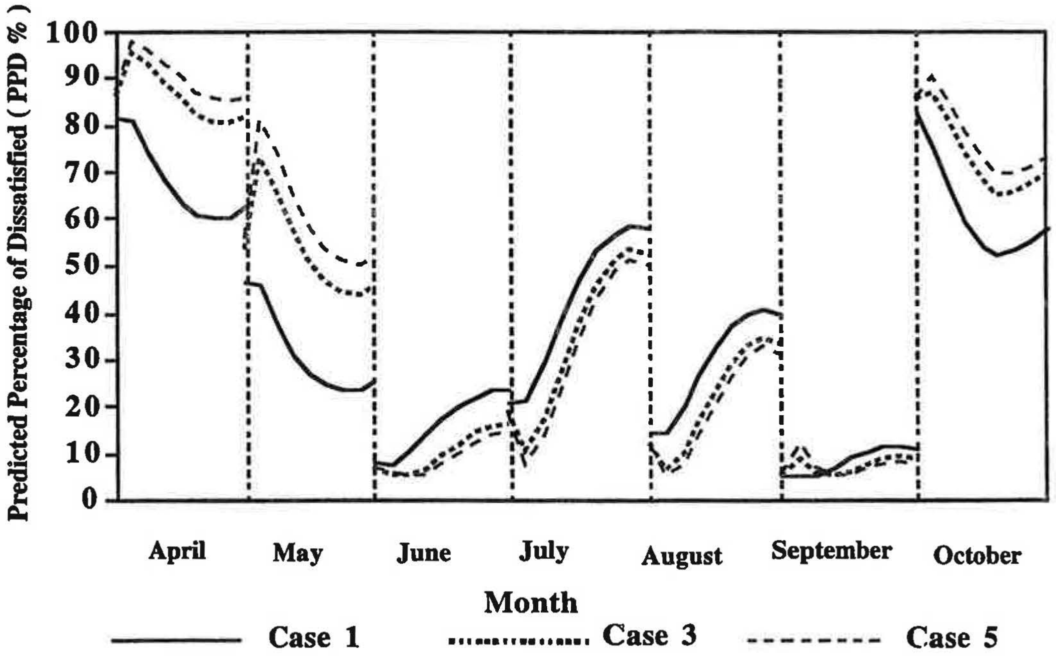

Figure 4. The PPD values for high thermal capacity test room

Also a 110 mm cavity thickness filled with rigid polyurethane insulation was added to the ceiling.

The results shown in Figure 4, demonstrated the same control strategy as before but with even lower PPD values than the above for the summer months.

CONCLUSIONS

Thermal comfort simulations were carried for a light weight test room which is naturally ventilated. The results showed that to achieve the desired thermal comfort the control strategy for the months of April, May and October is to close the louvres (case 1) and for the months of June, July, August and September to have maximum opening (case 5).

Additional mass was added to the test room and simulations were carried out for a medium and high thermal capacity room. For both cases similar control strategies were predicted with improvement in the PPD values by 20% and 25% respectively.

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