Occupants' satisfaction in BREEAM Excellent Certified Buildings

Azadeh Montazami[1], Sepideh Korsavi[2] and Gideon Howell[3]
Coventry University, Coventry, UK
Azadeh.montazami@coventry.ac.uk[1], korsavis@uni.coventry.ac.uk[2]
Gideon.Howell@coventry.ac.uk[3]

Abstract: This paper examines occupants' satisfaction of three BREEAM excellent certified buildings at Coventry University in the UK. Occupants' satisfaction is evaluated against passive and active sustainable approaches used in these buildings to improve Indoor Environmental Quality (IEQ). This paper adopts a quantitative approach by running a seven-point rating scale questionnaire to obtain occupants' overall satisfaction score in each building. A total of 180 occupants were surveyed to investigate occupants' satisfaction of the thermal environment, indoor air quality, visual and acoustic environment during summer and winter. The results show that average satisfaction scores are towards the more acceptable part of the scale in BREEAM Excellent certified buildings. The sustainable approaches towards these buildings and applied passive and active techniques improve occupants' satisfaction of Indoor Environmental Quality. It should be highlighted that Coventry University has improved its sustainability approaches towards its buildings over time, with newer buildings showing a higher level of satisfaction.

Keywords: BREEAM, Indoor Environmental Quality, Occupants' Satisfaction

1. Introduction

In the 1990s, it was acknowledged that occupant's discomfort and complaints about the indoor environment were not caused by one single parameter (Fransson et al. 2007). The concept of Indoor Environment Quality (IEQ) can be grouped into four main categories: thermal comfort, indoor air quality (IAQ), visual comfort and acoustic comfort (Marino et al. 2012, Wong et al. 2008, Sarbu and Sebarchievici 2013, Lai et al. 2009, Mendell and Heath 2005, Frontczak and Wargocki 2011, Dorizas et al. 2015, Astolfi and Pellerey 2008). The most important aspects of IEQ are satisfaction with the thermal environment (Frontczak and Wargocki 2011, Wong et al. 2008, Huang et al. 2012, Humphreys 2005, Zuhaib et al. 2018, Sakhare, V. V. and Ralegaonkar, R. V. 2014, Astolfi and Pellerey 2008, Lai et al. 2009, Ralegaonkar, R. V. and Sakhare, V. V. 2014, Yee 2014) and Indoor Air Quality (Zuhaib et al. 2018, Astolfi and Pellerey 2008, Humphreys 2005, Ghita and Catalina 2015), acoustic environment (Zhang, D. and Bluyssen 2019, Heinzerling et al. 2013, Astolfi and Pellerey 2008, Lai et al. 2009) and visual environment (Heinzerling et al. 2013). Due to the significance of Indoor Environment Quality and energy consumption, the Building Research Establishment Environmental Assessment Method (BREEAM) was launched in 1990. BREEAM is the world's leading and most widely used environmental schemes (Dutch Green Building Council 2010) that assesses the 'absolute' performance to minimize the overall CO2 emission and energy consumption (Lee and Burnett 2008). BREEAM is a voluntary rating system used in the UK and internationally to promote sustainable built environment practices (Curran et al. 2018). It can be applied to new and existing built environment developments to evaluate their impact on energy and indoor environmental quality

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(Curran et al. 2018). Overall the scheme promotes standards reflecting local sustainability issues and environmental conditions (Reed et al. 2011). BREEAM covers issues in different categories of sustainability including Management, Health & Well Being, Energy, Innovation, Transportation, Water, Materials, Waste, Land Use and Ecology and Pollution (Dutch Green Building Council 2010, Altomonte et al. 2016). Different aims of BREEAM include (Dutch Green Building Council 2010) to mitigate the impacts of buildings on the environment, enable buildings to be recognised according to their environmental benefits, provide a credible, environmental label for buildings, stimulate demand for sustainable buildings (Dutch Green Building Council 2010).

BREEAM has set benchmarks for different types of buildings, therefore, there is a growing interest to acquire BREEAM ratings in architectural, engineering, and construction industries. The total score is calculated based on the credits available, the number of credits achieved for each category and a weighting factor (Roderick et al. 2009). The overall performance of the building can be categorised as Unclassified (<30), Pass (≥30), good (≥45), very good (≥55), Excellent (≥70) and outstanding (≥85) (Roderick et al. 2009). This paper aims to investigate occupants' satisfaction of Indoor Environment Quality (thermal environment, Indoor air quality, visual environment and acoustic environment) in three BREEAM Excellent buildings. This paper studies how 'BREEAM' scheme and sustainable approaches affect occupants' satisfaction.

2. Methodology

This paper focuses on assessing students' satisfaction in three BREEAM excellent university buildings in Coventry, the UK with relation to sustainable approaches used in these building. All of these buildings were awarded the BREEAM "Excellent" which means that overall performance of the building is more than 70 and that the building represents performance equivalent to the top 10% of UK new non-domestic buildings.

Post Occupancy Evaluation (POE) Surveys were conducted in three Coventry University Buildings known as HUB, ECB and AGB. The POE survey employs Building USE Studies Methodology (known as BUS methodology). This survey was carried out in two episodes of summer and winter to have more comprehensive data. In each episode, 30 occupants were surveyed in each building, resulting in participation of a total of 180 occupants. The surveys were handed out to the students who are regular users of the buildings. The participants were mainly selected from the communal spaces of these three buildings, such as the lobby.

2.1. Buildings' Sustainable Features

Coventry University currently uses BREEAM to ensure sustainable design, construction and operation of new buildings. The passive and active systems, which are implemented in these building, are studied in the following.

2.1.1. The HUB

In 2011, the Hub was built to be a new innovative idea of "home-to-home" building where students can have access to the student union, retail, social learning, and support facilities. The Hub was built on 2600 m^2 of flexible floor space to facilitate most of the university events. Different architectural techniques and technologies that are applied in this naturally ventilated building include

- Boreholes water
- Heat rejection method for the central cooling plant,
- Ground source heat pump for sustainable cooling throughout the structure,
- Rooftop photovoltaics for on-site power supply,
- Solar thermal plants have been installed to heat the water,
- Low energy light fittings which are regulated with a PIR controlling lighting system,
- Water harvest tank to limit water usage.
- Atrium design to improve thermal comfort, indoor air quality and visual comfort

Figures 1 and 2 show the exterior and interior of the HUB building.

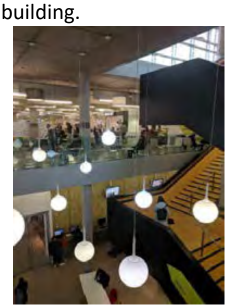


Figure 1: Exterior façade of HUB. Figure 2. Communal space and atrium in the HUB

2.1.2. Energy and Computing Building (ECB)

Engineering and Computing Building (ECB) is built on 15000 m^2 and houses over 4000 students, Figures 3 and 4. The ECB aims to promote the further use of technology and computer-aided software in higher education.

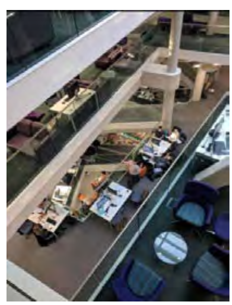


Figure 3: Exterior façade of HUB. Figure 4. Communal space and atrium in the HUB

Sustainable feature applied in this building include

- Applying Exposed concrete with a high thermal mass as an integral feature to facilitate nigh time ventilation during summer and reduce heating demand during winter
- Atrium design to improve thermal comfort, indoor air quality and visual comfort
- Designing air handling within the building so that nothing is wasted.
- Recycling the heat in the stale air to pre-heat the air drawn in into the building
- Using plate heat exchangers to pre-heat the air intake
- The solar thermal array of evacuated tubes on the roof to preheats the water going into the boilers and reduce the primary energy demand, Figure 5.
- Green roof on the lower wing of the building that retains rainwater like a sponge and decreases the occurrence of flash flooding, Figure 6.
- Capturing, harvesting and filtering the rain falling on the building to flush all the toilets within the new building.

Figure 5: Exterior façade of HUB.

Figure 6. Communal space and atrium in the HUB

Given a super-insulated structure, solar optimized space design and heat recycling features, the primary heat load is very small for this size of this building.

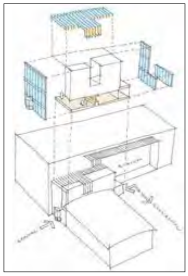
2.1.3. Alison Gingell Building (AGB)

The Alison Gingell building is the newest completed facility at Coventry University. The facility boasts 1170 m^2 of interactive and flexible spaces which function as simulated hospital wards. Figures 7 and 8 show the exterior and interior view of AGB. Questionnaire surveys were filled out in the lobby of the AGB.

Figure 7: Exterior of AGB showing courtyard.

Figure 8. Interior of AGB showing atrium space

The Reception Atrium in this building forms a narrow enfilade of space that connects the street with the Landscape Courtyard, Figure 9. The Large Atrium space with its "inhabited stair" has become part of the external landscape of the courtyard, delineated by the colonnade, Figure 10.



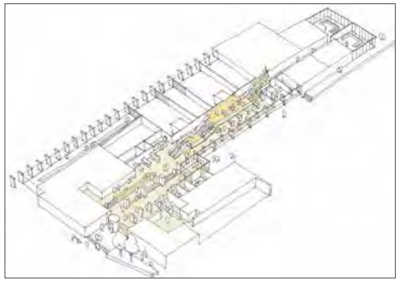


Figure 9: Reception Atrium that connects the street with the Landscape Courtyard (left). Figure 10. Atrium space with its "inhabited stair" (right) (Source: Aidan Ridyard: Architect of AGB)

3. Results

3.1. Satisfaction level at HUB by Sustainable approaches

Occupants' average satisfaction of the indoor environment quality is assessed in different buildings. Table 1 shows that occupants' average votes on IEQ are towards the more satisfying part of the scale, i.e. 4-6 at HUB. As can be seen in Table 1, the satisfaction level with the visual environment (average of 6) is the highest, followed by the thermal and acoustic environment.

Table 1. Occupants' satisfaction level of IEQ at HUB

Satisfaction Factors	Scale	1	2	3	4	5	6	7	Scale
Temperature in Summer	Uncomfortable					5.1			(7) Comfortable
Temperature in Winter	Uncomfortable				4.3				(7) Comfortable
Air in Summer	Stuffy (1)				4.3				(7) Fresh
Air in Winter	Stuffy (1)				4.3				(7) Fresh
Condition in Summer: Overall	Unsatisfactory				4.2				(7) Satisfactory
Condition in Winter: Overall	Unsatisfactory					4.8			(7) Satisfactory
Lighting: Overall	Unsatisfactory						5.6		(7) Satisfactory
Noise: Overall	Unsatisfactory					4.8			(7) Satisfactory

Various passive and active strategies that are implemented in this building impact on occupant's satisfaction level. This building has a deep compact plan with an atrium in the middle that maintains visual comfort and benefits thermal comfort in communal spaces passively. As an active strategy for thermal comfort, this building has a ground source heat pump for sustainable cooling. Furthermore, the curtain wall cladding system provides intelligent control of the internal environment via an easy to use building management system.

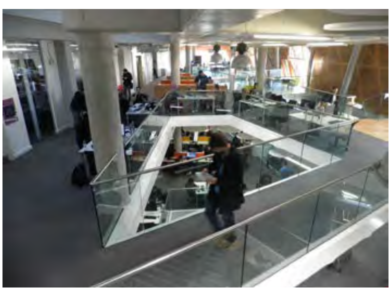
3.2. Satisfaction level at ECB by Sustainable approaches

Table 2 shows that occupants' average satisfaction votes on IEQ are towards the more satisfying part of the scale, i.e. 4 and 5 at ECB. Results show occupant's positive perception of the thermal environment, indoor air quality and visual comfort. This can be related to the internal atrium that promotes stack ventilation, improves the thermal environment and invites light into the building. As can be seen in Figure 3, the innovative honeycomb facade is very well insulated and designed to maximise the control of solar gain. These restrict solar glare into the building during the summer months when the sun is high in the sky and channel light into the building during winter when the sun is low. This reduces the base demand for lighting and heating and gives a light and airy feel to the internal space. The acoustic panels also are installed inside the space to reduce the reverberation time and maintain acoustic comfort.

Table 2. Occupants' satisfaction level of IEQ at ECB

Satisfaction Factors	**Scale**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Scale**
Temperature in Summer	Uncomfortable (1)					5.3			(7) Comfortable
Temperature in Winter	Uncomfortable (1)				4.4				(7) Comfortable
Air in Summer	Stuffy (1)				4.4				(7) Fresh
Air in Winter	Stuffy (1)					5.2			(7) Fresh
Condition in Summer: Overall	Unsatisfactory (1)					5.1			(7) Satisfactory
Condition in Winter: Overall	Unsatisfactory (1)					5.1			(7) Satisfactory
Lighting: Overall	Unsatisfactory (1)					5.2			(7) Satisfactory
Noise: Overall	Unsatisfactory (1)				4.0				(7) Satisfactory

Regarding the thermal environment, the extra heat is absorbed on the internal surface of the building (concrete column) during the day. Absorbed extra heat can be released to the outside during summer months through stack ventilation or internal spaces during winter. During the winter months, the absorbed heating will go off from the concrete, maintaining a good temperature overnight. Therefore, boilers don't have to work so hard to obtain a comfortable temperature for the next day. In the summer months, the benefits are even greater as the concrete keeps the building cool by removing the need for inefficient air conditioning units. Heat is absorbed into the concrete throughout the day and is driven out of the building at night by opening large glass vents at the top of the central atrium. In the morning, the concrete is nice and cool and ready to soak up the heat of the forthcoming day.



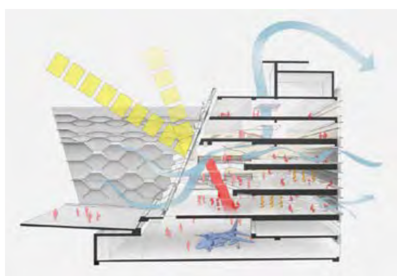


Figure 11. Communal spaces in ECB (left)
Figure 12. A summary of sustainable approaches applied in ECB (right)

3.3. Satisfaction level at AGB by Sustainable approaches

Table 3 shows that occupants' average satisfaction votes on IEQ are towards the more satisfying part of the scale, i.e. 4 and 5 in AGB. In this building, designers have considered the complex relationship between indoor air quality, thermal, visual and acoustic environment. Several strategies are considered in this building to maintain Acoustic comfort. The south side windows are carefully designed to bounce back and attenuate external noise from the adjacent road. Acoustic panels are also installed in the internal atrium to attenuate reverberation time. Furthermore, the north side atrium promotes stack ventilation, improves the thermal environment and invites light into the building.

Table 3. Occupants' satisfaction level of IEQ at AGB

Satisfaction Factors	Scale	1	2	3	4	5	6	7	Scale
Temperature in Summer	Uncomfortable (1)					5.3			(7) Comfortable
Temperature in Winter	Uncomfortable (1)				4.4				(7) Comfortable
Air in Summer	Stuffy (1)				4.4				(7) Fresh
Air in Winter	Stuffy (1)					5.4			(7) Fresh
Condition in Summer: Overall	Unsatisfactory (1)					5.4			(7) Satisfactory
Condition in Winter: Overall	Unsatisfactory (1)					5.4			(7) Satisfactory
Lighting: Overall	Unsatisfactory (1)					5.3			(7) Satisfactory
Noise: Overall	Unsatisfactory (1)					5.3			(7) Satisfactory

Several other studies have shown the importance of atriums on improving indoor environment quality. The study by Wang et al. (2017) shows through overflow into the atrium, air with higher temperature returns to the heat recovery unit for the heat exchange with the new fresh and cold air outside. The study by Du et al. (2020) highlights that large-volume atriums equipped with a large number of indoor architectural structures can absorb the sound to a certain extent. The design of the atrium should focus on a balance between the light and the thermal physical environments (Du et al. 2020). Several other studies have highlighted the role of outdoor atriums (courtyards) on improving the visual environment and indoor air quality (Korsavi et al. 2017, Gou et al. 2012).

3.4. University's Approach to Improving IEQ over time

Figure 13 (left) shows the distribution of occupants' vote on the overall noise level in HUB, ECB and AGB. The level of noise satisfaction in AGB (newly built) is higher compared to ECB and HUB. The designer team of AGB worked closely with both specialist technicians and stakeholders to maintain acoustic comfort by carefully attenuate background noise level and reverberation time. Therefore, noise satisfaction (Vote 4 to 7) in AGB is around 75%. Furthermore, overall noise satisfaction has increased in ECB during the last years. In 2015, a comprehensive Post Occupancy Evaluation (POE) Survey was conducted on regular occupants of the ECB which showed noise dissatisfaction of occupants. The results suggested that high noise dissatisfaction could be related to lack of soft surfaces, the large space and bare concrete columns. Therefore, the noise bounced off hard surfaces, which increased the reverberation time and reduced the occupants' overall noise satisfaction. Following the 2015 survey, it was decided to hang acoustic panels from the ceiling to absorb the extra noise. This resulted in an improvement on Noise Overall satisfaction with the average satisfaction of 5, Table 3, while it was below 4 before the refurbishment.

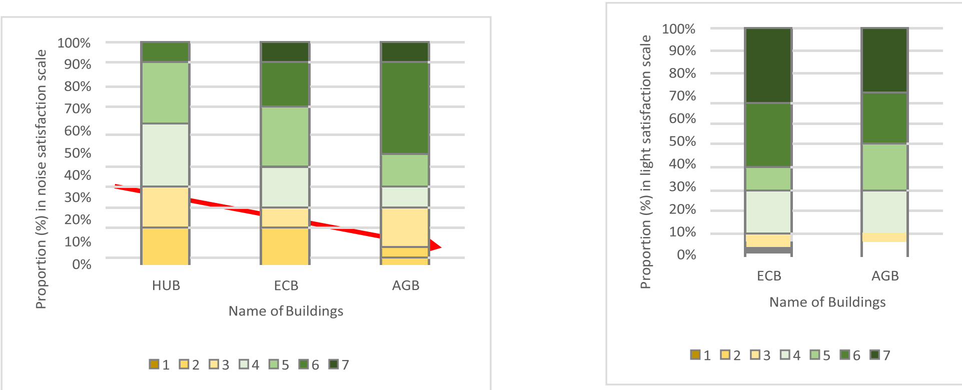


Figure 13. Proportion (%) in noise satisfaction scale (left), Proportion (%) in light satisfaction scale (right)
Scale [1= Unsatisfactory ……7= Satisfactory]
[1= Lowest level of dissatisfaction: 7= Highest level of satisfaction]

In addition, Figure 13 (right) shows the level of light dissatisfaction at AGB is lower than ECB with the lowest unsatisfactory level of 1.6% at AGB which is half of the lowest unsatisfactory level at ECB (3.3%). The lower level of dissatisfaction is partly related to different design at AGB. According to the AGB' Architect (Aidan Ridyard), AGB atrium core is design differently from ECB and connect positively to the external space on its north side.

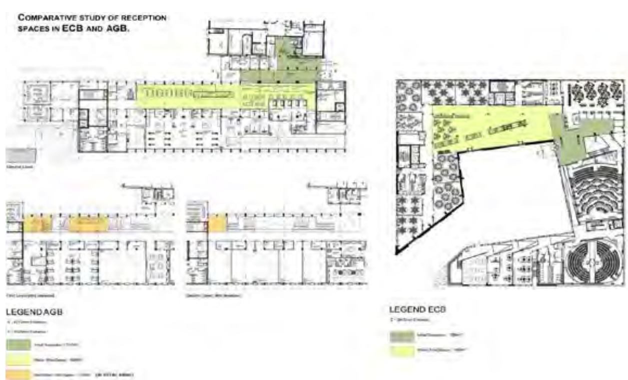


Figure 14. Comparative study of reception spaces in ECB and AGB
(Source: Aidan Ridyard: Architect of AGB)

4. Conclusion

The results show how integrating different passive and active strategies in three BREEAM Excellent buildings impact occupants’ satisfaction level towards the thermal environment, IAQ, visual and acoustic comfort. The main sustainable architectural feature used in these three buildings is the atrium that improves lighting comfort, thermal comfort and indoor air quality. Occupants in the atrium may suffer from acoustic discomfort, however, these spaces are equipped with acoustic panels to absorb extra noise, reduce the reverberation time and improve acoustic comfort.

Furthermore, Coventry University protocol aims to deliver the best internal environment quality for the occupants by running post-occupancy surveys. In the AGB, only two Satisfaction Factors have an average of 4. In the ECB, three Satisfaction Factors have an average of 4 which is lower than that in HUB with 4. This differences may be related to its construction time and learning a lesson from the past and types pf the atrium which are different in these buildings. AGB is newer than ECB and ECB is newer than the HUB. This result highlights the Coventry University’s approach to delivering better conditions for occupants.

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