# Assessment of indoor environment quality at the Rose Bowl, Leeds Beckett University

**Paul Ajiboye[1], Vyt Garnys[1], David Hemming[2]**

[1]CETEC Foray Ltd, 2B25 Technopark, 90 London Road, London, SE1 6LN

[2]Estates services, Leeds Becket University, Leeds, LS2 BNJ

**Keywords:** IAQ, Ventilation, Surveys, NABERS

## Abstract

*This paper examines the post occupancy performance of a building designed for energy and wellbeing of occupants when set against internationally recognised indoor environment quality wellbeing benchmarks. The Rose Bowl is Leeds Beckett University's iconic building created to provide the best working and studying environment. Indoor environment quality (IEQ) has been assessed within the building using specific methodology relating to thermal comfort, indoor air quality, noise, lighting and occupant satisfaction as set out in the long established National Australian Built Environment Rating Scheme (NABERS) for Indoor Environment. This inaugural wellbeing rating scheme was launched in 2008 by the Australian Federal and State Governments and used widely by public, private and other country facilities. The Rose Bowl building has been evaluated against this mature benchmarked scheme to determine how well it performs for staff and students. In addition to monitoring specific environmental parameters occupants of the building have been surveyed to examine their satisfaction with the indoor environment in use. Environmental assessments have been performed in offices, classrooms and the main lecture theatre. Results of the IEQ assessments are discussed in this paper. In addition a summary of the feedback from staff and students working in the building is provided. The discussion looks at the IEQ results in conjunction with the occupant survey. Initial remedial actions taken by the Estates Services team are briefly presented.*

### Indoor Environment Quality

Indoor Environment Quality (IEQ) measurement provides a way to measure how satisfactory a building is from wellbeing benchmarks and viewpoint of its occupants. A lot of focus has been placed on energy efficiency within buildings and there is a growing view that this has overlooked the impact on health and wellbeing of people that work in them.

The Rose Bowl building in Leeds is an iconic working and teaching centre which has been designed as a building that is concerned with sustainability and the wellbeing of people. This

is the first study allowing the design aims to be tested against established independent health and wellbeing standards.

There are a number of rating systems that examine IEQ for buildings. Commonly these have looked at issues concerned with sustainability and therefore have provided relatively small weighting towards the health and wellbeing of occupants. Examples of standards that have included a small element of IEQ include BREEAM and LEED. The total weighting of IEQ within each of these standards is less than 15%.

Rating schemes that take a harder independent look at IEQ include the NABERS and more recently, the USA based Delos-WELL scheme. The Delos-WELL scheme considers wellbeing more from a broad occupant level and as a relatively new product has not yet seen many ratings delivered around the world, with onlu one in the UK. However, there is increasing awareness and interest in this rating scheme.

The National Australian Built Environment Rating Scheme (NABERS) was launched in 1998 with an energy rating scheme and has developed over the last two decades to now include four core tools namely NABERS Energy, Water, Waste & Indoor Environment.

NABERS IE for offices has been used for approximately 10 years and is an established assessment process for measuring how office buildings in use are delivering satisfactory indoor environment quality for people in buildings and the concurrent satisfaction of its occupants. It has been used in many buildings in Australia. A NABERS IE protocol, adapted for teaching and office spaces has been selected by Leeds Beckett University to evaluate the performance of one of its iconic buildings, the Rose Bowl. This building is based in the heart of the City and is located adjacent to a Grade II listed Civic Hall. Sustainability was at the heart of the design of the 12,000m$^2$ space and against this the building project was rated as BREEAM Excellent. An element of health and wellbeing is examined within BREEAM, however this is a relatively small consideration within the overall scheme and not based on actual IE performance. NABERS IE offered a comprehensive performance based assessment platform to measure how well the building performs for the people that work within the building through a survey of occupant's satisfaction.

**NABERS IE Research Methodology For The Rose Bowl**

There are five specific categories that are assessed for IEQ under the NABERS IE approach; air quality, thermal comfort, acoustic comfort, lighting comfort and occupant satisfaction through surveys. There are three levels of assessment available, namely:

*Base Building* - designed for building owners and managers, who generally control and maintain the thermal services provided, air systems and building cleaning and the ability for the building to minimise external noise.
*Tenancy* - designed to measure the indoor environment parameters directly controlled by the tenants such as the materials used in an office fit-out, lighting and internal noise.
*Whole Building* - intended for organisations that both manage and occupy their office space. This rating type assesses the indoor environment parameters associated with both the tenancy and base building.

Within each category there are specific parameters that are examined with internationally recognised guidelines underlining good performance for a building. As the Rose Bowl building is both owned and managed by Leeds Beckett University the 'whole building' rating level was used and applied to both teaching and office environments.

Only in the case of the 'whole building' rating do all parameters covered by NABERS IE need to be measured and this has been the approach in examining the Rose Bowl building. Table 1 identifies all relevant parameters that have been used to review IEQ for staff and students that use the building. The testing regimes for each parameter are set out in brief in Table 2. The IEQ assessment of the Rose Bowl was performed on 17th February 2017.

To evaluate air quality, acoustic and lighting comfort across the Rose Bowl building a NABERS prescribed minimum number of samples and ISO 17025 accredited measurement methodology was required. Measurements were made in all of the major types of spaces that were present. As such, measurements were performed in classrooms, lecture halls and offices. Rooms were selected that represented the whole building in terms of its overall use.

The Rose Bowl has 5 floors and two measurement were undertaken on each floor. Ambient conditions on the day were recorded as a roof top measurement. Table 3 identifies the locations where samples were taken and the IEQ parameters measured at each.

Following the IEQ assessment at the Rose Bowl, a staff and student online occupant survey was prepared and carried out. The NABERS accredited survey was designed and delivered independently by the Centre for the Built Environment at Berkeley, USA. The survey took place between 22nd March and 21st April. The report of the detailed findings was still being prepared by the time this paper was submitted, however preliminary results have been obtained. The overall response rate was approximately 40% of the building population.

A final NABERS IE rating will be obtained by evaluating how well the Rose Bowl building performs in all areas compared to other buildings that have undergone the same process. The overall relative performance of the building will be the basis upon assigning a 1 star (poor indoor environment) to a 6 star (market leading indoor environment) rating. This evaluation was still ongoing at the time of submitting this paper.

**Results Of IEQ Measurements**

Table 4 summarises the findings from the IEQ assessment across different rooms in the Rose Bowl building. The approach taken provides a simple overview of whether each tested parameter met the criteria for what passes for a satisfactory environment, Table 1.

There were no IAQ problems in relation to air speed, %RH, CO, $O_3$, $PM_{10}$, and TVOCs.

The shaded areas in Table 4 quickly reveal the IEQ parameters where issues have been discovered. These include elevated temperatures, concentrations of $CO_2$, concentration of the fine particulates ($PM_{2.5}$), concentration of Formaldehyde, noise levels and non-ideal light uniformity.

Figures 1 - 6 show the extent to which threshold limits were breached for each of the 6 parameters where measurements highlighted that there was an issue.

**Discussion and Recommendations**

*Elevated temperature measurements:*

Temperature was found to be higher in 2 out of 5 classrooms (40%), 1 out of 3 offices (33%) and the canteen area (Table 4). In total this represents 40% of the internal rooms that were sampled on the day. Figure 1 shows that ambient temperature measured on the day at roof level was under 14$^{o}$C. It is possible that heat gains to the building is not being adequately dealt with by the HVAC system. The HVAC system should be designed to ensure comfortable temperature conditions of between 21-24$^{o}$C.

The impact of higher than desirable temperature may create unsatisfactory conditions for staff and students using the Rose Bowl building. There is evidence that this is the case from preliminary results of the occupant satisfaction survey, Figures 7-10.

Figure 7 shows that of all occupants that responded to the question concerning how satisfied they were with the temperature of their work place a total of 40 individuals (approx. 33%) were either somewhat satisfied-satisfied-very satisfied. This compares to 64 individuals (approx. 52%) who were either somewhat dissatisfied-dissatisfied-very dissatisfied. Furthermore, Figure 8 reveals that 72 respondents (approx. 58%) felt that unsatisfactory temperatures in the work place interfered to varying extents with their ability to do their job.

Figures 9 & 10 suggest that those individuals that found temperature conditions unsatisfactory broadly felt the places that they worked/studied were too hot during the summer and too cold in the winter, respectively.

*Reduced ventilation performance:*

Concentration of $CO_2$ in a room is a good proxy for the performance of the ventilation system. The comfort guidelines stipulate that adequate ventilation performance is generally reached if $CO_2$ concentrations remain below 1000ppm (Table 1). Concentration of $CO_2$ was found to exceed this threshold in only 1 of the 5 classrooms (20%) and nowhere else. Fresh air supply to classroom 525 (on the 5$^{th}$ level) should be increased to reduce emissions from the high of 1094ppm to below 1000ppm.

When ventilation rates are not sufficient conditions in a room may become uncomfortable as air quality deteriorates from an occupant satisfaction point of view. Preliminary results from the occupant satisfaction survey indicates that there is some concern about air quality within the building, Figures 11-13.

Figure 11 shows that of all occupants that responded to the question concerning how satisfied they were with air quality of their work place a total of 50 individuals (approx. 42%) were either somewhat satisfied-satisfied-very satisfied. This compares to 45 individuals (approx. 38%) who were either somewhat dissatisfied-dissatisfied-very dissatisfied. Nearly 20% of all occupants that responded to the survey were neither satisfied or dissatisfied with air quality of their work place. The majority of occupants were to varying extents unperturbed by the air quality of their work place.

Figure 12 indicates that only 24 people (20%) felt that air quality at the work place could enhance to varying degrees, their ability to do their job. However, 46 people (approx.38%) felt that air quality at the work place could interfere to varying degrees, with their ability to do their job. The extent to which air quality is deemed a problem by the dissatisfied group is shown in Figure 13.

*Elevated particulate measurements:*

Concentration of the fine particulates ($PM_{2.5}$) was high within the Rose Bowl building only in the canteen area (Table 4). The canteen is located on the ground floor in an area that is near busy roads and may also contain cooking aerosols. A main entrance to the building is in close proximity to the open planned canteen.

Staff and students using the canteen will only do so for relatively short periods in a day so overall exposure will be limited. Even so filtration used in fresh air supply to the area should be examined.

*Elevated formaldehyde measurements:*

Concentrations of formaldehyde were above the health guideline value of 100 ug/$m^3$ in 50% of the locations where it was measured. Table 4 indicates that this was the case in 1 of 2 offices and in the only lecture room were a measurement was taken.

Figure 4 shows that the exceedance in relation to the health guideline threshold is significant (258ug/$m^3$ was measured in Lecture room 241 and 137ug/$m^3$ measured in office 148). Given the nature of this pollutant and its potential impact on health, steps have been taken to reduce it. Ventilation in Lecture 241 has been enhanced by increasing the variable speed drives operating fans serving the room by 10%. The ventilation performance of office 148 has been re-checked to ensure that it is operating as intended.

A re-visit to the Rose Bowl has taken place to measure formaldehyde. Samples are currently being analysed and results were not available before this paper was submitted. The high formaldehyde concentration measured in the one lecture hall has been discussed to review whether this was as a result of specific materials used for the type of zone in question. Consequently, during the revisit to examine formaldehyde concentrations in the Rose Bowl building two additional lecture rooms were monitored. The results of this investigation will not be known before this paper is submitted, but will be presented.

*Elevated noise measurements:*

Noise level, understandably for an educational purpose, was found to be outside the comfortable office range of 35 – 45dB in 1 of 5 classrooms (20%), the Lecture room and canteen (Table 4). In all, noise levels were higher than the office comfort criteria in 30% of the spaces where it was measured.

Figure 5 shows the extent to which noise measurements exceeded the office comfort range in each of the 3 locations. Highest noise loads were measured in the canteen area. This is an area within the Rose Bowl that people are least likely to be concerned about noise levels. Lecture and seminar areas are expected to have adequate and intelligible speech levels.

Inappropriate, unintelligible or elevated noise levels in the lecture theatre during lectures may be uncomfortable for staff and students. Similarly experiencing noise levels in classrooms where this is not part of the intended study experience, has the potential to be a nuisance to staff and students.

Figures 14 and 15 provide some evidence that noise levels are having an impact on staff and students.

Figure 14 shows that of all occupants that responded to the question concerning how satisfied they were with the acoustic quality of their work place a total of 54 individuals (approx. 46%) were either somewhat satisfied-satisfied-very satisfied. This compares to 34 individuals (approx. 37%) who were either somewhat dissatisfied-dissatisfied-very dissatisfied. Nearly 17% of all occupants that responded to the survey were neither satisfied or dissatisfied with acoustic quality of their work place. The majority of occupants were to varying extents unperturbed by the acoustic quality of their work place.

Figure 15 indicates that only 19 people (17%) felt that acoustic quality at the work place could enhance to varying degrees, their ability to do their job. However, 59 people (approx.51%) felt that acoustic quality at the work place could interfere to varying degrees, with their ability to do their job. Noise levels and intelligibility should be examined further to clarify dissatisfaction responses.

*Unbalanced light uniformity measurements:*

Lighting comfort in a room is best if the relative amount of light that falls on the horizontal plane (tables etc.) is not more than 3 times higher than the amount of light that falls on the vertical plane (computer screens etc.). This is the measure of light uniformity. If the value exceeds 3 then eye strain can result as individuals switch between looking up from their desks to directly what is in front of them. This is particularly important in areas without external views through windows.

Light uniformity ratios exceeded the threshold limit in 3 out of 5 classrooms (60%) though nowhere else where measurements were taken (Table 4). The extent to which this was the case is shown in Figure 6.

It is important to note that in some classrooms blinds were partially deployed and VDU screens were in use at the front of lessons. These will have had an impact on light distribution which may have been intended.

*Overall satisfaction and staff productivity*

Occupants of the Rose Bowl were asked about their overall attitude to their building and what if any impact it might have on their own productivity, Figures 16 and 17.

Figure 16 shows that of all occupants that responded to the question concerning how satisfied they were with their building overall a total of 58 individuals (approx. 51%) were either somewhat satisfied-satisfied-very satisfied. This compares to 44 individuals (approx. 39%) who were either somewhat dissatisfied-dissatisfied-very dissatisfied. A remaining 12 individuals (approx. 10%) were neither satisfied or dissatisfied.

Figure 17 shows that of all occupants that responded to the question concerning to what extent their productivity might be increased as a result of environmental conditions in their building, 23 individuals (approx. 20%) believed that their productivity could be improved by between 5-20%. This compares to 47 individuals (approx. 42%) who believed their productivity could be decreased by between 5-20%, if environmental conditions were not as they could be. Some 48 individuals (appro. 38%) felt that their productivity would be neither increased or decreased by environmental conditions within the Rose Bowl.

When reviewed together Figures 16 and 17 reveal that a majority of individuals that took part in the occupant survey were at least somewhat satisfied with the Rose Bowl building where they work. However, there is also a large minority of individuals who are at least somewhat dissatisfied with their building. Whilst only 20% of individuals that took part and responded to the survey felt that by improving environmental conditions in the building their productivity could be increased, more than 40% felt that poor environmental building conditions would decrease their productivity. In short, this implies that by not creating an ideal working environment occupant productivity can be disproportionately reduced. The importance of this finding is that the office or academic performance is being adversely affected by the indoor environment. It is well established that the value of occupant output greatly exceeds the value of energy and maintenance costs combined.

**Conclusions**

This paper reveals that through the NABERS IE rating process for the Rose Bowl building, important indoor environment quality issues can be highlighted that can be shown to influence people's workplace attitude and their performance.

Although the building project scored BREEAM Excellent indicating that it addressed pre-occupancy sustainability issues well, a post occupancy detailed assessment of the internal environment from the point of view of health and comfort of its occupants, has revealed problems that need to be addressed. Chief amongst them is the issue of temperature related comfort in teaching spaces which is contributing significantly to the dissatisfaction scores attributed to the building. A significant health concern was the elevated formaldehyde levels, which is being further investigated.

The early conclusions reached are being addressed by the University Estates Services team. Ventilation has been boosted in rooms to deal with specific potential health issues as well as to deal with thermal comfort. Further work is being undertaken to understand and correct other IEQ concerns. The main aspiration is to ensure that the Rose Bowl building is returned to being amongst the best places to work and study internationally.

**Acknowledgements**

The Estate Management team and staff and students at Leeds Beckett University.

The CETEC Australian team and CETEC's UK Expert Panel, Professor Gary Raw, Professor Derek Clements-Croombe, and Dr Derrick Crump.

The cooperation of the CBE survey team at Berkley University.

## List of tables

***Table 1**: IEQ parameters and internationally recognised thresholds*

| IAQ Parameter | Cited Threshold | Reference |
|---|---|---|
| Air speed | < 0.2 m/s | NABERS |
| Temperature | 21-24°C | ASHRAE 55 |
| Relative humidity | 30-70% | ASHRAE 55 |
| Carbon dioxide ($CO_2$) | 1000ppm | ASHRAE 62 |
| Carbon monoxide (CO) | 9ppm | WHO / LEED V4 / WELL / NABERS |
| Ozone ($O_3$) | 0.08ppm | LEED V4 / NEPM |
| Particulates - $PM_{10}$ | 0.05mg/$m^3$ | LEED V4 / WELL / NABERS |
| fine particulates - $PM_{2.5}$ | 0.015mg/$m^3$ | LEED V4 / WELL |
| Total Volatile Organic Compounds (TVOC) | 500µg/$m^3$<br>250µg/$m^3$ for 1 compound | LEED V4 / WELL / NABERS<br>NABERS / NHMRC |
| Formaldehyde | 40µg/$m^3$ (27ppb)<br>100µg/$m^3$ (80ppb) | LEED V4 / WELL<br>WHO / NABERS |
| Acoustic Comfort | 35-45db | NABERS |
| Lighting | 320 lux horizontal, h (min)<br>160 lux vertical, v (min)<br>Uniformity ratio, h/v <3 | AS1680 |

***Table 2**: summary of testing methodology behind each IEQ parameter*

| IAQ Parameter | Instrumentation / Method | Duration | Laboratory Method |
|---|---|---|---|
| Air speed, Temp., RH, $CO_2$, CO, $O_3$ | GrayWolf Advanced Sense Pro | 5 minute data log - measurements taken AM and PM during typical office hours | Field |
| $PM_{10}$ and $PM_{2.5}$ | GrayWolf Particulate Monitor 3016 | 5 minute sample - measurements taken AM and PM during typical office hours | Field |
| TVOC[#] | Active (pumped) sampling onto activated carbon tube | Approx. 2 hours @ 0.3L/min | EPA Compendium Method TO17 |
| Formaldehyde[#] | Active (pumped) sampling onto DNPH Treated Silica | Approx. 2 hours @ 0.2-0.5L/min | Compendium Method TO11A |
| Acoustic comfort | Cirrus Class 1 Optimus Integrating Sound Level Meter | 5 minutes, roaming | Field |
| Lighting | Testo 545 | 1 minute | Field |

Notes

[#]Sample tubes were sent to an independent laboratory for analysis of total VOC and Formaldehyde

***Table 3**: sampling locations within the Rose Bowl*

| Location | Floor | IEQ parameters measured at each location | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Air speed | temp | RH | $CO_2$ | CO | $O_3$ | $PM_{2.5}$ | $PM_{10}$ | TVOC | Form. | dB | lux |
| Ambient - Roof | 6 | y | y | y | y | y | y | y | y | n[#] | n[#] | n[#] | n[#] |
| Classroom 513 | 5 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Classroom 525 | 5 | Y | Y | Y | Y | Y | Y | Y | Y | n[#] | n[#] | Y | Y |
| Office 404 | 4 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Office 421 | 4 | Y | Y | Y | Y | Y | Y | Y | Y | n[#] | n[#] | Y | Y |
| Classroom 320 | 3 | Y | Y | Y | Y | Y | Y | Y | Y | n[#] | n[#] | Y | Y |
| Classroom 307 | 3 | Y | Y | Y | Y | Y | Y | Y | Y | n[#] | n[#] | Y | Y |
| Lecture 241 | 2 | Y | Y | Y | Y | Y | Y | n[@] | n[@] | Y | Y | Y | n[@] |
| Classroom 208 | 2 | Y | Y | Y | Y | Y | Y | Y | Y | n[#] | n[#] | n[@] | n[@] |
| Office 148 | 1 | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Canteen area | 1 | y | y | y | y | y | y | Y | Y | n[#] | n[#] | Y | n[#] |

Notes

[#] not required [@]loss of power

***Table 4**: summary of pass/fail results of IEQ assessments across the Rose Bowl*

| Location | Pass (✓) / Fail (x) – in relation to threshold values in table 1 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air speed | temp | RH | $CO_2$ | CO | $O_3$ | $PM_{2.5}$ | $PM_{10}$ | TVOC | Form. | dB | lux |
| Ambient[#] - Roof | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | - | - | - | - |
| Classroom 513 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | x |
| Classroom 525 | ✓ | ✓ | ✓ | x | ✓ | ✓ | ✓ | ✓ | - | - | x | x |
| Office 404 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Office 421 | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | ✓ | ✓ |
| Classroom 320 | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | ✓ | ✓ |
| Classroom 307 | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | ✓ | x |
| Lecture 241 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | ✓ | x | x | - |
| Classroom 208 | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | - |
| Office 148 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | x | ✓ | ✓ |
| Canteen area | ✓ | x | ✓ | ✓ | ✓ | ✓ | x | ✓ | - | - | x | - |

Notes

[#] The ambient measurements taken on the roof of the building are not are not applicable in relation to assessing the quality of the indoor working environment.

## List of figures

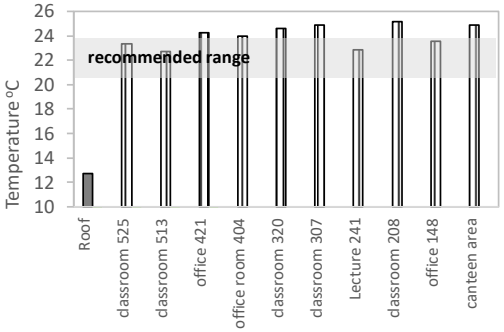


**Figure 1**: temperature measurements showing locations where high

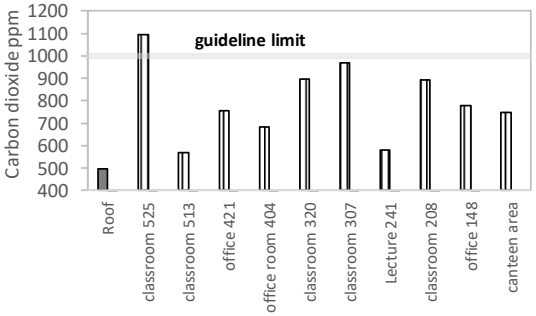


**Figure 2**: $CO_2$ measurements showing locations where high

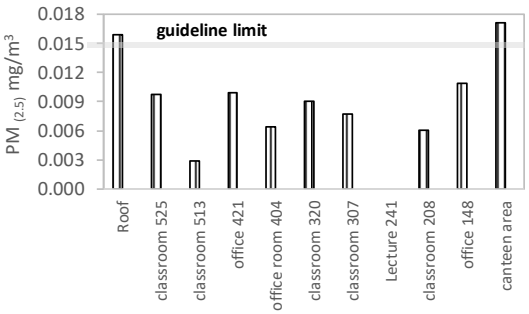


**Figure 3**: $PM_{2.5}$ measurements showing locations where high

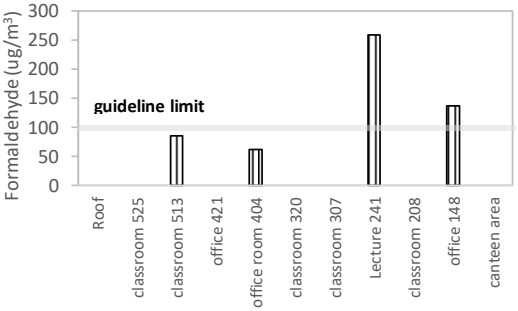


**Figure 4**: Formaldehyde measurements showing locations where high

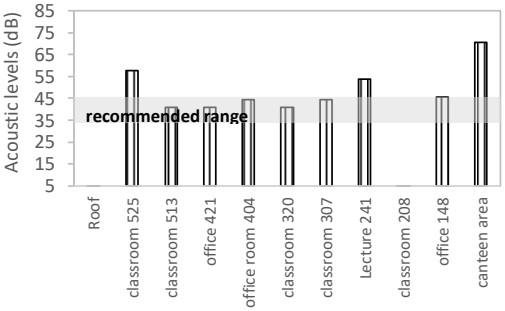


**Figure 5**: acoustic measurements showing locations where high

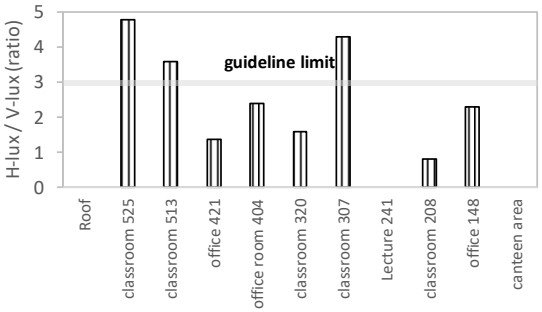


**Figure 6**: light uniformity measurements showing locations where poor uniformity

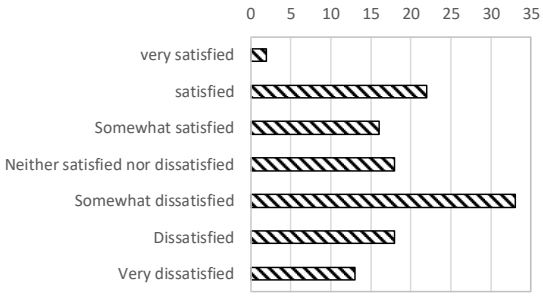


**Figure 7**: no. of responses to the question, 'how satisfied are you with the temp of your workplace"

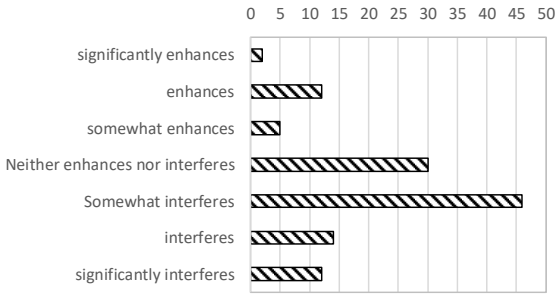


**Figure 8**: no. of responses to the general question does thermal comfort enhance/interfere with ability to perform job

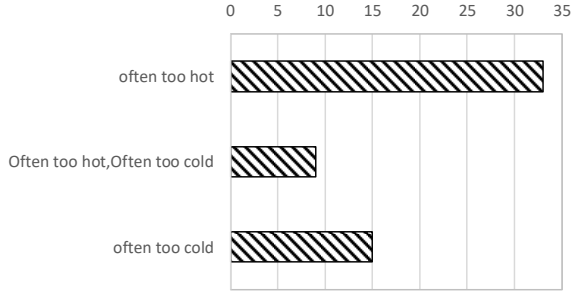


**Figure 9**: no. of responses to the general question of how staff feel in warm/hot weather

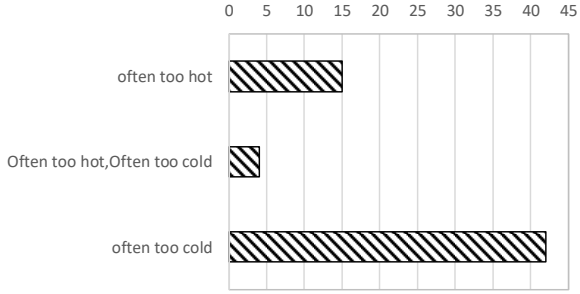


**Figure 10**: no. of responses to the general question of how staff feel in cool/cold weather

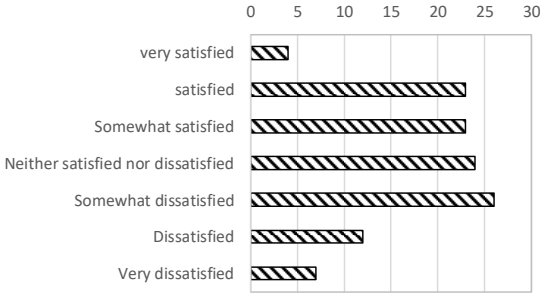


**Figure 11**: no. of responses to the question, 'how satisfied are you with the air quality of your workplace"

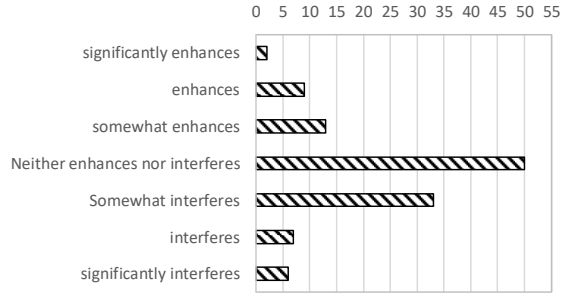


**Figure 12**: no. of responses to the general question does air quality enhance/interfere with ability to perform job


**Figure 13**: no. of responses ***from those who were dissatisfied*** with air quality who rated 'stuffy/stale atmosphere' as being a problem


**Figure 14**: no. of responses to the question, 'how satisfied are you with acoustic quality in your workplace"


**Figure 15**: no. of responses to the general question does acoustic quality enhance/interfere with ability to perform job


**Figure 16**: no. of responses to the question, 'how satisfied are you with the building overall"

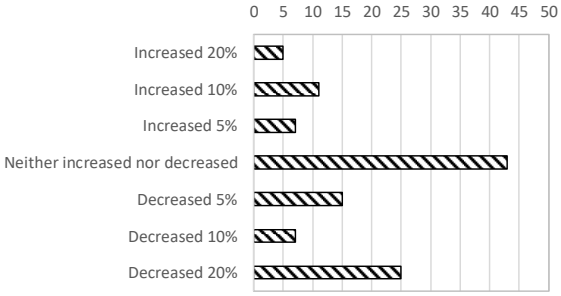


**Figure 17**: no of responses to the general question on how individual productivity is affected by building environmental conditions