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The Impact of Occupants' Energy Use Behaviour on Building Performance: a Case Study of a Tower Block in London

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ABSTRACT: This study assesses the building performance of a residential high-rise tower block in London, which, through preliminary studies was found to consume significant energy for heating. The aim of the study is to explore the effect of the dominant occupancy and heating schedules of the building on predicting the heating energy consumption of the building in the winter months in comparison to the benchmark profiles. A series of questionnaire-based survey and building simulation analysis were performed to understand the occupants' energy use behaviour and its effect on building energy use. The results show that buildings' physical issues including damp and mould caused in-efficient building envelope. To reduce the dampness and condensation effect and increase the thermal comfort, the occupants use considerable heating energy and as a result, the actual energy use patterns of the building are different from the benchmarks profiles, which caused uncertainty in predicting the building performance.
KEYWORDS: Building Performance, Energy Efficiency, Occupants' Behaviour, Retrofit, Council Housing

1. INTRODUCTION

Building energy use accounts for more than 40 percent of the global energy consumption [1]. Studies assert that occupants' energy use behaviour and their socio-demographic background may have a considerable effect on the intensity of energy used in buildings [2]. In addition, occupancy and energy use schedules associated with energy consumption are one of the main factors of uncertainty in predicting the building performance [2, 3]. However, there is a lack of consensus on approved methodologies of occupants' energy use patterns to be inputted into simulation tools [4]. For instance, a research study on ten different building typologies explored the occupancy and energy use profiles for energy simulation to develop energy calculation methods. The study showed that the average schedules cannot predict the actual energy required and highlighted the importance of realistic hourly profiles [1]. Considering the feasible and prominent occupancy and energy use patterns in building simulation may yield reliable outputs and reduce the gap between the predicted and actual building energy use.

This paper focuses on the effect of occupants' energy use behaviour on the energy performance of a 22-storey tower block in London Borough of Newham (LBN). The aim of this study is to explore the significance of occupancy and energy consumption schedules on predicting building energy performance using DesignBuilder (DB) dynamic building simulation tool.

2. RESEARCH METHODOLOGY

The methodology is based on a questionnaire-based survey, to gain more insight into the occupants' energy use behaviour, and building simulation modelling to explore the impact of occupancy and energy use patterns on heating energy consumption in the winter season. The primary studies including water ingress survey, structured interviews and field monitoring demonstrated that the thermally inefficient building envelope caused damp and mould as well as a significant increase on the heating energy use [6]. To improve the building energy efficiency, LBN Council has planned to retrofit the building. This study attempts to analyse the impact of occupancy and energy use profiles on predicting the building performance using dominant patterns obtained from the survey and compared them against the benchmark methodologies. The study aims to identify the most feasible occupancy and energy use profiles to predict the reliable heating energy use and support the Council's retrofit plan.

3. RESULTS AND DISCUSSIONS

3.1 Questionnaire-based survey

A questionnaire survey on the occupants' energy use behaviour and their lifestyles was conducted to understand issues affecting home energy performance. 108 questionnaires were distributed among the occupants of the building that includes one-bedroom and two-bedroom flats and more than 30% of the questionnaires were completed, which is an acceptable number [1,2]. According to the results, around one third of the properties have a single occupant while one third of the properties are occupied by four to five occupants including children. Notably, 46% of the households admitted that they had to use more heating energy to reduce the condensation and cold. The results of the survey demonstrate that there is a correlation between the age of the occupants and the heating energy consumption. As the occupants' age band increases, they tend to use less heating in winter ($r = -0.322$, $p < 0.05$) and

as the members of the households with children increase, the hours that heating is kept on rises as well ($r = 0.412$, $p < 0.01$). In addition, the damp and condensation problems in the flat correlate strongly with the heating energy bills ($r = 0.626$, $p < 0.01$), which confirms the occupants' complaints regarding heating energy use. From in depth analysis of the results, two representative flats were selected as the representative occupancy and heating energy consumption patterns to be incorporated into the simulation model. The dominant patterns were selected based on the highest and the lowest levels of occupancy with the associated high-energy use profiles (Flat A with one occupant and Flat B with 5 occupants including three children).

3.2 Simulation analysis

Building simulation analysis using DB software was conducted to assess the building energy performance using standardised occupancy and energy use patterns (SAP2012 and TM59), which use the average national domestic buildings patterns, against two representative patterns (Flats A and B). It should be noted that both flats have serious damp and condensation issues that have an impact on the heating energy use. The standardised methods exclude considering the effect of physical issues within the properties including condensation and damp on the energy use profiles and as a result, the predicted energy performance in the problematic properties might be different from the actual energy performance. Figure 1 presents the heating energy use patterns of flats A and B as well as SAP 2012 that applied to DB simulation model to predict the heating energy use of the tower block.

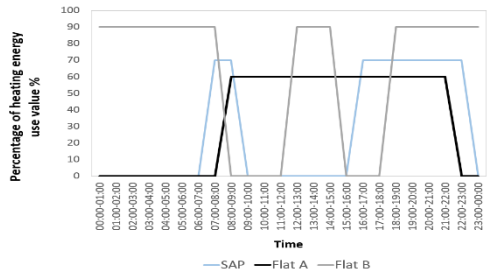

Figure 1: Heating energy use patterns applied to DB model

The results from the simulation show that the monthly heating energy consumption of the building in the winter using SAP2012 and TM59 patterns is 15067 kWh and increases to 25112 kWh using Flat B scenario while it increases to 21094 kWh using Flat A scenario (Fig. 2). It was found that because of the variances in occupancy patterns and the dampness and condensation issues of the case study, the heating period in the winter season is longer than the suggested patterns in guidelines. In addition, the occupants' energy use behaviour have an impact on the intensity of the heating energy use and causes a significant difference in the simulation outputs.

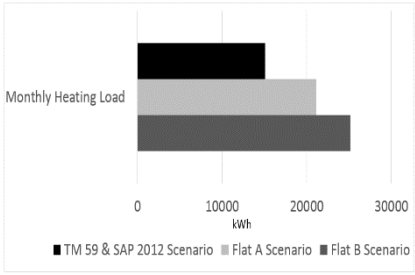

Figure 2: Predicted heating energy use of the tower block in a typical winter month using different scenarios in DB tool

4. CONCLUSION

In this study, the importance of the occupancy and heating energy use profiles on predicting the energy performance of the case study was explored. Based on the initial studies, 50% of the surveyed properties suffer damp and mould problems and to reduce the issues experienced, the occupants tended to use more heating energy. A questionnaire-based survey conducted on the occupants' energy use behaviour showed that the occupants' energy consumption behaviour and their socio-demographic backgrounds causing different energy and occupancy patterns compared to the standardised profiles. Two representative high and low patterns were identified from the questionnaires and building simulation modelling was performed using the dominant patterns as well as the benchmark patterns. It was found that the predicted monthly heating energy use of the building in the cold season is considerably higher using dominant scenarios compared against the standardise patterns. The study shows that it is not always possible to rely on standard methodologies for predicting the building performance for a building with hydrothermal issues, as the occupants' energy use patterns are different. To obtain reliable simulation results, the occupants' energy use behaviour as well as occupancy and energy use patterns need to be methodically considered as a key parameter.

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