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Building Performance Evaluation of an Office Building in the UK- A case study of a university office building

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Abstract: The efficiency of office building design has become increasingly important in recent years. This is both due to the negative impact inadequate office building design may have on the built environment due to excessive mechanical heating and cooling systems, as well as the impact of unsatisfactory thermal comfort and poor indoor thermal condition on the occupants' health, wellbeing and productivity at work. With the aim of discovering how the thermal comfort, and energy performance of a modern office building can be improved, a study of an existing office building, at one of the London based universities, and its occupants is carried out. The occupants had already reported several issues with the indoor environment that causes discomfort in summer and winter seasons, hence the significance of the study. An analysis of potential issues reported concerning occupants' thermal comfort and building energy performance is investigated to develop a potential design intervention to improve both aspects. In order to solve this problem, a quantitative research design has been adopted including three methods for data collection and analysis. Initially an occupant survey is carried out including questions on occupants' activity, comfort and overall experience with the indoor environment. Secondly, data loggers have been placed in the building to record air temperature and relative humidity for one whole year. At a later stage, computer simulation modelling will be used to further explore inefficiencies in the building and the potential interventions to improve the building performance and occupants' thermal comfort. The initial results show that different parts of the building have been deemed uncomfortably warm with a lack of air movement in the summer months and unacceptably cold and draughty in the winter months. This is expected to be due to the lack of adequate natural ventilation in some areas, and the lack of adequate heating and cooling in some rooms.

Keywords: Thermal comfort, building performance, questionnaire survey, field monitoring, office building

Introduction

The success or failure of a building design depends largely on the satisfaction of the building's occupants. In the case of office buildings, if occupants are not comfortable this can impact on their health, wellbeing and productivity (Amasyali & El-Gohary, 2015). Therefore assessing whether the needs of the occupants have been met after they have inhabited the space for at least a year can be a useful tool to examine the suitability of the design. Post occupancy evaluation (POE) can prove a beneficial tool to ascertain whether a building has met its design aims or whether improvements to aspects such as thermal comfort and indoor environmental quality (IEQ) would be advisable (Walbe Ornstein & Ono, 2010). It is possible that some relatively modern buildings designed and built to meet the current building regulations at the time of construction may not be considered comfortable to the users. This type of problem may occur because part of the building regulations is designed to limit the heat transmission through building materials. However, building regulations may not oblige designers to consider the unique qualities of individual buildings which also affect its internal temperatures. Each building has its own microclimate which is impacted by its surrounding buildings, orientation, geographical position, and so on (Gaspari & Fabbri, 2017). This may mean that in order to design and produce buildings which are comfortable for the occupants; more attention to detail is needed to discover the optimal geometry, orientation, fabric, etc. of the building by the designer in order to create healthy and efficient buildings. This may prevent situations in which buildings are discovered to have thermal comfort issues post occupancy. These issues may then be more difficult and costly to rectify than they would be if the prospective issues were addressed at design stage, for instance if façade retrofit is required (Martinez et al, 2015). Hence, if thermally inefficient designs are used, buildings can be very resource intensive and expensive to run. For example, Lin et al (2016) suggested much greater attention is needed in the design of sustainable office building facades in order to reduce the use of air conditioning systems. However, even when these factors are considered at design stage, buildings with thermal comfort issues provide a learning tool in which design professionals can learn from the faults made, and learn to better understand people's needs which can improve future designs of similar buildings (Hens, 2009). For example, Mlecnik (2012) carried out a post occupancy study of passive housing employing a questionnaire of the inhabitants. Passive houses are designed to be very air tight, while mechanical heating and ventilation is designed to regulate the internal temperature to a comfortable level throughout the year. The study found that some people had issues with overheating in summer and installed air conditioning. This information can be used to improve future passive houses. If buildings suffer from internal overheating and stale air in the summer months and unacceptably cold temperatures and draughts in the winter months then this will probably have implications on energy use where occupants try to achieve comfort levels. This may be exacerbated by the effects of climate change as temperatures rise. For example, Shibuya & Croxford (2016) found that there has been an increasing energy demand for heating and cooling in office buildings in Japan in recent years. This, in turn, increases operational costs for the building owner and/or its tenants as well as increasing the negative impact of the building on the environment.

The purpose of this paper is to investigate the efficiency of a university office building to fulfill its purpose as a comfortable and productive working environment. This will be tested utilising a quantitative methodology involving a questionnaire of the building's users, data loggers measuring the air temperature, relative humidity (RH) and lux levels of different areas of the building and in a further stage a model of the building using Design Builder software in order to test the existing thermal efficiency of the building and explore potential interventions that could improve the thermal efficiency of the building.

Literature review

Energy Efficient Design of Office Buildings

In recent years, increasing numbers of designers and clients have recognised the huge negative impact that the built environment imposes on the environment through carbon emissions both during the construction and operation phases (Alves et al, 2017, Jradi & Jorgensen, 2017, Wang et al, 2017). The positive outcome of this is a widespread shift in paradigm, where many buildings have been designed with sustainability as a primary concern. Some examples of this can be found in London where there are numerous BREEAM (Building Research Establishment Environmental Assessment Method) and a few LEED (Leadership in Energy and Environmental Design) rated buildings. 7 Air Street in London achieves BREEAM outstanding where the design includes sustainable attributes such as an innovative fuel cell technology heating system, a green roof and extensive cycle provision for staff. The Hub in London also attained BREEAM outstanding. Sustainable design features included a metering system to reduce electrical, heating and cooling energy use, low or no VOC or formaldehyde in the internal finishes and increased cycling facilities. 240 Blackfriars Road, London obtained the LEED platinum rating. Sustainability features include mechanical heat recovery via a thermal wheel, PV panels on the roof and an efficient building fabric with solar control glazing. Despite these efforts, Argelis & Papadopoulos (2010) contended that endeavors to produce environmentally friendly and low energy buildings may also have the unintended effect of worsening indoor air quality and the thermal comfort of the occupants. Some factors which may cause the worsening indoor air quality are that buildings, particularly office building, may have become increasingly air tight and increasingly artificially heated and cooled and may have fewer operable windows.

The British Council for Offices (BCO) stated in their report on the health and wellbeing of office workers that in 2014-2015 23 million days were lost as a result of illnesses caused by or caught at work. They concluded that the place people work in has a significant impact on this due to factors such as poor ventilation, high levels of gases such as carbon monoxide and carbon dioxide and substances such as formaldehyde (BCO, 2016). Further, Behzadi & Olawale Fadeyi (2012) stated that low ventilation rates can be correlated to the reduction in the productivity and health of office workers. In addition, more buildings have an open plan layout which needs to accommodate for many people with differing comfort levels, and there is an increasing use of electrical equipment which emit sometimes unwanted heat and light (Sakellaris, I. et al, 2016). On the contrary, Lin et al (2016) concluded in a comparison of the indoor air quality of office buildings that were intended to be environmentally friendly and standard buildings that people were more satisfied with the thermal comfort and indoor air quality in the environmentally friendly offices than the standard offices according to their survey. However the difference in the actual energy consumption of the green buildings assessed was not significantly different to the standard buildings they were being compared to. Thus, the design intentions to make them green buildings may not have materialised in reality. Chappells & Stove (2005) stated that UK building regulations are designed to minimise draughts and improve insulation, yet the regulations may well require improvements so as to address overheating issues in summer. In this study, they suggest including shading and natural ventilation requirements in the building regulations to account for better IEQ.

Therefore, the post occupancy evaluations (POE) of buildings to assess their success in terms of both the energy efficiency and the comfort of the user are crucial, both to check that the building is fit for purpose and performs as designed. Despite this, post occupancy evaluations are rarely carried out and the same anomalies may continue to occur (Meir et al, 2009). There are several different methods of POE including building performance modelling (BPM), occupant satisfaction surveys, walk-throughs and observations and monitoring of temperatures, humidity and so on during occupation. Oduyemi & Okorch (2016) argue that many of the mistakes that designers make relating to thermal comfort and energy efficiency can be negated through the use of BPM at the design stage. Whilst BPM is a useful tool to analyse design solutions and predict comfort, the assessment of occupants' satisfaction after the building has been handed over to the client will let the designers know if the building actually performs as intended. This knowledge can feed back into and strengthen the design process and BPM of prospective building projects. For example, Ohba & Lun (2010) found that building simulations cannot yet accurately emulate air flow in order to assess the comfort of naturally ventilated buildings. Therefore POE could be used to test the accuracy and validate computer simulation results.

Office Building Design for Productivity and Thermal Comfort

As stated by Hauge, et al. (2011), the indoor environment comfort of building users in terms of thermal, humidity, air movement, light, and noise is very important to the building performance, especially in the case of office buildings. This is because these factors can affect occupants' health, wellbeing and productivity which can have an impact on businesses economically. Therefore, the energy efficiency of buildings and the comfort of occupants need to be considered together in order to create successful designs. Ng & Akasah (2013) conducted research on office buildings which were designed to be highly sustainable and energy efficient. They utilised a post occupancy questionnaire involving the occupants of office buildings which had received sustainability awards and ratings such as LEED, in order to determine the comfort and indoor air quality of the buildings. They found that buildings which achieved a sustainability rating would not necessarily perform well with regards to the perceived comfort of the occupants and indoor air quality. They argued that people's perception of comfort is not as valued by building owners as energy consumption in the construction and the use of the building. This is because it is easier to quantify the economic value of those factors compared to the economic value of occupant satisfaction and productivity. However, due to its impact on productivity, a lack of thermal comfort can have an economic impact and the lessons learned from POE studies could provide a useful tool in designing energy efficient offices in future. Corroborating with this view, Niemela (2017) analysed the cost effectiveness of different renovation options on a 1980s office building based on occupant productivity upsurge. The study found that the comfort of occupants and their productivity were closely related; hence investing in occupant comfort had a significantly positive economic effect.

Whilst BPM can be used at the design stage to gauge thermal comfort levels, one factor that could not be ascertained through building simulation alone is people's ability to adapt to outdoor temperatures. Pagliano & Zangheri (2010) discerned through occupant satisfaction surveys in actual buildings and in laboratory conditions that people's thermal comfort levels adapt to external temperatures, meaning people were able to be comfortable in higher temperatures in summer and lower temperatures in winter. This type of information discovered through POE can be used in BPM in order to improve its effectiveness and accuracy. Hens (2009) found through an occupant comfort survey that more people were dissatisfied than was predicted based on standard comfort levels. However they noted that occupants may exaggerate their discomfort in order to encourage improvements to their work environment. Conversely, if occupants are trying to encourage change then they must be dissatisfied with their environment. Chappells & Shove (2005) found that building regulations and policy makers sustain a narrow and therefore resource intensive ideal level of comfort. If this was more adaptive to unique requirements, buildings may be more comfortable and have less of a negative impact on the environment.

However, Rupp & Ghisi (2017) questioned the use of predetermined adaptive temperatures based on outdoor temperature alone as they found that cultural and behavioural factors unique to each region had a bearing on people's adaptation to changing temperatures. People in more developed countries were less accepting of warmer and colder temperatures.

Whereas, people in developing countries have been found to have a wider comfort band and tended to be more forgiving of building performance shortcomings. Additionally, people in naturally ventilated buildings are more adaptive to changing temperatures than those accustomed to air conditioned buildings (Gallardo et al, 2016). Baird (2010) noted in an assessment of the POE of the Torrent Research Centre in India that; "*the generally positive user feedback to overall temperature for all three seasons is particularly significant, given the indoor temperature ranges that are higher than those deemed acceptable in air-conditioned and western contexts*" (Baird, 2010, p.321).

Occupant Behaviour and Energy Consumption in Office Buildings

Surveys regarding occupants' perception and behaviour provide a highly valuable tool to gauge whether building designs are producing unintended behaviours in people due to a miscalculation of comfort. Langevin et al (2016) studied human behaviour in relation to energy use in office buildings. They incorporated human behaviour into BPM. However these were based on statistical behavioural models, so how accurately they represent how actual occupants would behave in a specific building is unclear. Thus, incorporating the actual occupants' behaviour in relation to thermal comfort into BPM could provide a clearer picture of the effectiveness of interventions aiming to improve thermal comfort. A methodology developed by Building Use Studies (BUS) is a post occupancy evaluation questionnaire aimed at office buildings users in order to establish how the building is performing. This is in relation to; thermal comfort and ventilation, lighting and noise, personal control, space, design and image, perceived productivity and how occupants travel to work. The aim of the methodology is to highlight areas which could be improved. This type of methodology could be used alongside building simulation and data logging to get a full picture of the efficiency of a building.

An unintended outcome of buildings which do not provide indoor comfortable, is that occupants may take measures such as using heating and cooling excessively in order to gain a satisfactory level of comfort (Painter et al, 2016, Langevin et al, 2015). This will clearly undermine the energy efficiency of the building's design and performance. However allowing occupants some control over their environment can improve the energy efficiency of office buildings. For example, Li et al (2014) studied buildings which took into account occupant behaviour when designing energy efficient office spaces. They concluded that allowing occupants to control their own heating, lighting, electrical equipment and ventilation and encouraging them to behave sustainably, such as encouraging them to turn off lighting when it was not in use, had a significantly positive impact on the energy efficiency of the building. Furthermore, assuming levels of comfort and controlling heating and cooling centrally can lead to an excessive use of energy. Gallardo et al (2016) assessed the thermal comfort of an office building in a temperate environment using an occupant satisfaction survey and recordings of temperature, air velocity and relative humidity. They found that if the use of mechanical heating and cooling were judged by the recordings alone then mechanical heating and cooling would be required. However, the survey revealed that people were more comfortable than expected and would not require mechanical heating or cooling. Therefore it is advantageous to ascertain the behavior and the opinions of the occupants in order to effectively judge the thermal comfort and the energy efficiency of buildings.

Research Methodology

The aim of this study is to determine the thermal comfort of an existing office building. This is so that the information gained in this study may be used in further studies to discover optimal strategies for improving the comfort of the office building, in order to make it more energy efficient and enhance the wellbeing, health and productivity of the occupants. This study will achieve this through a quantitative research methodology with concurrent data collection techniques applied to a case study building.

Case Study: University Business Unit Building

An office building located in one of London's universities has been selected as the case study as there have been a number of complaints received from the occupants regarding the lack of air movement and overheating of some of the offices in the summer, and the uncomfortably low temperatures of some offices in the winter. Additionally, the ground floor reception, café and seating area had reported problems with draught and uncomfortable temperatures in winter leading to the areas being underused. This building was built in 2006 and had refurbishment work at a later date. It was constructed with steel frame and has metal cladding. The building comprises three floors including a three-storey atrium. It contains 1098 square metres of office space with 75 businesses based there. The building is generally occupied from Monday to Friday between the hours of 9am to 6pm. The building is busier from September to June during the university's term time, but is used throughout the year by staff, who use some of the offices and laboratories, and businesses that rent the offices. The building is surrounded by a four-storey high building to its south, a 3-storey building to its east and a 2-storey building to its north. There are no buildings to its east.

Occupant Survey

The first research method used in this study is an occupant survey. Occupants were requested to fill in a digital or paper questionnaire including questions on occupants' usage patterns and behavior, perceived comfort, perceived indoor air quality,and any other issues experienced in the building. This is a mainly quantitative survey with close-ended questions with a couple of qualitative open-ended questions. Questions relating to comfort were asked on a five or seven point scale e.g. for the question '*How do you generally feel in your office during the summer season?*'. Answers ranged from cold to hot with neutral in the middle. Occupants were also asked how they adjusted their environment to make it more comfortable, e.g. occupants were asked when they opened windows and if they had any additional heating or cooling appliances in their offices such as fans or electric heaters. Occupants were also asked open ended questions such as; '*How do you think the thermal comfort of your office could be improved?*'. The questionnaire was distributed to the building users over a period of 4 weeks in July. Only 37 responses were received due to many users being on annual leave.

Data Monitoring

The second research method employed is data monitoring of internal physical parameters including; air temperature and relative humidity levels using Hobo data loggers. Altan et al (2013) utilised a similar methodology on their study of indoor air quality of homes in Scotland. This allowed them to compare the actual air temperature and relative humidity levels in the homes against the acceptable levels and graphically represent this for analysis. This provides a simple methodology to find areas which require improvement or further investigation in order to improve conditions. The physical parameters are measured at 30 minutes intervals from July 2017 and expected to continue until July 2018. There are four data loggers positioned on the ground floor including the lobby, the reception, café and seating area. This is because the occupants are normally not satisfied with the thermal comfort in these areas on the ground floor. These areas should be welcoming and comfortable and are important to the success of the building, as it has the potential to be a place where people from the businesses meet and have their lunch and is the first place the users will experience when they enter the building. In addition, five data loggers are placed in the office units on the ground, first and second floors. Three of them are placed in the ground, first and second floor corridors leading to the external businesses offices. One is placed in the atrium on the second floor and one is placed inside one of the offices on the first floor, which is one of the most problematic rooms. These offices are used by university staff or are rented to external businesses and these areas are also important to the success of the building. If the business unit areas are not thermally comfortable for the users it might reduce the health and productivity of the staff and as a result the current or prospective businesses may not remain in the building for the long term. CIBSE Guide A states that the comfortable operative temperature for offices in the winter months is between 21°C and 23°C, assuming for 0.9 clothing levels and 1.2 metabolic levels. In the summer months, they stipulate comfortable operative temperatures are between 22°C and 25°C, assuming for 0.7 clothing levels and 1.2 metabolic levels. Moreover, a minimum air movement rate is suggested to be 10 l/s per person and relative humidity levels between 40% and 70% are generally acceptable. In the non- air conditioned rooms relative humidity levels of 30% may be acceptable. The data loggers will remain in place for one year in order to have a full picture of the thermal comfort throughout the year.

Results and Discussion

Occupants' survey

As mentioned previously, a questionnaire-based survey was conducted in the case study building during the summer while the indoor thermal comfort variables for the summer months were being measured. Overall 37 questionnaire forms were completed by the users as the building was occupied by this number over the summer period. The results show that 63% generally felt hot in the summer in their office, while 18% felt warm. This indicates that the majority of the respondents were not satisfied with the indoor thermal environment during the working hours in the case study building during the summer season. In addition, in response to the question concerning rating the air movement in their office while the windows are open in summer, 54% felt it was either very still or still while only 14% reported it was breezy. This suggests that the majority of the respondents felt that there was a lack of air movement in their office space even when the windows were open. Additionally, the vast majority of respondents stated that they opened their windows at all times during the summer. Moreover, there were mixed responses to the question concerning people's experience with air humidity in their office during the summer with 41% reporting they would rate it as very humid and humid, while only 16% rated it as dry or very dry, while 43% reported it as neutral. In order to understand whether occupants were using additional cooling methods in their offices, and if the cooling methods they used in their offices were inadequate, they were asked if they had any secondary cooling systems in their offices. The result shows that the majority of the respondents had a secondary cooling system in their office; 63% having portable fans while 18% had portable air conditioning units. Table 1 summarises the main findings of the survey that conducted in the summer season.

Table 1. Summary of main findings of questionnaire survey for summer season

Thermal Perceptions	Air Temperature		Air Movement		Relative Humidity		
	Warm	Hot	Still	Breezy	Humid	Dry	Neutral
Respondents Percentages	18	63	541	4	41	16	43

With regards to the winter season, 55% of the people surveyed said they felt cold or very cold in their office, 17% responded neutral, while only 8% responded they felt warm. Furthermore, 62% reported they had electric portable heaters in their offices when asked about the secondary heating system in their office. This would also suggest that the offices are uncomfortably cold in the winter months so they had to bring in additional heating sources which increase the heating energy demands in the cold winter months. Therefore, the data loggers will be kept in the office spaces throughout the winter months to further understand the thermal comfort issues. Similarly to the summer season, half the respondents answered they felt the air was either very still or still, while only one person responded very breezy and three people responded breezy to the question '*How would you rate the air movement in your office during winter?*' This would again suggest that the respondents feel there is a lack of air movement in the offices throughout the year. Moreover, people surveyed were asked how they would suggest the thermal comfort of their offices could be improved. Nearly half the respondents suggested the installation of air conditioning system in the offices. Some of the other responses included more heating, more control over the temperature, better insulation, replacement of the metal roof, more windows and an improvement in air flow rate.

Field Monitoring

As mentioned previously, the thermal comfort variables of the case study building including the indoor air temperature and the indoor relative humidity levels have been monitored with data loggers on the ground floor and the business units of the building for one year to assess and optimise the building performance and the occupants' thermal comfort. The focus of this paper is on the month of August for the on-site monitoring to evaluate the thermal comfort and thermal performance of the business unit internal corridors on three floors, as well as the reception area on the ground floor including lobby, seating area, seminar room, and the main reception. Figure 1 presents the location of the data loggers in the case study building.

The results of the field monitoring of indoor air temperature and RH levels on the ground floor in August 2017 (figures 1 and 2) indicate that although the indoor RH levels fluctuated significantly they mostly remained within the comfort band. However, the indoor air temperature sometimes dropped below the minimum comfort temperature for summer, which is 22°C, in the reception area. This may be because the seating area is next to the external doors which are opened and closed on a regular basis throughout the day increasing the air flow rate and as a result causing heat loss on the ground floor. It has been noticed that some of these instances of under heating did occur outside office hours so this does not affect office workers' comfort levels. However, there were instances in which the low temperatures occurred during office hours. This was an expected result as the occupants of the ground floor reported problems with temperatures becoming too low in the winter months; they did not report any problems with overheating in the summer. Data monitoring of the ground floor spaces will continue throughout the winter period to understand if and reasons why the temperature falls significantly below the comfort range for offices during these months.

In contrast to the measured indoor air temperature on the reception area, the monitoring results of the internal corridors of the business units show that some of the measured area are normally above the maximum comfort range in summer (Figure 3). The results show that the indoor air temperature on the second floor is normally above the maximum comfort band for summer. In addition, in the 1st floor corridor, the indoor air temperature was normally just below the maximum comfort band and was sometimes above this range. However, the indoor air temperature stayed within the comfort band on the ground floor corridor.

Figure 1. Floor plans of the case study building presenting the location of the data loggers

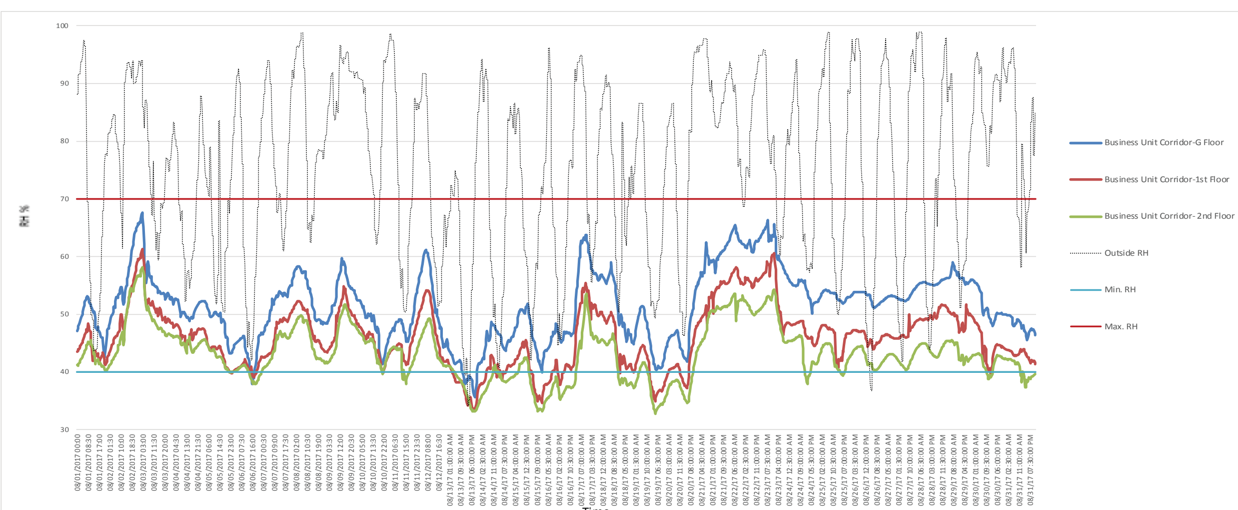

Figure 2. Indoor RH of the Business Unit corridors of the case study in August 2017

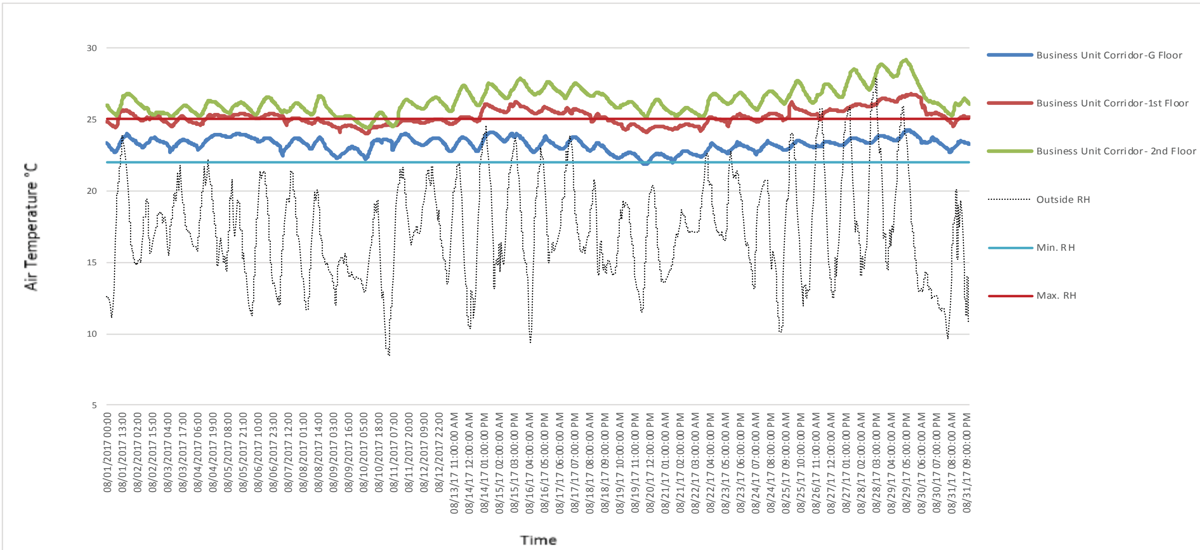

Figure 3. Indoor air temperature of the Business Unit ground, first and second floors in August 2017

Generally, the data loggers' results show that the higher outdoor temperatures, the worse the indoor thermal conditions in the office units became. In terms of the relative humidity in August, the measured RH levels are normally within the comfort ranges (Figure 2). However, sometimes the measured RH levels fell below the comfort range. The 1st floor corridor fell below minimum comfort levels for six days in this month, and was also at the high end or above maximum comfort levels for the measured indoor air temperature throughout the recorded period. The results of the field measurements show that the main areas of concern in terms of thermal comfort of the occupants are the business units' corridors on the 2nd and 1st floors. As a result, the main focus of the next stage of this study on building evaluation using DesignBuilder simulation tool will focus on these problematic areas.

Research Limitations

The results were limited by the number of respondents to the questionnaire. As there were only 37 respondents during the summer season, it cannot be assumed that all building occupants agree with the findings. The questionnaire will be redistributed during the working hours in cold season as well, when the building is fully occupied to get a larger number of respondents so that conclusions can be drawn with more accuracy. It should be noted that 45% of respondents were white, 16% were Asian, 8% were black, 6% were Pakistani or Bangladeshi, 3% were Latin and 3% were Chinese. In addition, 19% decided to give no comments. Therefore, the results may be biased towards white people. 32% of respondents were aged 25 to 34, 30% were aged 35 to 44, 16% were aged 16 to 24, 11% were aged 45 to 54, 8% were aged 55 to 64 and 3% were aged 65 and above. There does not appear to be a bias towards any age group as this matches the ages of the building occupants.

Conclusion

In conclusion, this study presents the results of the field studies of an office building at a London-based university in order to evaluate the building performance and thermal comfort of the occupants on the ground floor reception area and the business units' corridors on three floors. The field studies include the questionnaire-based survey and field monitoring of thermal comfort variables including the indoor air temperature and the relative humidity levels during the summer month of August 2017. The field study results indicate that the thermal comfort of the case study building needs to be improved in summer months in order to fulfill its main purpose as a being a productive and healthy working environment for both permanent and temporary staff. The questionnaire-based survey results show that the respondents are not thermally comfortable in the business units as their offices were normally too hot for them in the summer months and too cold in the winter period. In addition, the measured indoor thermal comfort variables by data loggers have corroborated with the views of the respondents by recording indoor air temperatures normally above the maximum comfort levels or at the higher end of the comfort band throughout the data collection period.

The results show that the second floor business unit's corridor have the most problems regarding the overheating risk in summer months, while the 1st floor corridor was also shown to not comply with the comfort levels. The reception area on the ground floor appeared to remain within the comfort range throughout summer according to the questionnaire results. However, the thermal comfort issues were reported to be during the cold winter period on this floor. In addition, based on the field monitoring results the indoor temperature and relative humidity levels during the summer months on this floor were normally within the comfort band. Therefore, the data loggers will remain in place throughout the winter season in order to discover the thermal condition of this floor throughout the year including the winter and the summer periods. The second phase of this project is the building performance optimisation for energy efficient retrofit of the building in the short term. This is in order to provide a comfortable and productive indoor thermal environment for the staff and consequently reduce the building's energy loads both in winter and summer seasons. This is with the aim of encouraging business tenants to be inclined to remain in the offices for the long term.

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