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Performance of hospital spaces in summer: A case study of a 'Nucleus'-type hospital in the UK Midlands

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ABSTRACT

Nucleus-type Hospital in Glenfield comprises connected cruciform blocks with numerous small courtyards between. The hospital has mechanical ventilation and perimeter heating. The wards have a hybrid ventilation strategy with a low rate of mechanical ventilation. Ventilation through windows is the main source of summer time cooling. This paper investigates the summer time performance of spaces that are mechanically ventilated but passively cooled. The paper presents the measured indoor temperatures in selected hospital spaces and compares them with thermal comfort criteria. Finally, future summer conditions for the ward space are predicted using a calibrated multi zone dynamic thermal model.

During June to September 2010, the maximum indoor temperatures in the case study spaces varied between 27.3 °C and 29.3 °C. The nurse station was found to be the hottest area. During this period the performance of most of the monitored spaces was reasonably within the thermal comfort threshold as defined by HTM03-01. The simulation results demonstrate that light-touch low carbon interventions could produce comfortable conditions in bedrooms into the 2050s in UK Midlands.

1. Introduction

In UK, due to intensity and scale of development, Hospitals on most occasions form deep build environments. These environments can experience overheating during the summer, especially when the outdoor temperature is more than 20 °C [1–4]. The Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC) research project is investigating the impact of summer overheating in hospital campuses operated by four National Health Service (NHS) Acute Trusts. The sites under examination are: Addenbrooke's (Cambridge); Bradford Royal Infirmary; Glenfield Hospital (Leicester); and St Albans City Hospital. In each of these hospitals, 125 spaces within 3 to 4 wards in 2 or more buildings have been monitored since June 2010.

The degree and duration of overheating, especially in hospital, will depend on geographical location, building design, ventilation strategy and internal gains [3,5–7]. Geographically, the Addenbrooke's tower[1] block is exposed to a climate which is similar to Southern England (warm summer[2]) conditions. The building has a hybrid ventilation strategy with a high rate of mechanical ventilation (4 ach^{-1}) while radiant ceilings provide space heating [2]. On the other hand, the Nightingale[3] wards (open wards) in Bradford are exposed to a Northern England (cool summer) climate and they are naturally ventilated with perimeter heating [3]. This paper will focus on Nucleus type hospital, which has a hybrid ventilation strategy with low rate of mechanical ventilation (1.2 to 1.8 ach^{-1}) and located in the UK Midlands so that one could have reasonably good understanding on performance of a third commonly occurring hospital building types and its responsiveness to the respective climatic conditions.

The Glenfield[4] Hospital design, developed in the late 1970s and opened in 1984, was based on the 'Nucleus' concept (Fig. 1). 'Nucleus' is the name given to a way of planning hospitals that was widespread in the UK between the late 1970s and the early 1990s; more than 100 whole 'Nucleus' hospitals or part-schemes were constructed [9,10]. 'Nucleus' was a template-based approach which accommodated hospital departments within a standardised cruciform floor area of 1000 m^2. These templates were laid out on one or both sides of a connecting corridor (the 'street') to a maximum of two storeys. In theory, any template could be placed above

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[1] Built in 1960s.
[2] This research considers 1st May to 30th September as summer.
[3] Built in 1900s.
[4] Construction was carried out in two phases. 1st and 2nd phases were completed in 1984 and 1989, respectively.

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Fig. 1. Aerial view of Glenfield Hospital. The light shade (yellow) areas indicate the locations of the case study wards and the waiting area. The black patch is the proposed new research centre. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
(Source: Google earth image modified [8]).

or alongside any other, creating a low-rise regular 'mat plan' [11] with numerous courtyards. One intended feature of the chequerboard layout was that areas could be naturally lit and ventilated from the courtyards where clinically appropriate [12].

At Glenfield, the principal cooling for the wards is by natural ventilation through window openings. This paper investigates the performance of a naturally cooled Nucleus ward in the UK Midlands, during summer 2010, and simulates light touch low carbon strategies to reduce overheating during future summers. Glenfield Hospital is located in a climate which is transitional between northern and southern England. The historical climate data[5] for Leicester (UK Midlands), covering the period between 1971 and 2000, shows that the summertime mean maximum and the mean temperatures were in the region of 20.0 °C and 14.5 °C, respectively [13]. Detailed analysis of 10 years hourly summer data[6] prior to 2010 shows that only in 2003 were there 9 h above 30 °C with a maximum temperature of 31.9 °C (Fig. 2). Generally, there were fewer than 90 h over 25.0 °C in each summer, except for 2003 (97 h) and 2006 (150 h). In 2010, there were 36 h over 25.0 °C with mean and maximum temperatures in the region of 14.3 °C and 27.3 °C, respectively. When compared with all the summers of the last decade, it appears that the 2010 summer was mild (Fig. 2) and the findings should be viewed taking this into consideration.

2. Methodology

The 'DeDeRHECC' research team has developed a standard methodology to study the performance of the hospital environments [1]. A brief description of the methodology is presented here. Firstly, representative recurring 'type' buildings are identified on case study sites and information on their geometry, construction, service strategy and environmental controls is sourced from construction drawings, discussions with facilities managers, and field visits. Secondly, internal temperatures are monitored in selected representative spaces, with the exact choice of spaces for each building being made in consultation with ward staff and facilities managers. Thirdly, the downloaded data are cleaned and results are compared with the thermal comfort criteria described in Health Technical Memorandum 03-01[7] [15], BSEN15251[8] [16] and CIBSE[9] Guide A [17]. Thresholds for these criteria are presented in Table 1. For a year, the HTM03-01 limiting value is 50 h. The study assumes that indoor temperatures do not rise above 28 °C outside the summer period (May to September). Therefore, 50 h are assumed for the summer period. For any performance evaluation carried out for less than five months of the summer period, the HTM03-01 limiting value is adjusted proportionately for the corresponding period. For the monitoring period[10] 1st June to 30th September, the threshold values for HTM03-01, BSEN15251 and CIBSE are 40, 147 and 12 h, respectively. Finally, a sample ward space is modelled using the IES dynamic thermal model [18]. Since the focus of the research project is overheating, the model is calibrated by comparing predicted with measured internal temperatures for the monitored period while keeping HTM03-1 threshold as principal guidance (section 5).

The simulation weather files for the year 2010 (Cottesmore[11]), current[12] (Cottesmore) and future (Leicester) were created by the 'Prometheus' research team at Exeter University. The future probabilistic weather files were derived using UKCP09 data [20]. A detailed account of this process has been presented elsewhere [1].

[5] Information is extracted from the climate maps produced by the Meteorological office for the Midlands [13].
[6] Cottesmore Meteorological Station, Oakham, Rutland, Leicestershire.
[7] Hours over 28 °C.
[8] Adaptive criteria.
[9] Night time sleeping condition.
[10] Total number of hours: 2928. Total number of night time (21:00 to 6:00) hours: 1220.
[11] Cottesmore Meteorological Station, Oakham, Rutland, Leicestershire. The station is located about 20 miles north-east of Leicester. This is the nearest meteorological station that provides all the data that are necessary to create simulation weather files.
[12] Current TRY is based on 1984 to 2004 weather data while the current DSY is 2004. Refer Levermore and Parkinson [19] for the method.