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Energy use and thermal comfort in a rammed earth office building

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Abstract

A two-storey rammed earth building was built on the Thurgoona Campus of Charles Sturt University in Albury-Wodonga, Australia, in 1999. The building is novel both in the use of materials and equipment for heating and cooling. The climate at Wodonga can be characterised as hot and dry, so the challenge of providing comfortable working conditions with minimal energy consumption is considerable. This paper describes an evaluation of the building in terms of measured thermal comfort and energy use. Measurements, confirmed by a staff questionnaire, found the building was too hot in summer and too cold in winter. Comparison with another office building in the same location found that the rammed earth building used more energy for heating. The thermal performance of three offices in the rammed earth building was investigated further using simulation to predict office temperatures. Comparisons were made with measurements made over typical weeks in summer and winter. The validated model has been used to investigate key building parameters and strategies to improve the thermal comfort and reduce energy consumption in the building. Simulations showed that improvements could be made by design and control strategy changes.

Keywords: Rammed earth; Thermal comfort; Energy; Office building

1. Introduction

A number of ‘green’ buildings have now been constructed in Australia and throughout the world. Many of these buildings have won awards. One of these is the two-storey rammed earth ‘Academic Offices Building’ on the Charles Sturt University (CSU) Campus at Thurgoona in New South Wales, Australia. This campus has been called “deep green” because of its claimed low environmental impact [1] and the Academic Office Building has received a number of awards including a special “jury award” from the Royal Australian Institute of Architects for an environmentally sound design. However, there has been little data presented on the performance of the campus or this office building.

Thermal comfort is recognized as a key parameter for a healthy and productive workplace. At the same time, lowering energy use in commercial buildings is vital if a significant reduction in greenhouse gas emissions is to be achieved. Traditionally thermal comfort has been achieved at the expense of significant energy use for heating and/or cooling. However, a well-designed building should be able to provide good thermal comfort, while simultaneously having low energy consumption. The objective of this research was to establish (a) whether the office building on the CSU Thurgoona Campus provides a satisfactory level of thermal comfort; and (b) if this building uses significantly less energy, and thus generates less greenhouse gas emissions, than a nearby comparable building of conventional construction and operation.

The purpose of this paper is to fill the information gap that can exist between an award-winning ‘green’ building design and the realities of occupancy and operation. To provide the necessary background to the study, the paper begins with a description of the rammed earth building and the prevailing climate at its location. The methodology used to assess its performance in terms of comfort and energy use is then presented, followed by some results. A TRNSYS model of three of the offices was developed and this has been used to further investigate the building’s performance. The simulation results are discussed and some conclusions are drawn from these and the earlier results.

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Fig. 1. Northern aspect of rammed earth office building (right of figure).

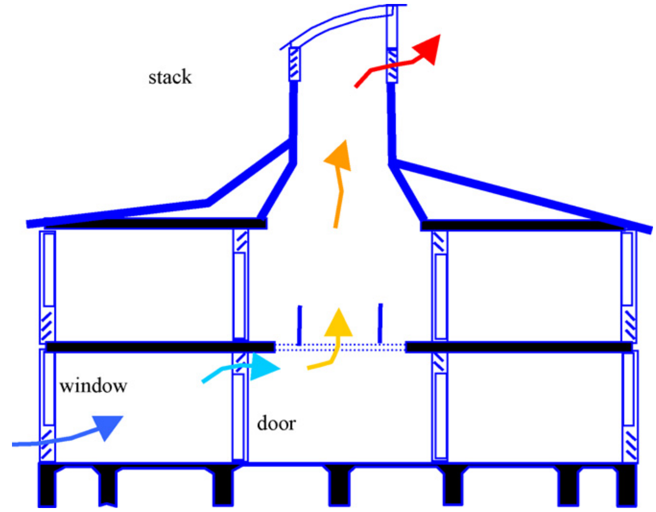

Fig. 3. Cross section through the building showing night ventilation path.

2. Building description

The CSU office building contrasts sharply with a typical office building in almost every feature (Fig. 1). It is a two-storey building with load bearing rammed earth external and internal walls and there is no steel frame. The windows open to permit natural ventilation. The building is curved and orientated as shown in Fig. 2. There is a central corridor running the length of the building on both levels with offices on either side. Each office is typically 10.5 m^2 in floor area. The circles in Fig. 2 are rainwater tanks. The ellipses are voids between the ground floor and upper storey giving a light and ventilation well. Ventilation towers or stacks are situated above these wells.

Hydronic heating and cooling has been installed instead of an HVAC system and there are circulation pipes embedded in the ground floor slab and the two ceiling slabs. Ninety-eight square metres of flat plate solar collectors have also been installed on the roof of the building. It was anticipated that these panels would collect sufficient energy in winter to significantly reduce gas consumption. By circulating water through the panels at night in summer, it was also expected that radiant cooling would produce a store of cold water to reduce cooling energy requirements on the following day.

Cooling is also achieved through using a night ventilation purge in summer (Fig. 3). Fresh air is allowed to circulate in through the louvres located under the office windows and out through the louvres in chimney ventilation stacks. These sets of louvres are computer controlled, whilst the louvres above the office doors may be only operated manually. Since a hydronic system is used, there is no need for a suspended ceiling to conceal duct work, and the concrete ceilings are exposed. In some places, a corrugated profile has been cast into the ceiling to increase its surface area to enhance convective heat transfer. The floors are carpeted.

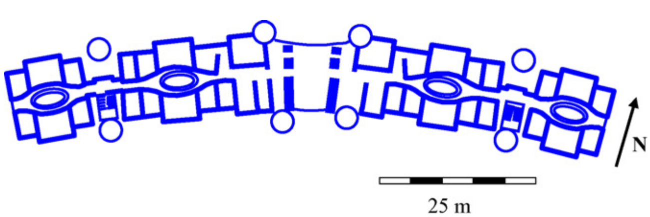

Fig. 2. Schematic plan view of second storey of rammed earth office building.

The windows are single 6 mm glass with wooden frames. The offices have double hung vertically sliding sash windows with weather strip sealing. In the stair wells and at the end of the corridors upstairs there are manually operated louvre windows. Window shading has been carefully designed to exclude all direct beam sunlight during the summer months. Each office has a variable speed sweep fan controlled by the occupier and these fans are seen as an important cooling mechanism. The building has woollen insulation placed underneath the roof sheeting rather than on top of the upper ceiling slab. Solid-foam insulation was installed around the edge of the concrete slabs. The external doors at CSU all close automatically and seal against a wooden frame.

3. Climate

The region is characterised by long-hot summers and cool/cold-wet winters, typical of a Mediterranean climate. The mean maximum temperature in January is 31.8 °C and the mean minimum in July is 3.1 °C [2]. There is a large diurnal variation between maximum and minimum temperatures. On average in January, the diurnal swing is 16.6 °C, while in July it is 9.5 °C. In January, the mean daily average temperature is 23.5 °C. In summer, on average there are 16.6 days when the maximum temperature is expected to be over 35 °C, while in winter there are 31.9 days with a minimum temperature below 2 °C (Fig. 4). Furthermore the daily maximum temperature is below 20 °C for 5 months of the year.

In this area of inland Australia the relative humidity in summer is between 30 and 50%. As expected, the skies are less cloudy in summer with an expectation of 10 h sunshine per day, while in winter on average there are 4.5 h of sunshine per day. The global irradiation on a clear day in summer may reach 30 MJ/m^2.