Research Paper

Assessment of thermal adaptability of Women in Naturally ventilated Houses of Chhattisgarh (India)

Swasti STHAPAK, National Institute of Technology Raipur, India

Abstract

Thermal comfort is a very vital issue in tropical climate, where high temperature is a consistent issue throughout the year. It becomes even more important in those houses where electrical and mechanical equipment cannot be afforded. Thermal comfort range also depends upon factors like social background, economical condition, and duration of exposure to extreme thermal conditions. Due to various constraints the occupants of these houses devise ways to mitigate the problem of thermal discomfort. A study is necessary, to create understanding towards the range of comfort temperature needed by the occupants of these houses for performing specific functions. This may help to devise ways to construct houses that might be capable of achieving comfortable thermal conditions for performing functions in such houses. In this study, an attempt has been made to assess the thermal environmental conditions and quantification of thermal adaptation by women for the function of cooking in Bhaismuda village of Raipur district of Chhattisgarh plains in India. The village falls under the warm climatic zone of India. Thermal neutrality and thermal adaptability of women have been derived in naturally ventilated houses of this region.

Keywords

Thermal Comfort, Adaptation, Naturally Ventilated Houses, Thermal Neutrality

1. Introduction

1.1. Background

South Asian countries such as India, Pakistan, Bangladesh, Nepal, and Bhutan have similar socio-economic and cultural characteristics. They also face similar climate challenges. As per the world bank reports, 65.12 % of the population of this region lives in rural areas in 2020. The socio-economic strata of the people residing in rural settings in this region is mostly low. They are unable to afford contemporary concrete houses and lack basic amenities such as ceiling fans and air conditioning systems.

India hosts one of the world's largest populations, second only to China. Majority of its population resides in rural setting. As per the population census of 2011 about 68.84% of the country's population resides in rural regions. These people have the minimal ability to afford concrete houses and install electrical fittings such as lighting fixtures, ceiling fans or air-conditioning systems (P. C. Deb, 1984). Most of these houses are constructed of mud or unburnt bricks, which are cheap and easily available materials (Fanger and Toftum, 2002; Baboli, Ibrahim and Sharif, 2015; Soleymanpour, Parsaee and Banaei, 2015). India, being in a tropical climate, faces the problem of heat in most parts of the year. Mud and unburnt bricks being one of the poorest conductors of heat help in mitigating the problem of overheating (Kenneth and Miller, 2009; Heathcote, 2011; Dong, Soebarto and Griffith, 2014; Serrano, de Gracia and Cabeza, 2016). These types of houses are generally termed as naturally ventilated houses or unconditioned buildings, both the terms being used alternatively (Rijal, 2014). Occupants of these naturally ventilated houses are exposed to environmental conditions that vary significantly throughout the day and through the year.

1.2 Thermal Adaptation

Adaptation to the environmental conditions is predominantly noticed in the occupants of these houses. Heat balance models are not the best-suited ones for studying the neutral or comfort temperature, as they have a problem of overestimating or underestimating the same (Brager and de Dear, 1998; Thapa, Bansal and Panda, 2016). For studying the adaptations to the environmental conditions, they suggested that adaptive thermal comfort model is the best suited one.

1.3 Role of Women

The rural household highly depends upon the woman of the family as she takes care of the household chores and children. The Woman, who spends most of her time in these houses faces challenges of heating and overheating and evolves methods to mitigate it. In day-to-day life they perform various activities such as cooking, sitting, sleeping and recreational activities. All these activities generate heat in the body, leading to perspiration and ultimately getting exhausted. If the working environment is not favorable to dissipate this heat, the body gets exhausted or starts sweating fast to prevent overheating. The dissipation can take place only when the temperature of the environment is lesser than the surface temperature of the human body.

The women occupants shift time or spaces for functions according to season and level of thermal comfort, as different functions require different working environmental conditions and working in extreme thermal conditions is not feasible and recommended for the human body.

2. Methodology

To study the thermal comfort range and methods of adaptation practiced by the women occupants of these houses, lifestyle of the women was studied in their normal setting.

This study mainly focuses on use of kitchen by the women occupants of these houses. Therefore, the respondents were asked to respond for the type of kitchen they use. A separate room designated as kitchen was termed as closed kitchen and kitchen adjoined with any other function was termed as open kitchen. They were asked to respond for whether they use open kitchen or closed kitchen. Further, they were asked whether they shift their kitchen in different seasons or not. The respondents were asked about time of the day for probable use of kitchen. This information was used to study the usage pattern and thermal adaptation. Based on the responses, that were collected from the respondents, Gantt chart was prepared. The Gantt chart depicts the function timings and the time overlap present in them, if any.

To study the thermal conditions and occupant's sensation in the kitchen by the women in sample houses in all three seasons, thermal profiles of these spaces were prepared. For collection of thermal profile of functional spaces, it was needed that a stationary data logger should be placed for 24 hours. The stationary data loggers were placed 1.2 to 1.5 meter above the floors in spaces of the sample houses for 3 days in all three seasons. The process was carried in all 20 identified sample houses. The devices used for data logging were of Hobo make.

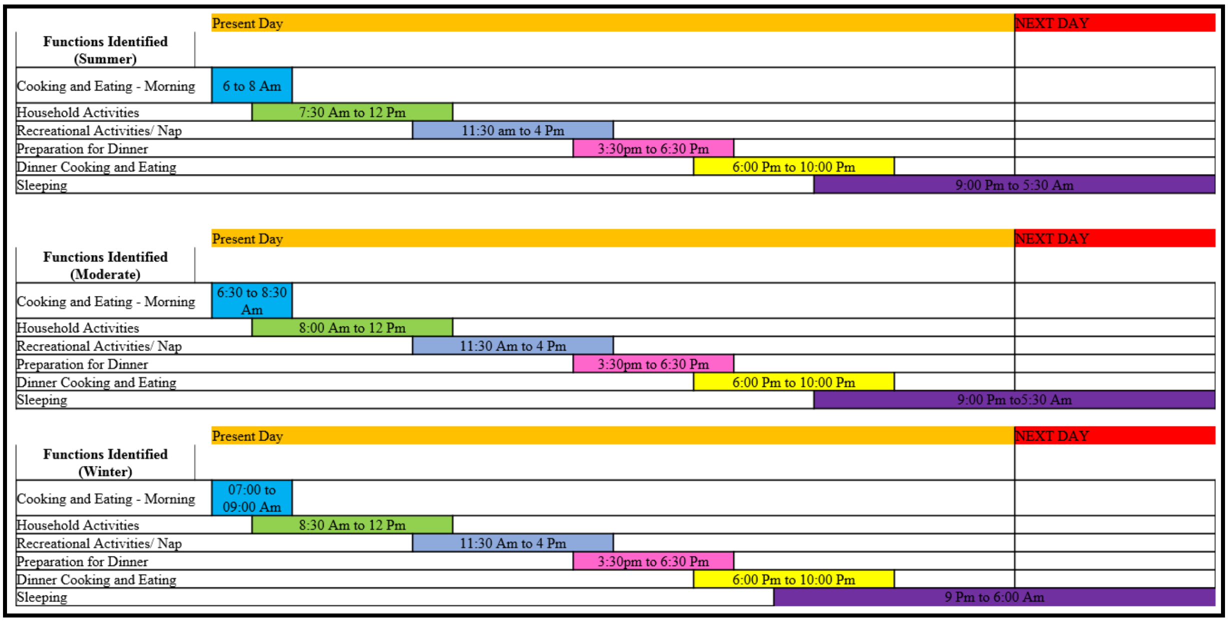
The readings for summer season were collected in the month of May. For the moderate season the readings were collected from August to September while for winter season the readings were collected from November to December.

Thermal Sensation Vote (TSV) was collected and corelated with simultaneous thermal parameters. The time of survey was set to collect the data preferably when cooking was taking place in the houses. Field survey was carried through questionnaire to collect TSV for the use of kitchen spaces. Simultaneous data of thermal parameters was collected using handheld devices. In the thermal survey information was collected about the thermal sensation, that the respondents were feeling, while performing the function of cooking in that season. The collected data was primary in nature and was collected on ASHRAE 7- point scale for TSV. The data thus collected was corelated to compute comfort temperature for cooking. For this, linear regression models were utilized., TSV was considered as dependent variable on independent variable air temperature (Nicol and Roaf, 1996; Dhaka *et al.*, 2013; Rijal, 2014; Ponni and Baskar, 2015). This was done for all three seasons. Based on the said parameters thermal adaptation was studied for cooking by women occupants of those naturally ventilated houses.

3. Analysis & findings

3.1. Lifestyle and Daily Routine

It was observed that the way of living of these women depend on the nature and climate to a great extent. The occupation of the family members also had bearing on deciding their daily routine. The male members of the house generally used to leave for their respective workplaces, by 08:30 am to 09:00 am. These workers mostly worked in shift of 09:30 am to 05:30 pm with a break of 1 hour 30 Minutes in the afternoon. Therefore, these people used to carry their lunch boxes with them. Due to this the morning breakfast and lunch was cooked together early in the morning in these houses. After the workers left for work, the houses were mostly occupied by the females of the house. Small children used to go to school in the only primary school present in the village. The elder children used to go to schools in other nearby villages. Apart from the household works the females also used to do the day-to-day maintenance and repair works of the house. The social interaction space of females was found to be mostly in and around the house, whereas that of males was observed in the streets or open grounds "*choupals*".



Figuur 1 Function Timing Description through Gantt Chart

To study the adaptation in functional use of spaces, a function time chart was prepared. It was found that in the morning hours the cooking and eating time in the village was around 06:00 am to 08:00 am in summer, 06:30 am to 8:30 am in moderate and 07:00 am to 09:00 am in winter season. The responses that had maximum frequency were used to construct the Gantt Chart (Figure 1). It was observed that the villagers performed the function of cooking with a certain time shift in different seasons.

3.2 Effect of Outdoor Temperatures on Indoor Temperatures

To study thermal adaptation, It was important to study the effect of outdoor temperature on indoor temperature. These two temperatures were collected, using handheld devices, while carrying thermal survey. This was repeated for all three seasons. The two temperatures were corelated. The models obtained for each of the season depicting relationship between indoor and outdoor temperature is saummiresed in table 1

Tabel 1 Summary of Correlation Between Indoor and Outdoor Temperature

Season	Regression Equation	Correlation Coefficient	Model Significance	Remarks
Summer	Ti= 0.733To + 10.39	0.792	Significant	High Degree of Correlation
Moderate	Ti =0.61To - 3.098	0.830	Significant	High Degree of Correlation
Winter	T_i =0.732T_o + 6.243	0.810	Significant	High Degree of Correlation

From the table 1 it is evident that, the regression model depicting relationship between indoor temperature and outdoor temperature is significant for all three seasons. This signifies that the outdoor temperature affects the indoor thermal conditions in these naturally ventilated houses. Further, this is an indicator that outdoor temperature would likely to affect the thermal sensation of the occupants of these houses to a large extent and in turn affecting comfort or neutral temperature for different functions.

3.3 Computation of Comfort Temperature

Field study of thermal comfort was carried out in these houses. To collect reliable data the survey was carried on adult people carrying apparently good and stable health condition for registering proper responses, as minors, old and physically ill persons would have a very different perception of thermal comfort. A self-administered questionnaire was developed using the inputs from reviewed literature. Sensation votes for thermal parameters were recorded. Simultaneous data of thermal parameters was collected using handheld devices. The questionnaire focused on recording of TSV of occupants for functional spaces under consideration. Simultaneously, air temperature of those spaces was recorded using handheld devices. This was done for all three seasons.

TSV and associated Air Temperature were subjected to regression model. In this model, the TSV was considered as dependent variable while the indoor room air temperature was considered as independent variable, capable of explaining variations in dependent variable. The model was found the best suited one, as numerous scholars have earlier used the same for computation of comfort temperature in their studies (Karyono, 2000; Feriadi and Wong, 2004; Cao, Zhu and Zhou, 2011; Dhaka *et al.*, 2013). The regression models, thus obtained, for cooking are presented in table 2 The TSV value in the obtained equations was then set as zero, indicating neutral sensation or comfort sensation. The temperatures so obtained were considered as neutral or comfort temperature for cooking for that season.

Tabel 2 Calculated Neutral Temperature: Cooking (Calculated in SPSS)

Season	Regression Equation	Neutral Temperature (°C)	R	R-Square

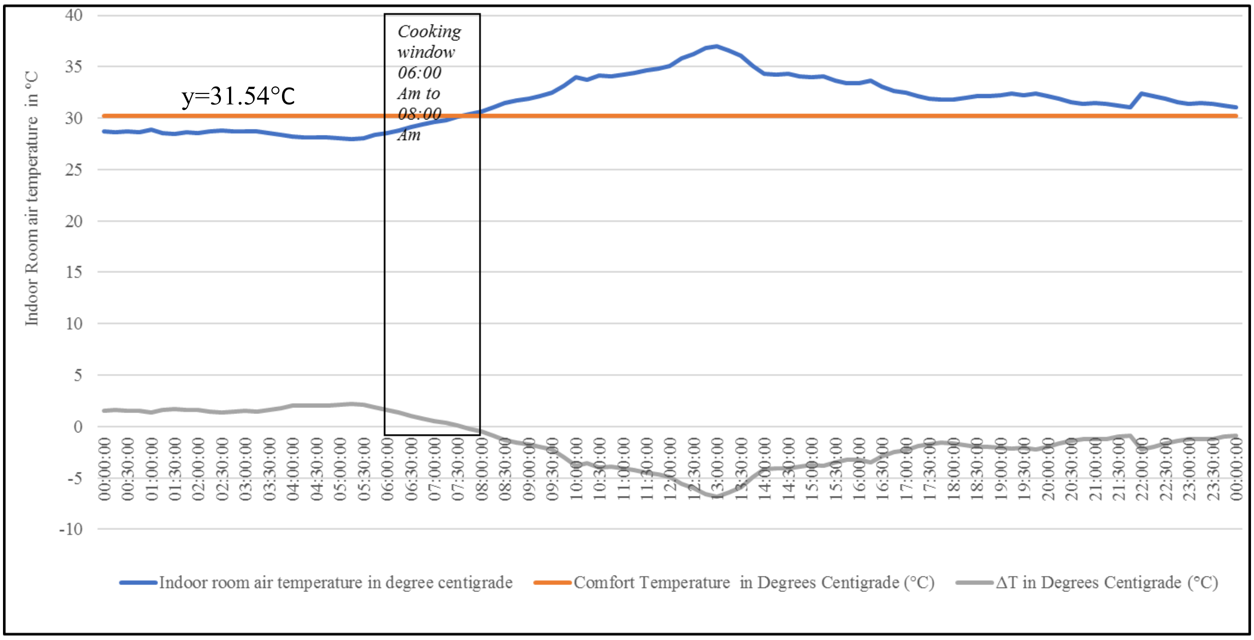
Summer	TSV= $0.2285T_{air}$ -6.94	31.54	0.92	0.85
Moderate	TSV= $0.2578T_{air}$ -6.94	27.76	0.89	0.79
Winter	TSV = $0.1581T_{air}$ -3.73	23.36	0.67	0.45

From the table 2, it is evident that, neutral temperature or comfort temperature for cooking in summer season was calculated as 31.54°C. For moderate season this was calculated as 27.76°C. For winter season it was calculated as 23.36°C.

3.4 Adaptation Method

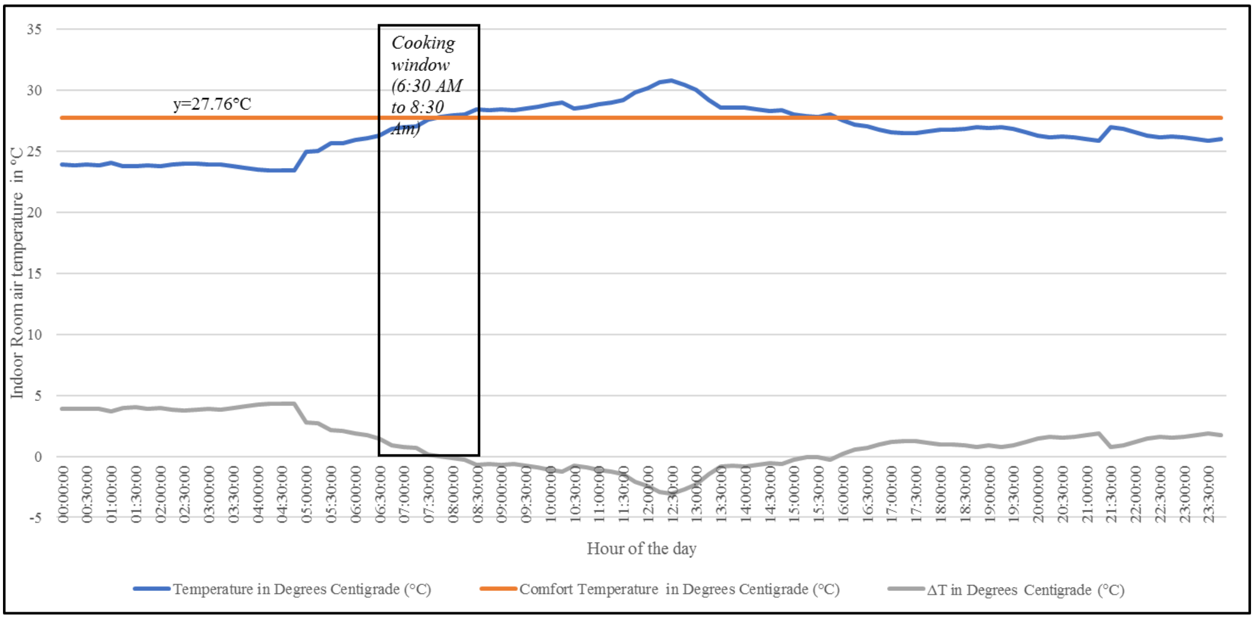
The survey exhibited the fact that, the cooking time was getting shifted by half an hour, as the season traversed from summer to moderate to winter. Moreover, maximum respondents, during survey, responded that, they prefer to cook at same space throughout the year. It was needed to relate the calculated comfort temperature with the thermal profile of the space, as many researchers have proved that it is a natural human tendency to execute a particular function in ones' thermal comfort zone (Auliciems, 1981; de Dear and Brager, 2001; ASHRAE, 2010; Dhaka *et al.*, 2013).

As per the Gantt Chart, the function of cooking was performed in time slot of 06:00 am to 08:00 am in summer, 06:30 am to 08:30 am in moderate and 07:00 am to 09:00 am in winter season. These time arrows were overlapped on thermal profiles of the functional space cooking for summer, moderate and winter season.



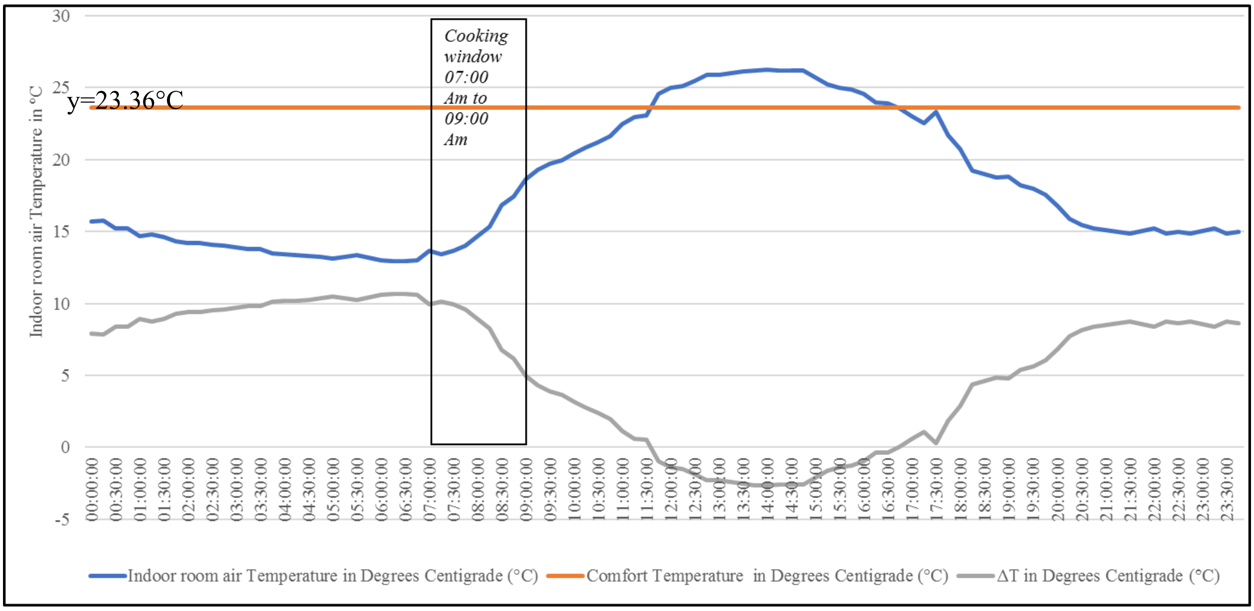
Figuur 2 Thermal Profile of Cooking space for Summer (Source: Onsite Data Logging)

The comfort temperature line for cooking in summer season y = 31.54°C i.e. line, parallel to x axis in figure 2 cuts the thermal profile of cooking space for summer season at 07:00 am. The temperature of the space starts getting separated from comfort temperature line and reaches peak at 01:45 pm. It was observed that, in summer season, the occupants of naturally ventilated houses were carrying out function of cooking when the temperature of the functional space was at a minimum distance from comfort temperature line for this function for this season.



Figuur 3 Thermal Profile of Cooking space for Moderate (Source: Onsite Data Logging)

The comfort temperature line for cooking in moderate season y = 27.76°C i.e. line, parallel to x axis in figure 3 cuts the thermal profile of cooking space for moderate season at 07:30 am. The temperature of the space starts getting separated from comfort temperature line and reaches peak at 12.45 pm. It was observed that, in moderate season, the occupants of naturally ventilated houses were carrying out function of cooking when the temperature of the functional space was at a minimum distance from comfort temperature line for this function for this season.



Figuur 4 Thermal Profile of Cooking activity space for Winter (Source: Onsite Data Logging)

The comfort temperature line for cooking in winter season y=23.36°C i.e. line parallel to x axis in figure 4 cuts the thermal profile of the space for winter season at 11.45 am due to late sun rise and lesser rate of daytime ambient temperature elevation. The figure also reveals that, the occupants of naturally ventilated houses were carrying out function of cooking during the time slot of 07:00 am to 09:00 am. During this time slot the thermal profile does not cut the comfort temperature line. It was observed that, the occupants of naturally ventilated houses had occupational constraints. They are needed to report at their respective workplaces by 09:00 am to 09.30 am in any season. Hence, it could be said that the occupants tried to minimize the distance of temperature of the functional space and comfort temperature line as much as possible to start cooking and eating. From figure 4 it is evident that, during the time slot of 07:00 am to 09:00 am the line of thermal profile of cooking space for winter season is at lesser distance (from line of comfort temperature) than it is at time slot of 06:00 am to 08:00 am, which is cooking time slot in summer season. Hence, it can be stated that, the occupants shift the function in time to adapt to the prevalent thermal conditions.

4. Conclusion

For achieving thermal comfort, the occupants carry out adaptive thermal control methods. They act in such a way that the air temperature of functional space is at a minimum difference with comfort temperature associated to that function.

Thermal adaptation for cooking was achieved by shifting time of function. The kitchens in the village houses were mostly immobile and operated in spaces near the courtyard. It was found that in the village, the kitchen was in general operated by female members of the house. The female members of the house were found to be reluctant to shift the spatial location of the kitchen and instead preferred to shift the time of function to another time slot to achieve thermal comfort. They found it inconvenient for them to shift the bulky chulha (earthen stove) repeatedly from space near the courtyard to inside any room. The smoke rising from the chullha chars the wall behind. Hence, shifting might result in multiple charred walls in the house. Ventilation holes were mostly present only in the cooking area, the smoke of the chullha could create suffocation in the room and could generate intolerable conditions. Due to these reasons the female members adopted a time shift rather than a space shift for adaptive thermal comfort.

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