Evaluating the Building Performance of an Office Building in London to Improve Indoor Thermal Comfort

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KEYWORDS:This study evaluates the building performance of an office building in London, which had issues reported concerning thermal comfort of occupants. The research aims to assess the occupants' thermal comfort, and building performance of this building during the winter season. The study undertakes field studies including a questionnaire-based survey, and on-site monitoring as well as building simulation modelling to evaluate the building performance and to validate a simulation model to be used in the second phase of the study concerning energy efficient and cost effective retrofit proposals.

KEYWORDS: Building Performance, energy efficiency, office building, thermal comfort

1. INTRODUCTION

It has been affirmed that issues within the indoor environment of the workplace has a significant influence on reduced productivity due to factors such as poor ventilation, lighting, and thermal discomfort [1].

Hence, efficient design of office buildings has become increasingly important due to its direct impact on occupants' health, wellbeing, and productivity. Moreover, when buildings fail to provide indoor thermal comfort, occupants may take measures that consume more energy than needed for heating and/or cooling in order to gain satisfactory levels of thermal comfort [3, 4]. This may inevitably undermine the efficiency of the building design and energy performance. The research aims to evaluate occupants' thermal comfort, and building thermal and energy performance of an office building in East London as a case study. The study explores the underlying issues causing occupants' complaints of cold and draught in the winter to help develop feasible retrofit proposals that improve occupants' thermal comfort and, in turn, reduce heating energy demand.

3. RESEARCH METHODOLOGY

To achieve the research aim a quantitative research design is adopted comprising three methods of data collection and analysis. An online survey questionnaire was designed and distributed to the building users in 2017 to gain insight into occupants' patterns of using the office spaces, levels of comfort and satisfaction, and overall experience with the indoor environment of their offices in the winter. Secondly, data loggers were fitted on all 3 levels of the building to record air temperature and relative humidity (RH) in winter 2017 (December – March) to facilitate a comprehensive analysis of indoor environmental conditions. Finally, dynamic thermal modelling using Integrated Environmental Solutions Virtual Environment (IES-VE) is applied for in-depth investigation of the building performance and to create a validated model for the subsequent stage of the study; developing energy efficient and cost-effective retrofit proposals.

4. RESULTS AND DISCUSSION

4.1 Survey questionnaire

Overall, a 25% response rate was achieved from the survey questionnaire distributed to all 152 building users. The results show that 35% of respondents normally felt cold and 32% felt slightly cool or cool during the working hours in their office in winter. Concerning air movement in the offices, 49% felt it was either very still or still while only 11% reported it was breezy or very breezy although 70% stated that they opened their windows for a few hours everyday, even during the winter. Concerning people's experience with relative humidity in their office, 60% reporting they would rate it as neutral while 27% reported it to be dry in the winter. Furthermore, the majority of the participants used secondary heating systems, 62% electronic portable heaters.

4.2 Indoor data monitoring

The indoor air temperature and RH levels have been monitored using highly sensitive data loggers fitted in the central corridors of the three floors of the building to evaluate the indoor environmental conditions associated with occupants' thermal comfort. The results shown in Figure 1 focus on the winter months from 21st Dec 2017 until 21st March 2018.

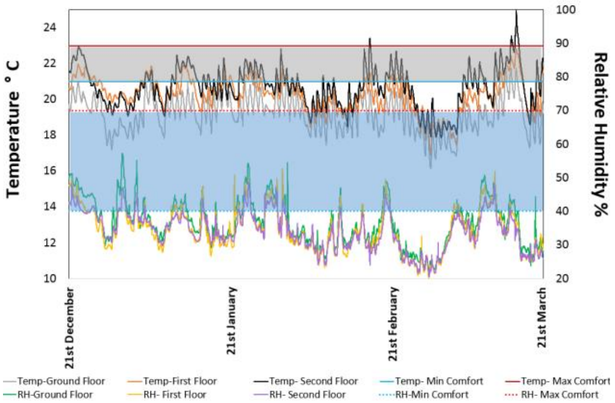

Figure 1: Indoor air temperature and RH of the ground, first and second floors between 21/12/2017 and 21/3/2018

The graph demonstrates fluctuations of indoor air temperature, where the range recorded was generally between 17°C (on the ground floor) and 23°C (on the second floor) whereas the external air temperature reached its highest at 14°C and the lowest at -6°C in winter 2017. However, the Chartered Institution of Building Services Engineers (CIBSE) Guide A [3] recommends that the acceptable indoor air temperature should be between 21° and 23°C in office buildings during the winter season for sedentary activities. In addition, an inside dry resultant temperature of 23°C should not exceed for more than 5% of the annual occupied period [4], which is not the case in this study. From the field monitoring, it was found that the indoor air temperature in the office area on the ground floor was normally below minimum comfort level. As for the measured RH levels, those have been normally below the comfort range (40-70%) reaching 20%. The results of the field measurements show that the main areas of concern with regards to thermal comfort of occupants are the offices on the ground floor followed by those on the first and second floors respectively.

4.3 Dynamic thermal modelling and simulation

Integrated Environmental Solutions- Virtual Environment (IES-VE) using ApacheSim for dynamic thermal simulation has been used as a reliable software [6] to simulate the building performance. The input parameters required for modelling include the building geometry and properties of the construction materials, occupancy patterns, internal heat gain sources, and the outdoor air temperature and RH. The building geometry is created using detailed drawings where each floor is modelled to include its specific thermal zones. The outcome is twofold; first, to validate the primary simulations of the base case against indoor monitoring results and occupants' survey; and second, to investigate potential design interventions that can help improve occupants' thermal comfort, and heating energy demand (second phase of the study). The results from IES simulation analysis have been assessed against the monitored indoor air temperature and RH levels. It was found that the percentage variation in indoor air temperature is between 5% and 15%, which has been asserted as acceptable variation and confirms that IES model can be used as a validated model. The simulation results also showed variance between the ground floor heating load and the second floor heating load (0.1KW).

5. CONCLUSION

The empirical data collected and analysed for the office building under study included a questionnaire-based survey, field monitoring of indoor air temperature and RH levels during winter 2017-18, and dynamic thermal modelling. The survey results showed that the majority of occupants suffer thermal discomfort in their offices which were typically cold or cool in the winter. Data loggers validated occupants' experiences where several cold peaks in indoor air temperatures have been recorded throughout the winter months. The results are also corroborated by IES-VE dynamic thermal modelling of the building to understand the building heating demands and help quantify energy and cost savings from the design intervention to be proposed on the second phase.

The results indicate that there are issues of discomfort in the winter that need to be addressed through appropriate design interventions. It has also been found that energy consumption in winter is higher than expected due to the use of multiple heating appliances in office spaces. The issues have been found to be mainly due to the thermally inefficient building fabric. The ongoing work in this study is the building performance evaluation using IES-VE aiming to explore the optimum design intervention to improve the indoor environment and consequently reduce the building loads.

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