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Thermal Comfort assessment of a Studio Classroom in Hot & Humid Climate Conditions

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Abstract

A study on the indoor comfort level of a studio space – where both theory and drawing classes takes place is carried out. This paper presents the study of indoor thermal comfort carried out in 6 classrooms from ground to first floor in an institution at Chennai. The field study was conducted during a hot summer week consisting of 5 working days from 8 am to 4 pm. This study is carried out to assess their thermal conditions during the student's lesson hours. Objective data analysis showing the environmental condition of the classroom, and Subjective analysis through questionnaire were collected to record the thermal sensation of the students. In any functional space the thermal adaptation can be attributed to three different processes - behavioral tuning, physiological accommodation and psychological training. Finally, the maximum acceptable temperature has been derived through Predicted Mean Vote and comfort level from the survey results.

Introduction

Thermal comfort is an important factor in a classroom which affects student's performance. 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 - behavioral tuning, physiological accommodation and psychological training. The evaluation of thermal sensation is based on the international standards like ISO, ASHRAE and takes into consideration of parameters related to individual and their environments. Indoor thermal comfort could be altered with the quality of indoor environments with environmental elements like the heat from electrical lighting, less ventilation, high humidity levels and unsuccessfully performing building envelopes. The assessment of thermal comfort helps us to find the quality of indoor environment and also helps in the optimization of energy required to achieve desired comfort levels.

The classroom requires appropriate temperature and humidity controls that respond to the students and staff sensitiveness. The continued environmental stress can drain student's physical and mental resources which ultimately affects their performance. Indoor environmental variables like air temperature, relative humidity, mean radiant temperature, air velocity, clothing levels during lecture hours, amount of physical activity done in classroom affects the human thermal comfort sensation. Fanger's PMV model based on the steady state heat transfer theory is the standard basis of thermal comfort (Fanger, 1970). The research works of Zingo (2001) in Malawi (East-Africa) specified the importance of the comfort temperature.

The human's reaction towards the tolerance of higher temperature depends on his expectations, personality and his work at that particular time (Mclntyre, 1980). A study of thermal comfort in a given location helps us to determine the acceptable range of environmental parameters. This permits to propose some architectural recommendations and to determine building materials best adapted to each type of climate (Jannot, 1993). Along with the control of physical variables, adjustments in the amount of furnishing in a space and lighting levels could probably provide a solution in improving thermal comfort (Rohles, 1981). A field study on the environmental conditions and occupant comfort was carried out in a block which has 10 classrooms from ground to second floor. From the subjective assessment, it was generally found that the occupants in the tropical environment have a higher heat tolerance and can adapt to the environment beyond the ASHRAE comfort zone (Hussein, Rahman, 2009).

Area of study

Sathyabama University is an institutional campus in the suburbs of Chennai experiencing hot humid climate (Fig. 1a) and the selected block for the study is shown in Fig. 1b. The maximum air temperatures during summer (May and June) varies between 38°C and 42°C and the minimum air temperatures during winter (December and January) varies between 18°C and 20°C. The average monthly relative humidity ranges from 63% (June) to 80% (November) and the vapour pressure varies between 22.6hpa and 32hpa. The institution houses several academic blocks of which the architecture block is considered for this study. Indoor environmental variables like air temperature and relative humidity were measured. The thermal properties of the built surfaces were similar in all the classrooms, the materials used for built surface include brick walls, concrete roof and tile flooring with less vegetation cover.

Fig. 1 a) Sathyabama University Campus, Chennai b) View of Architecture block

Fig. 2 Images of the typical studio classroom

The measurements were taken every 30 minutes at approximately 1.5 m height from the ground level, between 8 am and 4 pm on a typical summer week. This study is carried out to assess their thermal comfort conditions during the students' lesson hours. The data loggers were placed in six classrooms in the academic block and one in the outdoor environment. The images of the typical studio classroom which consist of desks for theory classes and drawing boards for practical hours are shown in Fig. 2.

Methodology

The air temperature and relative humidity data were measured continuously on an hourly basis using HOBO dataloggers (HOBO U20 Temp/RH) in the selected locations. The wind speed and the cloud cover data from the Sathybama Meteorological station were used for the study. This study is carried out to assess the thermal conditions in indoor environment during the student's lecture hours. Objective data analysis showing the environmental condition of the classroom and Subjective analysis through questionnaire, records the thermal sensation of the students.

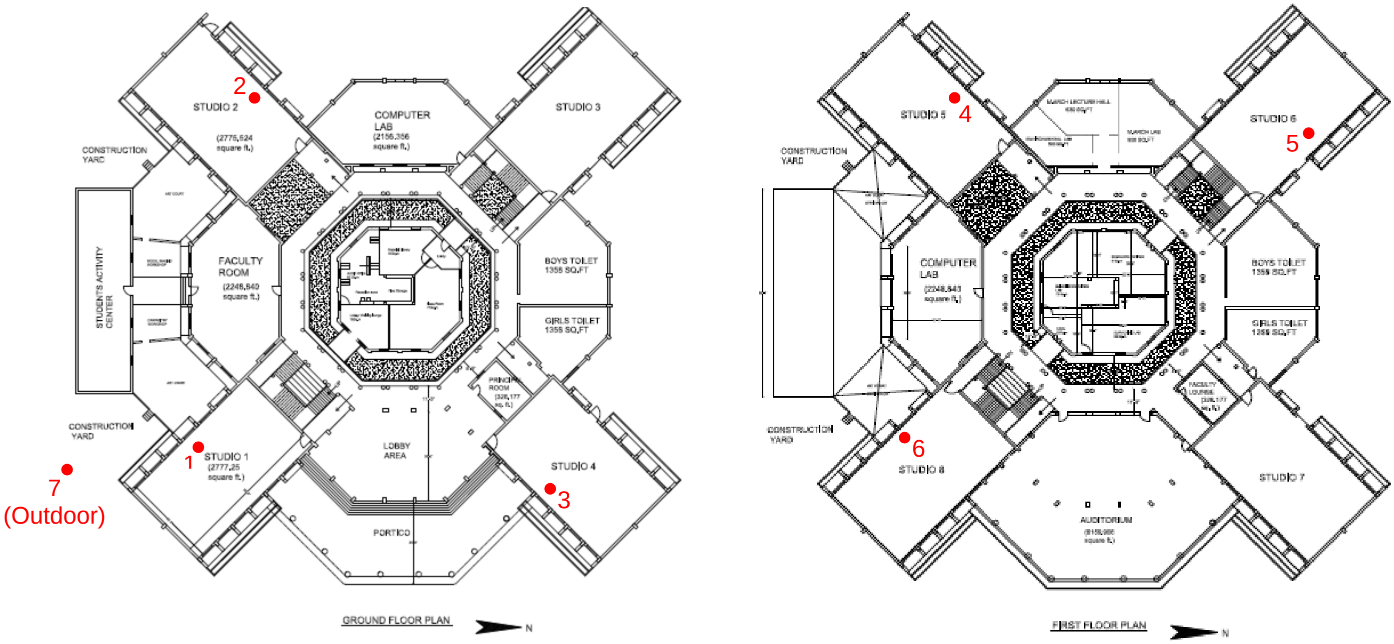

Fig. 3 Floor plans of Architecture department showing measurement locations

The field study were conducted on a typical summer week for 5 working days from 8 am to 4 pm and the air temperature and relative humidity data were measured to assess the thermal conditions during student's lecture sessions. The location of logger position in the classrooms and outdoor environment is shown in Fig. 3. Fig. 4 shows the typical layout of a studio classroom. Also a questionnaire survey on thermal sensation in the selected locations was conducted to study the subjective response of students to the indoor thermal comfort during daytime. The sample questionnaire used for survey is shown in appendix 1. The subjective response of the respondents, the temperature and relative humidity during daytime were compared to identify the maximum acceptable temperature for a thermally comfortable environment.

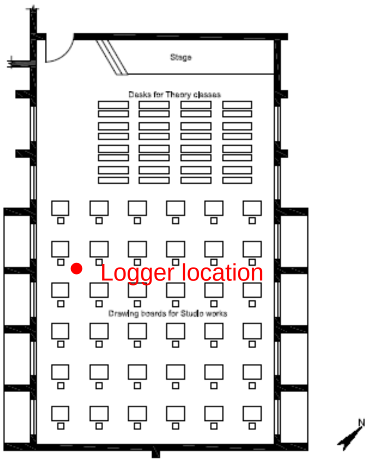

Fig. 4 A typical studio classroom layout

Results and Discussion

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. Daily Air Temperatures at Various Classrooms

Air Temperature Measurements									
Time (hrs) / Location	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Studio 1	32.7	33.0	33.5	34.0	34.3	34.4	34.5	34.4	34.6
Studio 2	32.1	32.3	32.8	33.4	33.8	34.0	33.8	33.9	33.7
Studio 4	33.1	33.4	33.6	33.9	34.1	34.2	34.0	34.0	34.0
Studio 5	31.8	32.3	33.0	34.2	34.8	35.2	35.2	35.5	35.3
Studio 6	32.6	33.1	33.8	34.4	34.6	34.7	34.6	34.6	34.5
Studio 8	32.2	32.7	33.5	34.4	35.2	35.9	36.2	36.8	36.6
Outdoor	31.0	32.8	35.1	36.3	36.9	36.7	35.9	36.1	34.0

Table 2. Daily Relative Humidity at Various Classrooms

Relative Humidity Measurements									
RH (%) / Location	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Studio 1	65.25	62.24	59.37	57.41	56.84	57.23	57.73	57.59	60.84
Studio 2	66.31	63.95	61.09	58.51	57.14	58.75	59.47	58.51	62.55
Studio 4	64.09	62.00	60.06	58.27	57.46	58.35	58.93	58.65	61.56
Studio 5	65.43	62.48	58.95	55.25	54.20	54.41	54.64	53.49	58.45
Studio 6	62.42	59.24	55.97	53.55	53.45	54.67	55.78	55.19	59.40
Studio 8	67.02	64.33	61.11	58.52	57.14	57.27	57.10	55.64	59.90
Outdoor	68.63	61.71	53.46	49.97	50.29	52.04	54.60	53.42	63.74

Average air temperatures and relative humidity recorded has been mapped at 08:00 hrs, 09:00hrs, 10:00hrs, 11:00hrs, 12:00hrs, 13:00hrs , 14:00hrs , 15:00hrs & 16:00hrs with a one hour interval. The air temperatures variations are plotted in graph are shown in Fig. 5 which revealed a distinct temperature difference with respect to indoor and outdoor locations, floor plates and window orientations and ranged from 32.1 ^{0}C to 36.8^{0}C. The roof of the first floor classrooms were directly exposed to solar radiation and have a significant impact on the temperatures.

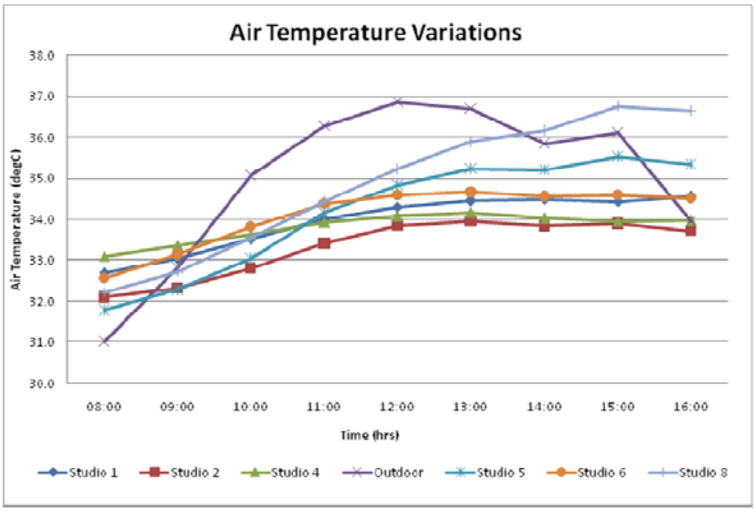

Fig. 5 Graph showing Air temperature variations for a day with one hour interval

At 8:00 hrs studios which has opening on west side experienced the lowest temperature and studio 4 on the northeast orientation recorded the maximum temperature with a difference of 1.3^{0}C. The increase in morning temperature is attributed to eastern orientation as studio 4 receives the morning sun from the east. Between 9:00hrs and 11:00hrs, the temperature difference between classrooms were minimal and ranges from 0.4 ^{0}C to 1.1^{0}C. But the outdoor temperature had a gradual increase to about 3.5^{0}C between 9:00 hrs to 11:00hrs. From noon the studios in the first floor shows a gradual increase due to the opening in the western side and the direct heat radiation from the roof. The temperature difference ranged from 1.37 ^{0}C to 2.33 ^{0}C from studio 2 located in the ground floor to the studios 5 and 7 in the first floor. Towards evening at 16:00 hrs the air temperature starts decreasing gradually by 0.1 to 0.2 ^{0}C in the indoor and 2 ^{0}C in the outdoor environment. The temperature variation in the indoor environment varies according to the movement of sun and the heat penetration through window openings.

During daytime, the relative humidity varies from 53.44% to 67.00% and the maximum humidity is recorded at studio 8 (Fig. 6) the humidity levels are high in the morning at 8:00 am and it varies as the time goes on due to the closed window openings in the night time. In the afternoon as the sun moves towards west and due to the surface cooling of the ground floor the ambient air temperature at ground floor studios are less. The elevated air temperature at studio 8 reduces the humidity in the noon.

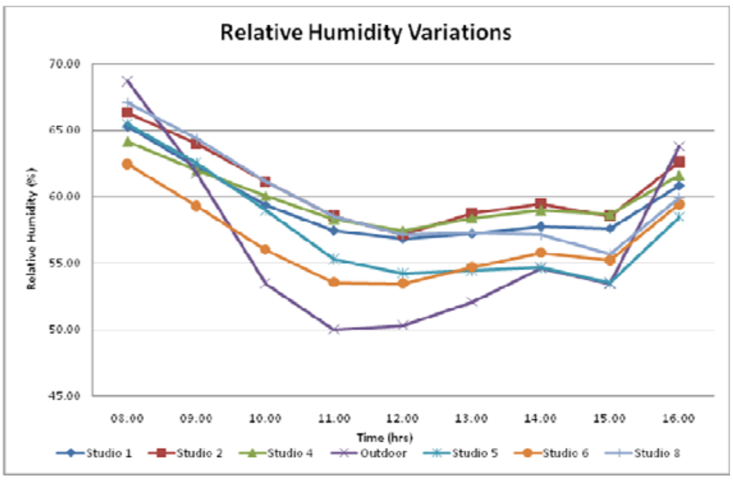

Fig. 6 Graph showing Relative Humidity variations for a day with one hour interval

Analysis of Questionnaire Survey

A questionnaire was distributed to the students in order to evaluate their thermal perception, while measurements were taken. The questionnaire was divided into three parts like personal data, thermal aspects and comfort levels.

The results of questionnaire survey in the selected locations are compared with the graphs to comprehend the thermal sensation of the users in the classrooms. The thermal perception of human with respect to the thermal sensation, feeling of comfort, satisfactory level of comfort in the place and the overall conditions of acceptance are compared. The result on thermal sensation revealed that the respondents felt the heat and were almost tolerable at all the classrooms in the ground floor and 2 classrooms in the first floor. In the studios 5 and 8, the thermal perception of the respondents was hot due to the openings on the western side and the heat from the roof.

The users were not fully satisfied with the ambient air temperature in the classrooms. The dissatisfaction is more at locations 5, 6 & 8 and satisfaction rates are higher in the classrooms in the ground floor. The overall conditions inside the classrooms are acceptable for the users as the indoor environment gets reduced gradually after their lunch break in the noon. The classrooms provide a comfortable indoor environment as the occupants in the tropical environment have a higher heat tolerance (Hussein, I.Rahman, 2009). The result scale ranges from -0.5 to +0.5 and the temperature is comfortably warm with the preferable air movement inside the classrooms.

Conclusion

A study on thermal comfort was conducted in the classrooms for understanding the acceptable temperature. It is clearly stated from the measurements recorded that the solar irradiation is the main aspect of classrooms' heating, as the direct radiation to the classroom increases the indoor temperature. For reducing the indoor temperature the exposed surfaces needs to be protected by vegetation, shades and fins, as the increase in air temperature accelerates discomfort and in turn affects the performance of the students. With the good air ventilation system either naturally or mechanical the classroom comfort levels can be improved. Some architectural recommendations through building materials can be adopted to improve the indoor thermal comfort along with passive techniques.

References

1. Nyuk Hien Wong, Shan Shan Khoo, 2003, Thermal comfort in classrooms in the tropics, *Energy and Buildings 35, pp.337-35.*
2. Khadijah Kamaruzzaman, Azimin Samsul Bin Mohd Tazilan, Thermal comfort assessment of a classroom in tropical climate conditions, *Recent Advances in Energy, Environment and Development*, pp.87- 91.
3. Nematchoua Modeste Kameni, Rene Tchinda, Noel Djongyang, 2013, Field study of thermal comfort in naturally ventilated classrooms of Cameroon, *Universal Journal of Environmental Research and Technology*, volume 3, issue 5, pp. 555-570.
4. Nematchoua Modeste Kameni, Rene Tchinda, Jose A.Orosa, 2014, Adaptation and comparative study of thermal comfort in naturally ventilated classrooms and buildings in the wet tropical zones, *Energy and Buildings* 85, 321-328.
5. ASHRAE 55 (2004): Thermal environment conditions for human occupancy, Atlanta, GA, USA.
6. Fanger PO, 1970, Comfort thermique, New York, MC Graw Hill.
7. J. Van Hoof, M. Mazej, J.L.M. Hensen, 2010, Thermal Comfort: Research and practice, *Frontiers in Bioscience*, Vol.15, No.2, 765-788.
8. D.Teli, m.F. Jentsch, P.A.B. James, 2012, Naturally ventilated classrooms: An assessment of existing comfort models for predicting the thermal sensation and preference of primary school children, *Energy and Buildings* 53, 166-182.

Appendix 1

Study on Indoor comfort and Air quality in a Studio classroom of Institution Building

I like your participation in answering this questionnaire based on your thermal sensation, the inputs from this survey helps us to find out maximum acceptable temperature in a studio classroom.

Age: Sex: Time:
Clothing: Are you under fan: (Yes/No/Partial)

Please tick ( ) the suitable bubble against the various scales:

1. In which orientation your classroom is located?

North	South	East	West	NE	NW	SE	SW

2. How do you feel about the thermal environment in the room (Thermal sensation)?

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot

3. What is your feeling of comfort in the room?

Too cool	Comfortably cool	Comfortable	Comfortably warm	Too warm

4. At which satisfactory level the temperature of the place is?

Very satisfied	Satisfied	Dissatisfied	Very dissatisfied

5. At present what would be your liking in the level of air movement in the room?

Less air	No change	More air

6. What can be the humidity level in the room?

Lesser	As it is	More

7. Would you prefer some mechanical ventilation and air-conditioning?

Cooler	As it is	Warmer

8. Is the thermal environment acceptable?

Yes	No