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MEASURED INDOOR TEMPERATURES, THERMAL COMFORT AND OVERHEATING RISK: POST-OCCUPANCY EVALUATION OF LOW ENERGY HOUSES IN THE UK

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ABSTRACT

There is growing concern in Western Europe that higher insulation and air tightness of residential buildings may lead to increased overheating risk during the summer. This risks undoing the energy savings as it may lead to the introduction of active cooling systems in buildings that so far have been cooled by natural means. This paper discusses temperature monitoring from houses in the Southwest of the UK that were built to low-energy standards (Code for Sustainable Homes Level 5). Results were analyzed using both established static overheating criteria and an adaptive thermal comfort standard. Findings suggest that these houses can be considered uncomfortably warm during summer and that they are at risk of overheating.

Keywords: low energy houses; thermal comfort; measurement; social housing; post-occupancy evaluation

1. INTRODUCTION

The domestic sector accounted for 26.4% of final UK energy consumption in 2011, with space heating accounting for 61% of the sector's energy consumption [1]. Consequently, winter temperatures and reducing the energy demand for space heating has been the main focus of attention for the UK government and the research community. Previous studies [2, 3] have demonstrated that even in the current UK climate, overheating is possible in residential buildings. In future, this risk is likely to further increase due to the effects of global climate change [4]. As low energy homes (i.e. exceeding regulatory compliance) are only recently emerging in the UK housing stock, little is known about actual indoor temperatures and risk of overheating in dwellings constructed to these advanced performance standards; moreover monitoring studies are expensive and time consuming, meaning field data of indoor temperatures in UK homes remains rather limited. Also there is high interaction between indoor temperatures and occupant behaviour, such as the opening of windows, or the use of various types of heat-producing equipment.

2. METHODOLOGY

This paper presents measured temperature data collected from two Code for Sustainable Homes (CfSH) Level 5 mid-terrace houses and an identical mid-terrace building house built to current building regulations only in Torquay, UK. The CfSH [5] is a voluntary code, stemming from BREEAM for homes. It has various levels' level 5 roughly equates to a home that is twice as thermally efficient as what currently is required by building legislation. Data is from the summer of 2013; it is part of the monitoring of a sample of 10 buildings in a development comprising 140 units. The measured indoor temperatures of the houses must be considered in the context of a warmer than average period, with two distinct hot spells. The indoor temperatures were gathered from the living rooms and bedrooms of the houses that were operating in free-running mode. Calibrated HWM Ecosense dataloggers (±0.3°C) were used to record indoor air temperatures in the living room, main bedroom, as well as outdoor air temperature. The time interval for data logging was 5 minutes. Loggers were installed sited away from heat sources and direct sunlight. Thermal comfort and overheating risk were assessed using both established static overheating criteria according to CIBSE Guide A [6] and the adaptive thermal comfort standard BSEN15251 [7]. CIBSE Guide A recommends summer indoor comfort temperatures in dwellings of 25^{o}C for living rooms and 23^{o}C for bedrooms and provides overheating criteria for evaluating the predictions of thermal models, which state that there should be no more than "*1% annual occupied hours over operative temperature of 28^{o}C*" for living rooms and "*1% annual occupied hours over operative temperature of 26^{o}C*" for bedrooms. BSEN15251 provides comfort envelope thresholds for each value of the exponentially weighted running mean of the external temperature T_{rm} within the range $10 < T_{rm} < 30^oC$ for the assessment of both warm (upper threshold) and cold (lower threshold) thermal discomfort. The adaptive criteria allow the assessment of thermal comfort over any time period. In this study, 5% of hours in the two warmest categories was used as an indication of warm discomfort.

3. RESULTS

While the overall monitoring period is three years, data in this paper relate to the timeframe of 1st July - 31th August 2013. During this period, the outdoor air temperature ranged from 10.7^oC to 35.1^oC. The monitoring period included two distinct 'hot spells' (6-10th July and 13 – 26th July), where the average daily temperature exceeded 19^oC for five and fourteen successive days, reaching 24.4^oC on 9th July and 25.2^oC on 14th July. During these two hot spells the external temperature exceeded this threshold for 143 hours and on the hottest day (14th July) 11 hours were over 25^oC and never fell below 19^oC.

Results as assessed by the static criteria are presented in Table 1. Results of house 2, assessed using adaptive criteria [B] are presented in Figure 1.

Table 1. Percentage of occupied hours with measured temperatures over 25^oC and 28^oC for living rooms and 24^oC and 26^oC for bedrooms in the houses

HOUSE (CONSTRUCTION STANDARD)	CIBSE STATIC CRITERIA					
	LIVING ROOM (08:00-22:00)		LIVING ROOM (18:00-22:00)		BEDROOM (23:00-07:00)	
	% OCCUPIED HOURS OVER 25^oC	% OCCUPIED HOURS OVER 28^oC	% OCCUPIED HOURS OVER 25^oC	% OCCUPIED HOURS OVER 28^oC	% OCCUPIED HOURS OVER 24^oC	% OCCUPIED HOURS OVER 26^oC
HOUSE 1 (CSH LEVEL 5)	50.4	1.0	54.5	1.3	71.5	25.6
HOUSE 2 (CSH LEVEL 5)	59.9	0.0	61.6	0.0	97.5	60.6
HOUSE 3 (BUILDING REGS)	1.2	0.0	1.3	0.0	3.4	0.0

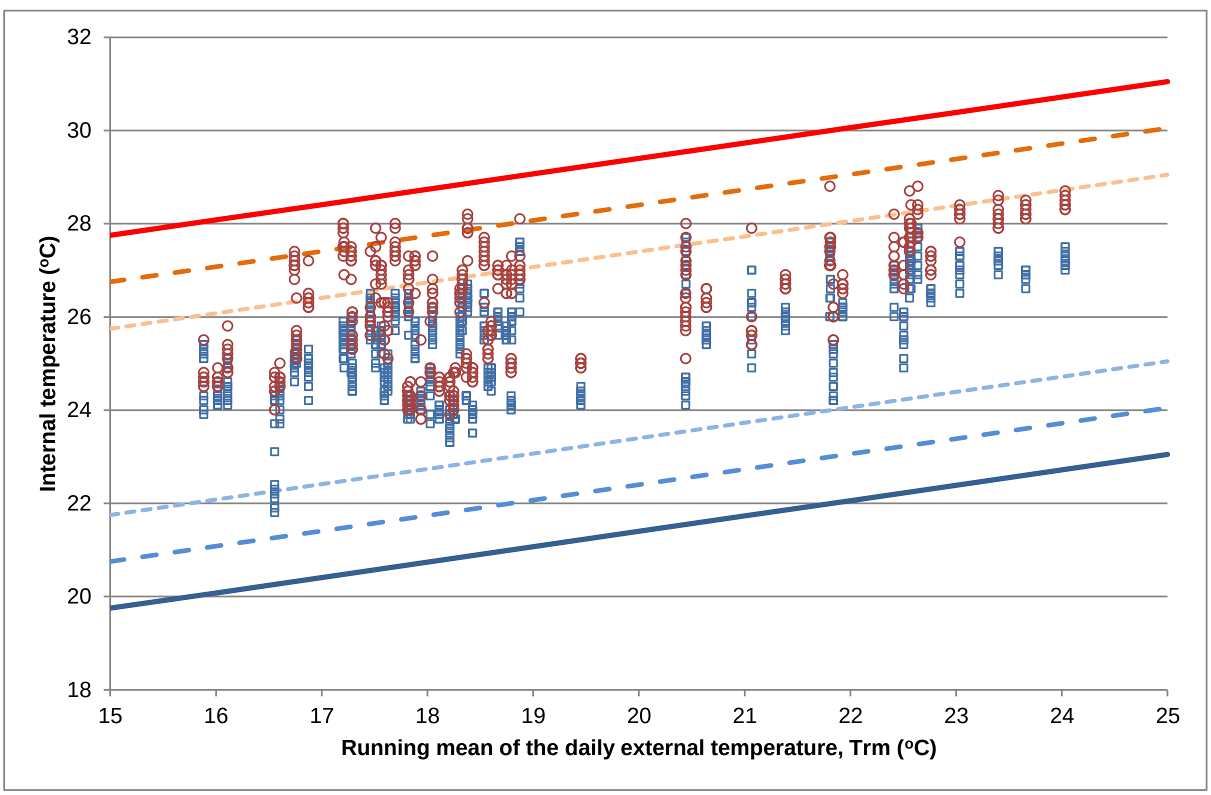

Figure 1 BSEN15251 thresholds and the hourly temperatures measured in the living room and bedroom of House 2 (Code for Sustainable Homes Level 5)

4. DISCUSSION

According to the static criteria the living rooms in the Code Level 5 houses were generally warmer than considered acceptable, but had only limited periods with extremely high internal temperatures (greater than 28°C) throughout both the day (08:00-22:00) and evening (18:00-22:00). At night (23:00-07:00), the bedroom temperatures in the Code Level 5 houses were very warm. The building regulations house however performed within the acceptable bandwidth for both the living room and bedroom.

Using adaptive criteria results the Code Level 5 houses generally performed within the acceptable bandwidth for warm and cold discomfort as defined in BSEN15251. The main bedroom temperatures in House 2 however tended towards the upper threshold, suggesting warm discomfort for the building occupants. In the building regulations house this was not the case.

As houses 1 and 2 were identical in design, services installed and orientation, variations observed are likely to reflect the role of occupant behaviour. The occupants of House 1 may have taken more effective actions to mitigate the higher internal temperatures, such as opening windows and doors, creating shade using curtains or blinds in areas exposed to direct solar radiation and switching off heat-producing domestic appliances. It is also possible that the occupants of House 2 may simply spend more time in the main bedroom and their presence as a source of heat could have resulted in increased internal temperatures. Further empirical evidence is needed about the relationship between occupancy and the avoidance of high internal temperatures and overheating in domestic buildings. Such work is currently undertaken in the IEA Annex 66 [8]

5. CONCLUSIONS

The results of the study showed that the living rooms and bedrooms of the Code Level 5 houses had average internal temperatures exceeding the recommended summertime temperatures of 25°C and 24°C respectively. Furthermore, the analysis using the static overheating criteria (CIBSE Guide A) suggested that the living rooms in the Code Level 5 houses were generally warmer than would be considered acceptable by the building occupants. Limited periods with extremely high internal temperatures (greater than 28°C) were also identified. The bedroom temperatures in the Code Level 5 houses were very warm and thereby at increased risk of overheating.

By comparison, the building regulations house had both lower internal temperatures consistent with summer thermal comfort expectations and performed within the acceptable exceedances for warm discomfort in the living room and main bedroom.

This work also identified some variations in average internal temperatures and thermal comfort between the main bedrooms of the two identical Code Level 5 houses. This finding suggests that the behaviour of the occupants may play an important role in reducing or increasing temperatures in homes. Additional work is needed to understand the effectiveness of potential occupant behaviours, such as window opening, closing curtains or blinds, and controlling ventilation to prevent excess warm air entering the dwelling during the warmest parts of the day. Further research is also needed to establish the full extent of the potential overheating risk in a broader range of dwelling types constructed to advanced performance standards. Research on the impact of occupant behaviour on temperatures is ongoing, with presence and window actions being measured over a three year timeframe.

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