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A Study on Adaptive Thermal Comfort in Naturally Ventilated School Building in Kathmandu

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Abstract

Students spend about 30% of their daily time in school.Extremely high and low temperature inside the classroom interrupts the student learning ability and focus. It will also degrade the health and productivity of the students. In Nepal, classrooms do not meet the required thermal comfort standards.A classroom is called satisfactory if 80% students feel thermally comfortable.The performance of the building is directly related to the indoor thermal environment. Ventilation and insulation have a direct impact on the thermal comfort of the classroom. In naturally ventilated classroom, windows are mostly open during school time. This study investigated the thermal perception of the students by conducting a thermal comfort survey in 100 students in four different schools in Kathmandu during February of 2020. In this study mean indoor temperature range 20°C–22°C and the mean outdoor temperature range 19°C–24°C . Seven-point thermal sensation vote survey shows that 92 % respondent voted for central three points and only 8 % voted outside the central point.This shows that the students are comfortable in their classroom in naturally ventilated school in the month of February. The simulation results show that the thermal performance of 9” brick wall is better than EPS sandwich panel and cement board with rockwool wall.

Keywords

Thermal comfort, schools, naturally ventilated classrooms, adaptive thermal comfort

1. Introduction

The global population is increasingly dependent on energy-intensive indoor climates. However, reducing the building’s energy consumption and improving the indoor environment thermal performance is one of the conflicting criteria [1]. Buildings consume up to 40% of the total energy used in developed countries, whereas it is anticipated that developing nations will likely consume more energy than advanced nations by 2020 [1]. Thermal comfort is one of the most important parameters of the indoor quality and is defined through [2] as the state of mind that expresses satisfaction with the thermal environment in which it is located. Thermal comfort is affected by heat, conduction, radiation and heat losses by evaporation. There are six factors which influence the thermal comfort of humans, among them four are environmental and two personal factors [3].The environmental factors are the air temperature, the mean radiant temperature, the air velocity and the air humidity. Personal factors are the metabolic rate of the human and the insulation through clothing. The human body has a very effective system of regulating the temperature, which is constant at about 37°C.

School buildings constitute a rather special case of building [4]. Thermal conditions in classrooms have to be considered carefully mainly because of the high occupant density in classrooms and because of the negative influences that an unsatisfactory thermal environment has on learning and performance [5, 6]. Specifically, comfort conditions affect users physically as well as psychologically and consequently, they have an impact on the performance of their activities.Due to topography, Nepal has a large difference between the regional comfort temperature [7]. This may be due to adaptive behaviour and clothing adaption to their climatic region. Our Neighbouring country India and Pakistan have their own thermal comfort standards. But our country has not yet established any such thermal comfort standards. This study may help the government to formulate the standards and policy in the near future.

2. Need and Importance of research

Thermal comfort in school classrooms has a significant impact on children's performance and health. Children spend more time in schools than in any other building except at home evidence the importance of achieving a comfortable thermal environment in school buildings [8]. According to the Ministry of education Nepal,2074 census, in Kathmandu there are 102 community school and 1060 institutional school. These schools are made up of different building materials mostly brick masonry. Other construction technology like a prefab, cement board, hollow concrete blocks, bamboo etc. are also used to construct the school. However, there is less research done regarding thermal comfort in the school. Government records show over 33,000 classrooms in 7,923 public schools in 32 districts across the country were destroyed in the 2015 earthquakes. Due to the lack of student, 370 such schools were merged and 7,553 school buildings have been rebuilt. So far, 4,476 school buildings have been built, while 1,772 buildings are under constructions [9]. Hence it is necessary to conduct this research so we can suggest how can we achieve thermal comfort in the school buildings which are going to be constructed. Government sectors, private sectors, NGOs, INGOs, academia who are involved in promoting the educational sector in Nepal can get benefit from this research. This research provides comprehensive knowledge of adaptive thermal comfort in a naturally ventilated school building in Kathmandu.

3. Research Objective

The general objective of this research is to study the adaptive thermal comfort of a students in a naturally ventilated school building. The specific objectives of this research are as follow:

- To find the thermal perception of the students under the naturally ventilated mode.
- To compare the thermal performance of the building materials.

4. Research Design and Methodology

Qualitative and exploratory research is carried out to gain in-depth knowledge regarding the study of the thermal comfort of the students in a school building. Thermal comfort vote of the student is taken with the help of ASHRAE scale by conducting field studies to find out the thermal perception of the student.In the meantime, the temperature inside and outside the classroom is measured using room thermometer for two consecutive days in each school for the whole school time in the interval of each period. In addition to that relative humidity was also measured. To achieve our second objective, the thermal behaviour of three different building materials are analyzed in Ecotect software. For this detail measurement and study of the floor plan, building material and tenchnology was studied.

4.1 Climate of Kathmandu

To study the adaptive thermal comfort of any place,local climate of that place need to be analysed. Kathmandu is located on the latitude of 27.7172 °N and longitude of 85.3240 °E in the central part of Nepal. The climate of Kathmandu can be classified as warm and cool temperate climate [10]. There is a hot-arid climate from Chaitra to Jestha (March 15 to June 15). Monthly mean maximum temperature i.e. daytime temperature is 30.7 °C in June. Likewise, monthly mean minimum temperature i.e nighttime temperature is 3.6 °C in January. The annual mean temperature of Kathmandu in 2019 is 19.38 °C. We can find the warm-humid climate from Ashar to Bhadra (June 15 to Sep 15) during Monsoon season. There is a cool climate in Mangshir, Poush and Magh (November 15 to January 15). The most favourable climate in Kathmandu is Ashoj, Kartik and Falgun (September 15 to October 15 and February 15 to March 15). Annual average relative humidity of Kathmandu in 2019 was 77.12 %. The humidity is maximum in the morning and decreases in the day time.There is a total rainfall of 1529.3mm. Kathmandu receives maximum rainfall in July(485.4mm) and minimum rainfall in October and November (0 mm).Annual average solar radiation measured in 2015 was 318.89 W/m2. There was maximum solar radiation in May (424 W/m2). In Kathmandu, indoor thermal comfort temperature is 26° C in summer and 15° C in winter for free running buildings [11]. The climate of the Kathmandu is the Warm temperate climate and is most suitable without the need for any mechanical cooling and heating system. But due to climate change, there seems extremely cold in winter and extremely hot in summer. Climate change results in melting of glaciers and snow covers, change in the weather pattern, irregular rainfall and increase in frequency and severity of an extreme event, including drought, flooding, cyclone and heatwaves [12].

4.2 Study Area and Buildings

The research is carried out in four schools. The schools are Ashiyali Tarapunja Secondary School(ATSS), Laboratory Secondary School(LSS), Samata Shiksha Niketan School(SSNS) and Jalpura Primary School(JSS). The total number of students surveyed are 100. The survey was taken during the regular class. The questionnaire was filled by students themselves with the guidance of the researcher. The teachers in the classroom also help to smoothly perform the survey in Ashiyali Tarapunja Secondary School and Laboratory Secondary School.The summary of the study area is shown in table 1:

Table 1: Study Area

Date	School	Location	Class	Student
Feb8	ATSS	Dakshinkali	7,8,9	48
Feb16	LSS	Balkhu	9	30
Feb 25	SSNS	Boudha	9	18
Feb 19	JSS	Baniyatar	teacher	4

4.3 Thermal comfort survey

The thermal comfort of the student is determined by taking the comfort vote survey based on ASHRAE SCALE. Hot (+3), Warm (+2), Slightly warm (+1), neutral (0), Slightly cool (-1), Cool (-2), Cold (-3). Those who vote outside the three-central point (+3, +2, -2, -2) are counted as dissatisfied and those who voted among three central points are counted as satisfied. If the satisfied counted are equal to or more than 80% than it is considered that the respondents are thermally comfortable otherwise not. Students voted their perception of thermal sensation (TS), thermal preference(TP) and overall comfort(OC) under sedentary conditions in a regular class. The students voted the thermal scale presented in the questionnaire which is translated in the Nepali language too for better understanding. The thermal scale used is shown in table 2.

Table 2: Thermal Comfort Scale

TS	TP	OC
hot(+3)	Much warmer(-2)	Satisfied
warm(+2)	Slightly warmer(-1)	Disatisfied
slightly warm(+1)	No change (0)	
neutral(0)	Slightly cooler(+1)	
slightly cool(-1)	Much Cooler(+2)	
cool(-2)		
cold(-3)		

5. Results and Discussion

5.1 Indoor and Outdoor temperature

In naturally ventilated space an indoor environment is highly influenced by the outdoor environment. The seasons and region are the major factors that bring changes in air temperature. The indoor and outdoor temperature of each naturally ventilated school building was measured. In this study mean indoor temperature range 20°C-22°C and the mean outdoor temperature range 19°C-24°C.While studying thermal comfort, role of humidity also come. However, in ordinary environment, the effect of humidity on our thermal perception as measured by comfort vote is very small. High humidity reduces the range of comfort temperature rather than shifting it up and down . According to Givoni,1962, “humidity does not affect the rate of evaporation from the body, except under extreme condition, because the body has capacity to compensate for higher humidity by increasing its wetted area. The measured average relative relative humidity inside and outside the classroom is same (51%), due to natural ventilation. The structure and performance of the building along with the material used are the other factors that effect in air temperature. The measured data is shown in the table 3.

Table 3: Inside and outside Temperature

School	Mean Indoor	Mean outdoor
ATSS	21.5	23.85
LSS	18.1	19.6
SSNS	21	22
JSS	20	20

5.2 Thermal sensation and thermal preference

From our thermal comfort vote, 92% respondent voted for central three points and only 8% voted

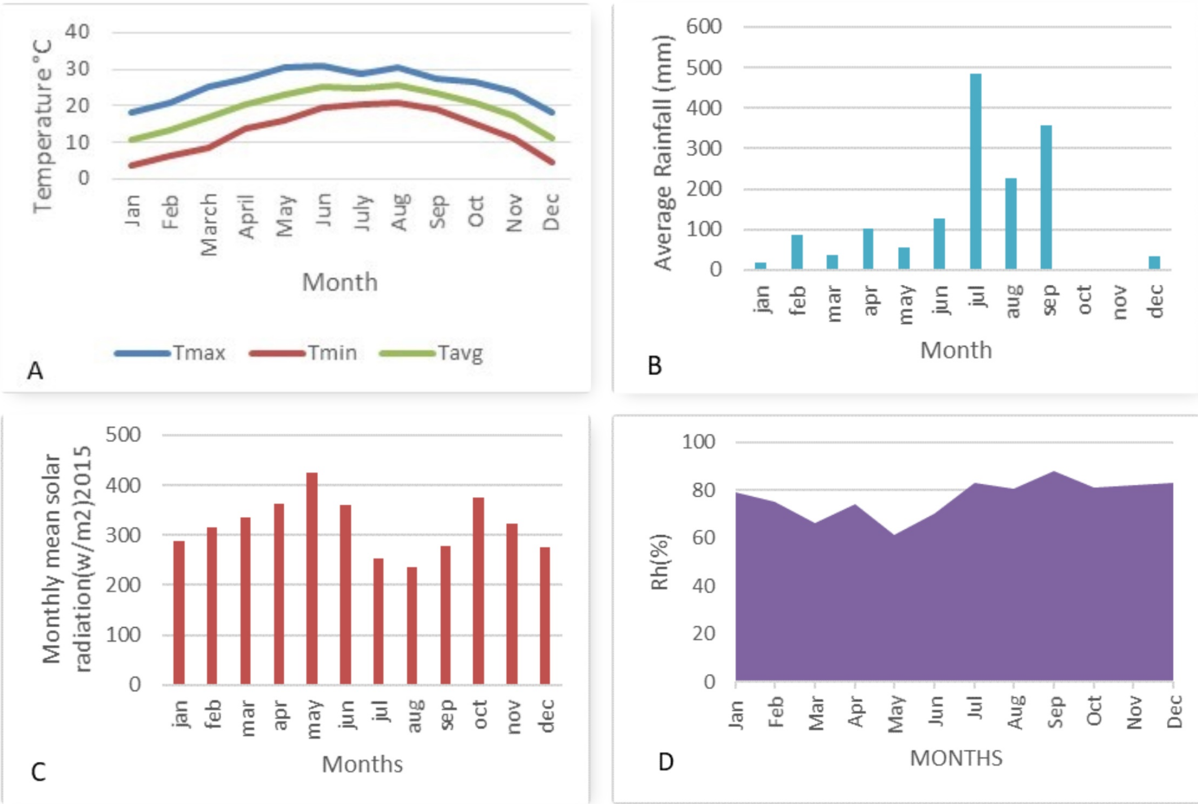

Figure 1: Graph A showing max., min., average temperature ; B shows average rainfall (mm); fig C shows mean solar radiation (W/m2) and fig D shows average relative humidity (%) of each month of Kathmandu(Source: DHMN,2019))

outside the central point. This shows that the students are comfortable in their classroom in a naturally ventilated school in the month of February. The thermal perception of the student was collected by using the 7-point ASHRAE scale. In seven-point thermal sensation vote (TSV), it is found that about 89%, 90%,100% and 100% respondent of the students were found in a comfort zone of classrooms of Aishiyali Tarapunja Secondary school, Laboratory School, Samata school and Jalpura school respectively.In fig 2, TSV is plotted in x-axis whereas the percentage of student voted in particular scale is represented in Y-axis and A,L,S and J represent the schools where survey was conducted.

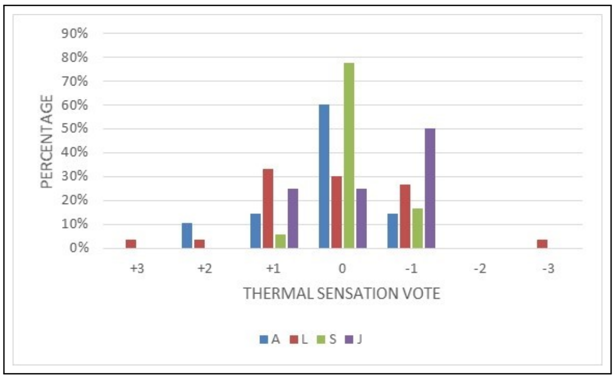

Figure 2: Distribution of thermal sensation

The result of the survey shows that the mean thermal sensation of the respondent was found “Neutral”. Very few students voted very hot, hot and very cold, cold .It is expected that, those students are seated on the window side or may suffer from some illness. The clothing of all the students are same as in school one have to strictly follow the dress code.

Similarly,thermal preference of the students was collected using a 5-point thermal preference scale. Students who respond “No Change”: Aishiyali Tarapunja School (38%), Laboratory School (23%), Samata School (56%) as shown in fig 3.This shows that this percentage of respondent accept the indoor environment and do not want any change in it.However, the mean thermal preference of all areas was found to be slightly warmer.

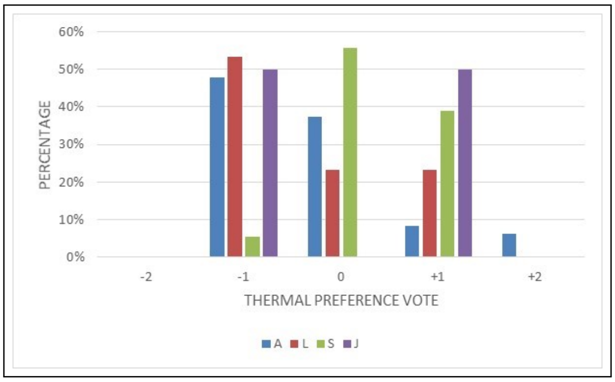

Figure 3: Distribution of thermal preference

A direct binary question was asked to the students to obtain responses on overall thermal comfort. Among them, 87% responded comfortable for their immediate environment as shown in figure 4. The results show the satisfaction of the students with their current environment.

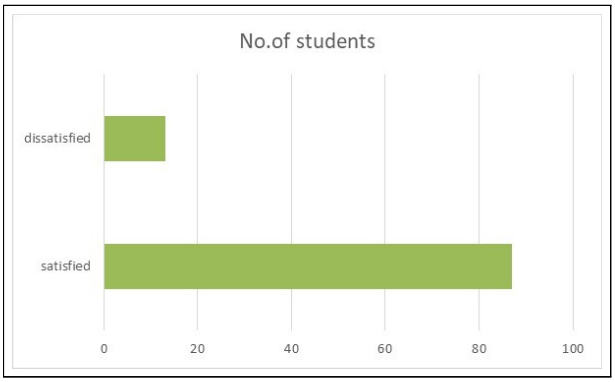

Figure 4: Overal comfort of the students

Figure 5 shows the distribution of subjects' thermal preference votes in relation to thermal sensation votes.The graph shows the thermal sensation vote from warm (+2) to slightly cool (-1) scale only on the x-axis. At 'warm' thermal sensation, 50% of the subjects are comfortable and don't want any change while other 50% wants to be slightly warmer to be more comfortable. As the sensation moves from 'warm' to 'slightly warm', 64% of subjects preferred to be slightly warmer, 18% desired no change and remaining 18% desired slightly cooler. At 'neutral' sensation, 43% of the subjects reported being slightly warmer while 30% didn't want any change and 27% wants to be slightly cooler. Those who voted for "slightly cool" thermal sensation desired thermal preference slightly warmer(28%), no change(44%), slightly cool(22%) and much cooler(6%) In nutshell we can say that from thermal comfort vote survey we cna conclude that 87 % students are thermally comfortable with their thermal preference slighlty warmer in month of February in 2020.

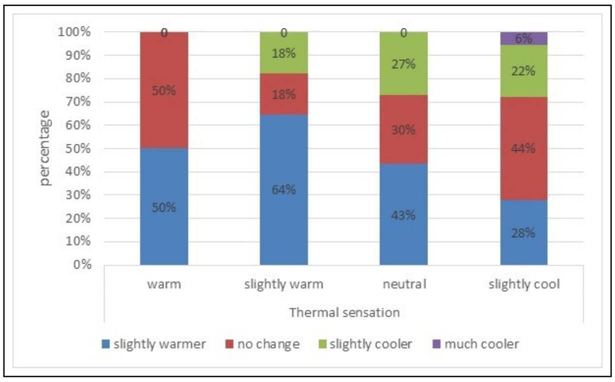

Figure 5: Cross tabulation of thermal sensation vote Vs thermal preference vote

5.3 Ecotect Simulation

Thermal performance of three building materials which the school we surveyd is made up of is analysed. Brick, EPS sandwich panel and cement board with rockwool are analyzed in Ecotect software. Simulation is done by putting the meteorological data which is obtained from HMD, Nepal. All the parameters of the building like building floor plan, orientation, doors, windows, roof are kept the same. Only the material properties of wall is altered in each run to find direct effect of wall material on thermal behaviour of the building. U-value of the wall material is calculated by assigning relevant wall component in the programme.

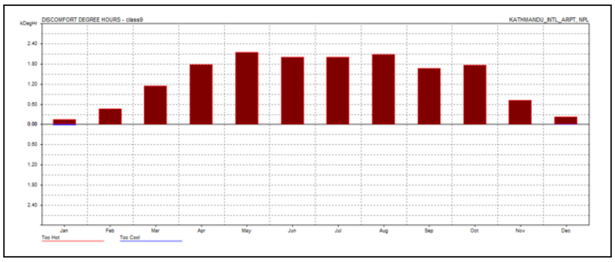

Figure 6: Brick wall: Monthly load discomfort; Discomfort Degree Hours too hot = 16213.2, too cool = 32.1; total discomfort = 16245.3

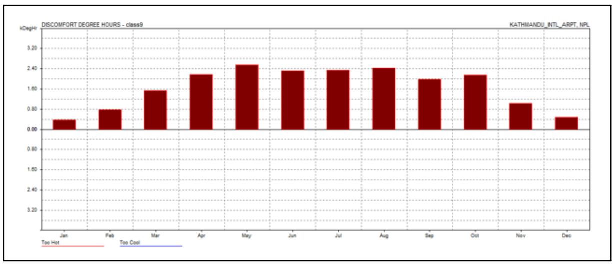

Figure 7: EPS sandwich pannel wall: Monthly load discomfort; Discomfort Degree Hours too hot = 20113.4, too cool = 11.1; total discomfort = 20124.5

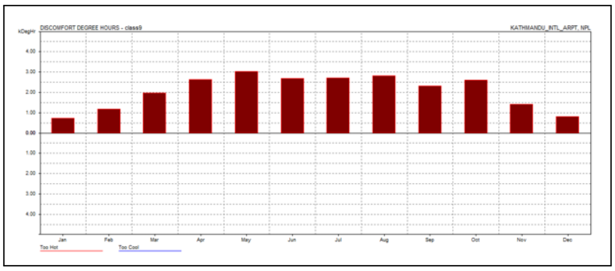

Figure 8: cement board with rockwool wall: Monthly load discomfort; Discomfort Degree Hours too hot = 24911.7, too cool = 2.0; total discomfort = 24913.7

The simulation results show that the thermal performance of 9" brick wall is better than EPS sandwich panel and cement board with rockwool wall. Cement board with rockwool wall shows least thermal performance than the other two.This shows that in Naturally ventilated building the insulation of the envelope doesn't play a significant role in maintaining the thermal comfort.

6. Conclusion

From the results and observation obtained from the literature review, comfort survey and Ecotect simulation, we can conclude that in naturally ventilated classroom students can adapt to their immediate environment. Natural ventilation is one of the important design guidelines to achieve thermal comfort. It is also concluded from the simulation that thermal performance of Brick wall is good than the Prefab panel.

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