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Post Occupancy Evaluation of Thermal Comfort in Studio Classrooms in Humid Subtropical Climate

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Abstract - *After an institute is constructed there are large number of students who use that space for their learning and development. This research paper is about the analysis of thermal comfort level in studios where the students of architecture spend most of their time during college hours. Studios of an architecture college have both design and other classes for lectures. The field study is conducted through post occupancy evaluation during a week in a typical winter season carried out in 5 studios in an architecture institute in Aligarh. Objective data analysis showing the indoor environmental condition of the classroom, and Subjective analysis through questionnaire were collected to record the thermal sensation of the students.*

Post occupancy evaluation is like the investigation of the designed environment with regard to its human user experience and building performance. The end use of these types of analysis is to help the university management for retrofitting the spaces which provide better learning space for students.

Key Words: Post Occupancy Evaluation, Thermal Comfort, Studio classrooms, retrofitting.

1 Introduction

When people are in a designed space where they can work efficiently and rest comfortably then it means that the thermal condition of that space is ideal according to human requirement. Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ASHRAE, 2013). As anyone may guess, thermal comfort has to do with more than the temperature. It can be achieved only when the air temperature, humidity and the movement of the air are in proper balance with each other. Adding to the complication, it is obvious that one person's thermal comfort zone is not the same as another's.

Thermal comfort can be defined as the satisfaction towards a given environment. In any functional space the thermal adaptation can be attributed to three different processes - behavioural tuning, physiological accommodation and psychological training (Rajkumar, Amirtham, & Horrison, 2015).

In this era of sustainability where we can see some bold decisions in which countries are changing their radical development attitude to more green and non-hazardous policies. These sudden change in the attitude didn't arrive in a day and didn't come from only few people's narrative, but it's a fact now that how human ambition and their ill practices and less sensitivity sabotaging the whole ecosystems on earth.

Learning spaces like lecture halls and libraries and accommodation like hostels are needed to retrofit time to time to maintain the learning and overall growth of the students in the universities. There is a separate budget in universities for these maintenance works which not only have to cover the basic maintenance work but also that works which will ensure the healthy user experience.

It becomes essential to provide the students the atmosphere and comfort within their learning spaces. Compromising with the thermal comfort in the learning spaces results in less attentiveness during lectures by the students which will be not their faults. Retrofitting of any space depends upon the user experience data and here the users are the students so their feedback about their thermal comfort.

1.1 Role of studios

Educational institutions, always plays a major role in upbringing of the societies throughout time in human civilization. Universities act as research and development departments for countries where maximum output can be achieved at minimum risk. Both professors and students effectively contribute in developing researches which lead to the enhancement of the spatial settings more economical and sustainable.

The studios plays a very important role as in these learning rooms the students of architecture spends most of their time and flowers a studio culture. If an architecture college needs to be successful than it should have a studio culture in it and to do so the studios must have the indoor environment which enables students to sit and work for hours. The thermal comfort of such spaces must be the first priority for an architecture college so that a studio culture can be created. The aim is to do the analysis of the building so that future retrofitting will be more precise and user friendly. All this can be achieved with objective and subjective survey carried out in the studios. The studios in architectural

college are comparatively larger than typical lecture halls of an engineering college because the large size furniture which is called architecture table or workstations on which the students of architecture work with their usually A1 size sheets. So the analysis of these studios are slightly different as with

1.2 Importance of POE

The task of the designer is to create the best possible indoor climate or even the environment for the users as they judge the quality of design based on physical and emotional point of view. Thermal comfort is maintained when the heat generated by the human metabolism is allowed to dissipate at a rate that maintains thermal equilibrium in the body. Every designer wants to improve their design and now it becomes a social responsibility to make create sustainable designs as per current environmental situations. To know the success of the designed space feedbacks from the building occupant are necessary. Building occupants are a valuable source of information on building performance as well as indoor environmental quality and their effects on comfort and productivity (Aliyu, muhammad, & bukar, 2016). Basically methodical and scrutiny of a building space carried out with users of the building is called post occupancy evaluation.

1.3 Area of study

The study is conducted in the department of architecture, Aligarh Muslim University in Aligarh, Uttar Pradesh, India. It is during a typical winter season for a week in 5 studio classes on ground and first floors. Both subjective and objective study is required here to understand gravity of the situation for precise future retrofitting.

The maximum air temperatures during summer (May and June) varies between 36°C and 40°C and the minimum air temperatures during winter (December and January) varies between 6°C and 8°C. The average monthly relative humidity ranges from 24% (June) to 40% (November). Indoor environmental variables like air temperature and relative humidity need to be measured. The thermal properties of the built surfaces are similar in all the classrooms, the materials used for built surface include brick walls, concrete roof and stone flooring with less vegetation cover. The university have this different kind of fresh atmosphere because the lush green vegetation maintained all over the university area. So this is the advantage the students get while studying here that they are expose to natural environment of fresh air passing through humungous trees that are planted all the over the university.

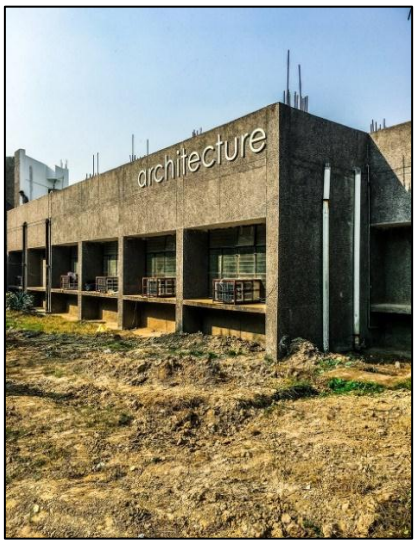

Figure 1: Department of architecture, A.M.U

The objective analysis are done by collecting the temperature and relative humidity readings inside these studios and outside between 9 am to 3 pm on a typical winter season week in February 2020. The readings are collected by a data logger device which is specialized for collecting multiple data readings and stored. The data logger location was in the middle of the studios at the height of approximately 1.5m from the floor. The data collected at every 2 hours of the class hours in the college. The post occupancy evaluation part is achieved through the questionnaire survey in which students were asked to fill the questionnaires papers with as feedback according to their thermal comfort and sensation.

The subtropical climate is the climate of the Aligarh city which is often characterized by hot summers and mild winters with infrequent frost.

2 Methodology

Readings measured in the highlighted studio rooms which are highlighted with pink colour in the floor plans as shown in Figure 2. This study is carried out to assess the thermal conditions in indoor environment during the student's lecture hours. The readings are collected at an interval of every 2 hours during student's lecture sessions and at the thermal assessment done through the questionnaire survey. The location of data loggers are shown in Figure 2. The design periods are usually 2-3 hours long as 2-3 class periods are combined. Such long hours for design periods are necessary for architecture students as they learn to create designs with creativity which needs time to accomplish it.

The thermal assessment through the feedbacks from students is done to do a comparative analysis with the readings measured during the sessions in a scrutinized manner.

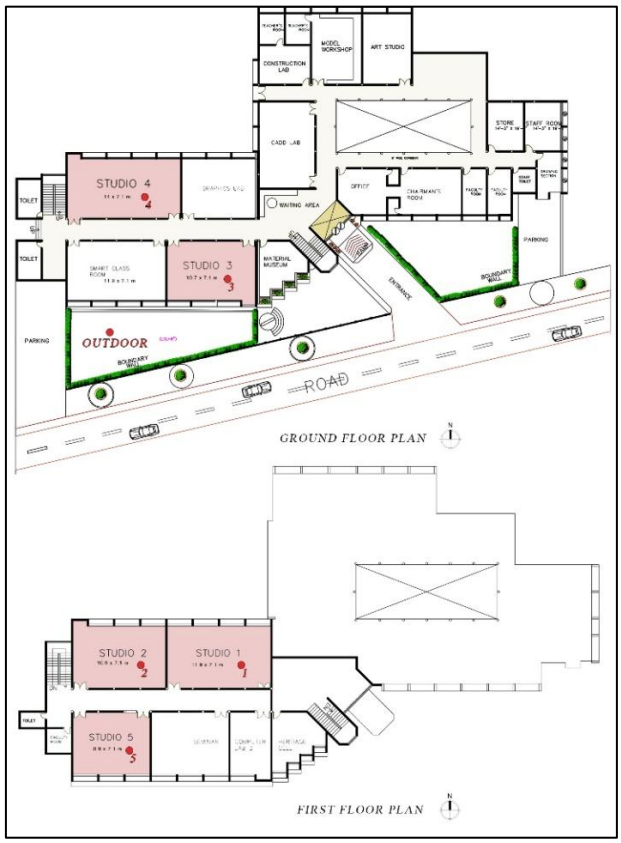

Figure 2: Floor plans of the department of architecture, A.M.U

The outdoor temperature and relative humidity readings are measured to analysis the role of materials and the effectiveness of orientation of the building.

Figure 3 shows the typical layout of a studio classroom where students work on the architectural tables/stations during their design periods.

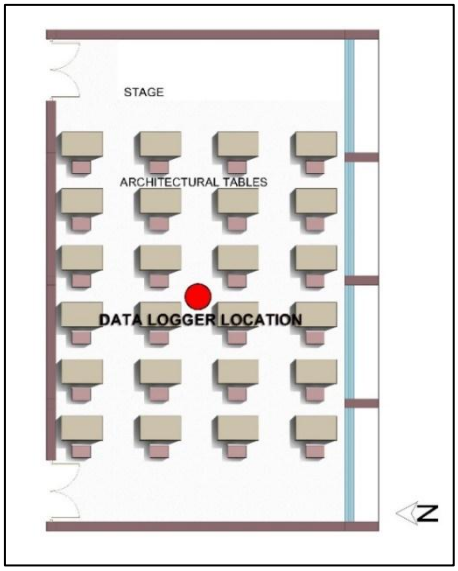

Figure 3: Typical Layout of a Studio Classroom

There are 24 students in each year and there are 5 studios means 100 architecture students spends long hours in a building which requires proper retrofitting to meet ideal thermal environment.

3 Results and discussion

3.1 Analysis of the air temperature and relative humidity variations

The classroom has its function as both theoretical class and practical hours that needs concentration and the relaxed mind for their performance thus highlighting the need of a thermally comfortable indoor environment. Table 1 shows the average ambient air temperature and Table 2 shows the average relative humidity recorded during the study.

Table 1: Air Temperature readings

AIR TERMPERATURE VARIATION				
TIME / LOCATION	09:00	11:00	01:00	03:00
STUDIO 1	17.7	18.9	20.5	21.7
STUDIO 2	17.9	19.0	20.7	21.8
STUDIO 3	17.3	18.5	20.1	21.2
STUDIO 4	18.7	19.5	20.9	21.6
STUDIO 5	17.5	18.7	20.4	21.5
OUTDOOR	18.9	19.8	21.3	22.2

Table 2: Relative humidity readings

RELATIVE HUMDITY READINGS				
TIME / LOCATION	09:00	11:00	01:00	03:00
STUDIO 1	83.3	53.4	41.6	62.4
STUDIO 2	83.2	52.9	40.8	62.1
STUDIO 3	85.2	55.2	42.3	63.4
STUDIO 4	80.3	48.1	38.6	60.2
STUDIO 5	84.5	54.8	42.3	63.1
OUTDOOR	78.3	45.5	36.4	58.6

The air temperature and the relative humidity readings are taken by data loggers at 9:00hrs, 11:00hrs, 1:00hrs and 3:00hrs means at every 2 hours interval from the starting of the class hours to end.

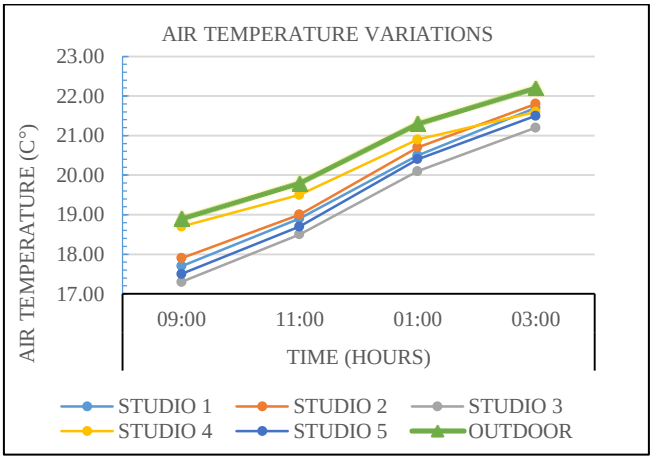

Figure 4: Graph showing Air temperature variations for a Day with Two Hour Interval

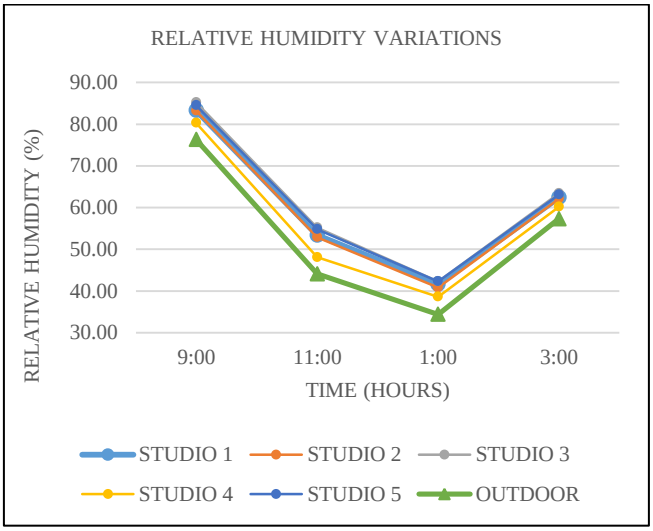

Figure 5: Graph Showing Relative Humidity Variations for a Day with Two Hour Interval

By analysing these charts which are evolved from the collected readings of air temperature and relative humidity certain things came into light. The variations in air temperature cab be observed in studios in ground floor and first floor and also in the studios who face north and south.

No studio in this department as windows on opposite side or on two walls, large window openings are on from end to other for proper natural lighting. Louvers are provided on all sides of the windows for cutting for the direct sun rays into the rooms.

The studios in which the wall with windows is oriented towards the north have less fall in temperature as it welcomes the sky light inside from morning to afternoon. While on the other side the studios facing south tends to have more fall in temperature because of less direct sunlight admits into it. The readings shows the factors like the orientation, sizes of louvers and cross ventilation are literally making the differences (favourable or not) in the indoor environment of studios. At 9:00hrs the studios 3 and 5 had more cool temperature than others while studio 4 was having temperature and humidity readings near to outside readings recorded. Between 1:00hrs and 3:00hrs, the temperature difference between classrooms were minimal and ranges from 0.1°C to 0.6°C. But the outdoor temperature had a gradual increase to about 1.5°C between 11:00hrs to 1:00hrs. The studios on the first floor also have comfortably cool temperature in afternoon as the result of direct heat radiation from the roof.

The relative humidity level are recorded highest in studio 3 in the morning time as it is not getting proper skylight entering inside nor direct sun radiation from roof. The rooms where the humidity levels are high the air temperature recorded lowest in winter season. In the afternoon time from 11:00hrs to 1:00hrs the humidity levels were recorded the lowest as compare to the levels all day long. The difference in the humidity levels between inside of studios and outside ranges from 2.0% to 9.7%.

3.2 Thermal comfort assessment through questionnaire survey

Questionnaire was designed to evaluate the thermal comfort levels among students. The questions are designed to draw out the user experiences of the students while studying and convert it into systematic data. That's why the questions are made simplified even non-technical course students can fill it easily, all they have to do is share their thermal sensational experience inside those classrooms. The feedbacks given by the students of all 5 years in the questionnaire survey forms are collected in between 11:00hrs to 1:00hrs.

The analysis is done according to adaptive thermal comfort model which comfort is based on the findings of surveys of thermal comfort conducted in the field. Field surveys concentrate on gathering data about the thermal environment and the simultaneous thermal response of subjects in real situations, interventions by the researcher being kept to a minimum.

The questionnaire have 12 questions total and is divided into three parts like personal data, thermal comfort situation and requirements. The sample questionnaire used for survey is shown in Appendix A.

Responses then converted into results showing the percentage of the student's agreeing or disagreeing on questions asked. Pie charts are of the responses taken from the studio 4 students and are shown in Figure 6 and Figure 7. This thermal assessment is conducted to do a comparative analysis with the temperature and relative humidity readings recorded.

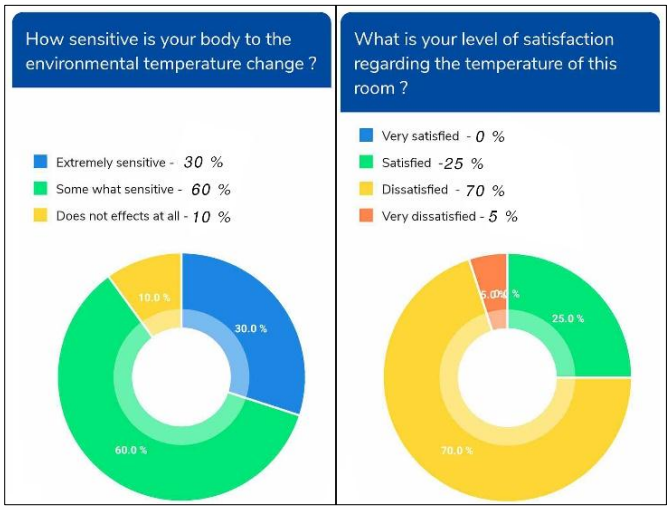

Figure 6: Pie charts depicting results of the thermal comfort situation part in thermal assessment survey

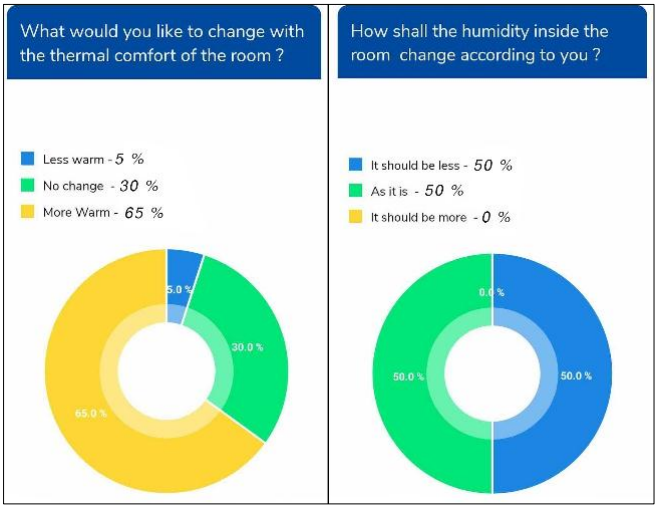

Figure 7: Pie charts depicting results of the requirements part in thermal assessment survey

The result shows approximately 70% students are dissatisfied with the current thermal conditions provided inside the studios. Their responses are unsatisfactory towards the air temperature inside the studios while their reactions for relative humidity are somewhat neutral. No student claimed to have no effect at all on their bodies by cool winter winds and humidity. So the retrofitting demanded by all the students as per their feedbacks.

The dissatisfaction levels are more in studio 3, 5 and 1 as these are the same studios where the air temperature readings were recorded lower than other. In afternoon time the overall inner environment are acceptable to students as the temperature rise up because the sun radiation.

4 Conclusions

The analytical study conducted to understand the thermal comfort conditions of the studios of an architecture college by objective and subjective manner simultaneously. This study revealed out some problems that students have to face while studying during the long hours in studios. Design features like cross ventilation by providing windows on opposite sides of the wall in studios, installing window blinders and maintaining vegetation covers near the windows can be effective in reducing heat gain during summer season but not as much useful for winter season.

The main retrofitting measures are rectification of the window frame structure as it becomes hardly functional, installing of the clear double glazed window glass with low SHGC (solar heat gain coefficient) value for optimal heat balance inside and installing of centralized HVAC systems for balancing an equilibrium in maintaining thermal conditions and less energy consumption. A centralized HVAC systems should be install after conducting a cost benefit analysis and only in the studios as these rooms are larger than normal lecture rooms and other rooms in the department already have AC units. Other tactics like replacing the steel plate stools with leather bar stools which can provide students to sit more comfortably. And many measures can be taken according to the maintenance budget of the architecture department in future but the retrofitting measures mentioned above should be implemented as necessary steps for improving thermal comfort conditions in the studios.

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Appendix A:

Thermal comfort assessment survey:

I like your participation in answering this questionnaire based on your thermal sensation, the valuable feedbacks from this survey helps us to find out ideal thermal comfort condition in your studio classrooms.

1. Age:

2. Sex:

3. Time:

4. Season:

Please tick the suitable bubble against the various scales:

5. How sensitive is your body to the environmental temperature change?

- Extremely sensitive
- Somewhat sensitive
- Does not effects at all

6. Is there any external source of change in temperature (heaters or AC units)?

- Yes
- No

7. In which direction is your classroom oriented?

- North
- South
- East
- West
- North East
- North West
- South East
- South West

8. How is the thermal sensation of the room?

- Very Cold
- Cool
- Slightly Cool
- Neutral
- Slightly Warm
- Warm
- Hot

Others……..

9. How much comfortable do you feel inside the room?

- Too Cool
- Comfortably Cool
- Normally Comfortable
- Comfortably Warm
- Too warm

Others……..

10. What is your level of satisfaction regarding the temperature of this room?

- Very Satisfied
- Satisfied
- Dissatisfied
- Very Dissatisfied

11. What would you like to be change with the thermal comfort of the room?

- Less Warm
- No Change
- More Warm

12. How shall the humidity inside the room change according to you?

- It should be less
- As it is
- It should be more