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Understanding traditional comfort practices:

Case-study of a low-income community in Ahmedabad, India

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ABSTRACT: An indoor thermal comfort study was carried out in a low-income community during the hot summer in 3 different categories of houses: Type-1: New_builds, Type-2: DMU_new_builds and Type-3: Old_houses. The performance of Type-2 houses (architecturally designed with passive strategies) were significantly better than Type-1 and Type-3 houses with the former being 1.0^{0}C cooler on average than the later. All respondents of the study expressed little concern for indoor thermal comfort as they are accustomed to sleep outdoors, either in the courtyard, roof, or balcony as a cultural practice. During daytime, they spend most of the time in outdoor shaded conditions. This is a unique example of how people can adapt through behaviour that makes us rethink the impact of immediate outdoor conditions rather than focusing solely on indoor conditions in a low-income residential context. However, the residents still use indoor spaces for cooking, eating and other social and household practices and for sleeping during the other seasons. It means there is a balance to be made. However, the attempts to incorporate courtyard in the design by the architect for improved social and environmental performance were mostly unsuccessful due to opposition from the residents. This identifies a challenge for local designers to design low-income houses in a high-density context while providing for the socio-cultural and environmental needs of the residents.

KEYWORDS: Thermal comfort, low-income house, hot-dry climate, comfort practices, developing country

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1. INTRODUCTION

Recent studies by Sansaniwal *et al.* (Sansaniwal, Mathur, Garg, & Gupta, 2020) have identified the lack of organised thermal comfort research for the diverse climate zones in India. Their study has also identified a need for understanding the comfort practices by exogenous factors such as occupant behaviour, climate, income, and sociocultural factors. Likewise, Nicol and Roaf (Nicol & Roaf, 2012) has emphasised that people's thermal experience and behaviour not only indicates their own personal surroundings but also the culture and climate in which they reside. Therefore, from a thermal comfort perspective it is essential to examine people in their everyday habitat amidst its complexity to ensure important variables are not overlooked (Indraganti, 2010). Indian people have a diversified culture and adaptive behaviour which needs to be acknowledged in thermal comfort studies. For instance, in hot-dry climatic zone in India, it is a common cultural practice to sleep in outdoor courtyards, roofs or semi-outdoor spaces like balconies during the summer months. Outdoor sleeping is further coupled with night ventilation and diverse seasonal and diurnal occupancy pattern as a part of living style (Rajasekar, Anupama, & Venkateswaran, 2014). This does not mean that indoor spaces are less important in terms of thermal comfort for other household activities. To provide comfortable habitat for these people, it is therefore important to gain understanding of their living style and cultural practices to ensure appropriate application of indigenous strategies to combat adversities of the local climate. Climate-responsive architecture is strongly evident in Indian traditional architectural practices that endeavours to provide comfortable indoor and climatically modified outdoor spaces. However, it is challenging to apply passive architectural solutions for providing adequate thermal comfort in a low-income setting where resources are limited. Often in such situations, the client cannot foresee the benefits of bioclimatic strategies as it often creates conflict with their trivial personal interests. In many cases they are overwhelmed by more pressing and urgent issues like hunger, poverty and natural disasters like floods, cyclones etc. In this context, this study presents a case study scenario to depict thermal comfort practices of a low-income group in a climatically harsh region in India that has implications for future design and strategic development of low-income settlements.

2. METHODOLOGY

The data collection involved questionnaire surveys, interviews, visual inspection, photographic survey, and thermal comfort survey alongside environmental measurements in the case study houses. Onsite measurements included air temperature, relative humidity, wind speed and mean radiant temperatures.

2.1 Study area

The study area is located on the outskirts of Ahmedabad, India at 22°59'58.6"N and 72°38'40.0"E which is 8.41 km south-east of Sardar Vallabhbhai Patel International Airport, Ahmedabad. Named by the Gandhi Leprosy Seva Sangh as the Loving Community, it was formed in 1968 after the land was provided by the Government of Gujarat to accommodate leprosy-affected people from all over India who were socially excluded due to the contagious nature of the disease. The community has 125 houses with a population of approximately 500 people.

Ahmedabad has a hot semi-arid climate. An average maximum temperature of 45.0^{0}C in the pre-monsoon summer months of March-May makes Ahmedabad one of India's hottest cities with heat posing a significant public health challenge. A diurnal temperature range of 12.0 -16.0^{0}C throughout the year (Udaykumar & Rajasekar, 2015) makes evening temperatures somewhat tolerable during the summer months.

2.2 Measurements and thermal comfort study

An indoor thermal comfort study was carried out in the Loving community during the hot summer months of May. The study included 12 households of 3 different categories: Type-1: new-builds (New_builds - designed/ built by individual owners), Type-2: new-builds (DMU_new_builds - designed/ built by local architects) and Type-3: old, existing houses (Old_houses).

A standard thermal comfort survey was carried out alongside immediate measurements of air temperature (T_a), relative humidity (RH), wind speed and mean radiant temperatures (MRT) using Testo 480 with humidity/temperature probe (accuracy of up to ± 1% RH), comfort probe for turbulence measurement and globe thermometer (TC type K) for the measurement of radiant heat. Residents were asked about their thermal sensation, thermal preference, and acceptability during the survey period. Thermal sensation was recorded using ASHRAE comfort scale ranging between -3 and +3 while considering the clothing levels (0.5 clo) and metabolic rate of the occupants (1.2 met). An elaborate interview was carried out to learn about the daily activities, thermal comfort practices and satisfaction levels of the respondents in the households. Simultaneous T_a and RH measurements over a 3-day period was carried out using HOBO dataloggers to investigate the thermal performance of different house types.

2.3 Building construction and environmental conditions of house-types

Type-1: New_builds – These are generally two or three-storied buildings constructed by individual owners with local contractors without any architect's supervision/ involvement (Figure 1 a). The entire plot area of approximately 20 sq. metre is built-up with minimal cross ventilation and daylighting options. The rear room generally does not have an outside window or daylight access (Figure 1 b). Building envelop consists of brick wall with plastered finish with concrete roof slab.

Type-2: DMU_new_builds – These are typically one-storied buildings (except one two-storied building) (Figure 1 c) designed and built by SEALAB Architects. Building envelop consists of brick wall with plastered white finish with concrete roof slab. Those two-storied high, have a ferro-cement roof mesh with white tiled surface on top. Natural ventilation and daylighting have been maximised in all buildings with stack ventilation in the two-storied buildings. Courtyard has been incorporated for social as well as environmental reasons to provide mutual shading and cross ventilation (Figure 1 c).

Type-3: Old_houses – These are one-story buildings originally constructed under the government initiatives (Figure 1 e). Rear rooms do not have any natural ventilation or daylighting (Figure 1 f). The wall consists of single file brick walls with plaster finish with corrugated iron sheet roof.

2.3 Passive strategies in architecturally designed buildings

Residences in the hot–dry climatic zone of India are traditionally climate responsive (Rajasekar et al., 2014). Consequently, the use of courtyard as a climate modifier or vernacular passive cooling system is common in the hot-dry climate of Ahmedabad. Architect has incorporated front courtyards in all Type-2 houses and back courtyards in some Type-2 houses, depending on the availability of space. The front courtyard provided mutual shading and space for day-to-day social interaction with the neighbours, whereas the back courtyard served a more functional purpose such as cleaning utensils and washing and drying clothes alongside ensuring privacy of women. The other critical role of the back courtyards is to facilitate cross ventilation especially because houses were originally arranged back-to-back by sharing a common back wall. So, the only way cross ventilation could be arranged was to make provision for a back courtyard.

Additionally, the architect has incorporated roof extractor fans to increase stack ventilation alongside cross ventilation through the windows. He further used foldable window/ door (Figure 1 d) to maximise cross ventilation when necessary. These ventilation strategies are effective to maximise night ventilation and thereby, can improve comfort levels due to the large diurnal temperature swing prevalent in this region (Rajasekar et al., 2014).

Figure 1: a) A typical Type-1 house, b) A windowless room in a typical Type-1 house c) Front courtyard in Type-2 house, d) Foldable window/ door in a Type-2 house, , e) A typical Type-3 house, f) Interior of a typical Type-3 house

3. RESULT

Figure 2 presents two and half day's temperature data for the 12 houses. A mean is calculated for each group of house types at every 5-minutes interval. The data is then plotted, and the resultant graph is presented in Figure 2. Overall, the graph shows that the Old_houses have the greatest fluctuations and highest temperatures with an average temperature of 36.8^{0}C (Fig. 3) over a 60-hour period. Air temperature in the New_build houses is more stable with an average temperature (36.8^{0}C) equal to the Old_houses. DMU_new_builds, on the other hand had the lowest average temperature (35.8^{0}C) during the above time-period, and the lowest average temperature of 33.3^{0}C occurring at 9:30 am on the second day. It means, even in very hot conditions, passive strategies applied in architecturally-designed buildings as in Type-2 houses, were able to reduce air temperature compared to the new buildings (Type-1) which were designed ignoring any passive strategies such as courtyard spaces, natural lighting and ventilation and appropriate thermal mass.

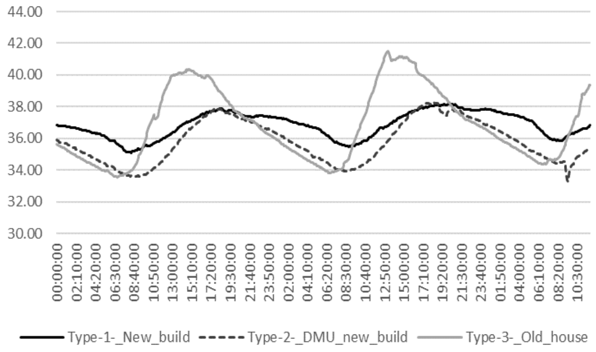

Figure 2: Average indoor air temperature time series over a 60-hour period across the three house types

National Building Code of India recommends the acceptable thermal comfort limits for naturally ventilated buildings with an upper limit of 32^0C and 60% relative humidity (RH), provided an air velocity (AV) of 1.6 m/s is available. Udaykumar *et al.* (Udaykumar & Rajasekar, 2015) suggested a local comfort range of 25 – 31^0C in summer for the hot-dry climate of Ahmedabad. The average air temperature measured in all three types of houses during the survey period is well above the comfort range reported in (Udaykumar & Rajasekar, 2015). Especially, the environmental conditions in the Old_houses were found to be uninhabitable. The maximum temperature of 47.6^0C was recorded at Old_house_01 on the second day and the lowest temperature (32.6^0C) was recorded at DMU_new_build-03 on the first day. The maximum difference on air temperature of 12.8^0C was recorded between Old_house_01 and DMU_new_build-03 at 12:50 pm on the second day.

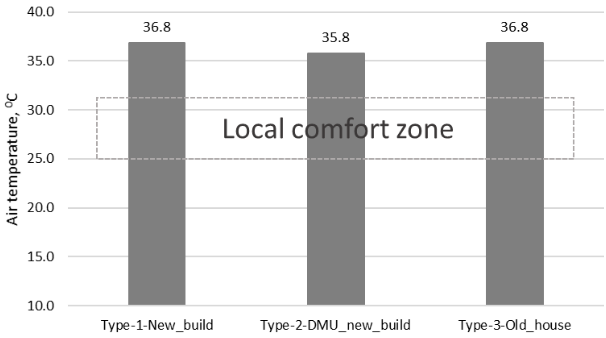

Figure 3: Average indoor air temperature over a 60-hour period across the three house types

All respondents in the DMU_new_build houses felt comfortable/ neutral during the survey period whereas TSV (Thermal Sensation Vote) for people in the New build and Old_house houses varied between neutral to warm and warm to hot, respectively (Figure 4). In the Old_houses, 100% people felt either warm (22.2%) or hot (77.8%). This corresponds with the air temperature measured in the houses. In the Type-1 houses the responses were comfortable (33.3%), slightly warm (22.2%) and hot (44.4%). There was no response in the cold, cool and slightly cool category for the extremely hot conditions.

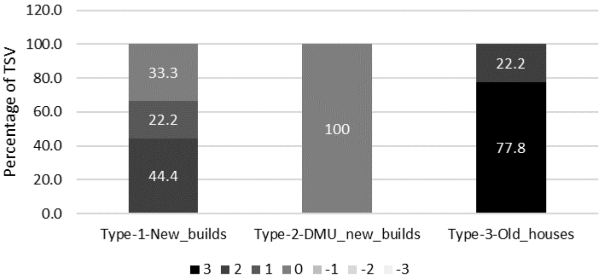

Figure 4: Percentage frequency for the TSV across the three house types

During thermal comfort survey, average instantaneous air temperature in the three house types were 37.0^0C, 37.0^0C and 40.6^0C for house Type-1, Type-2, and Type-3 respectively. Given the local comfort zone between 25 – 31^0C as mentioned above, it is quite remarkable to see people were comfortable in the Type-1 and Type-2 houses at an average temperature of 37.0^0C. It could be due to their overall satisfaction with the housing conditions as well as their ability to acclimatise with high temperature conditions linked to their daily livelihood. The responses match with the level of satisfaction reported in the self-build houses (Type-1) and DMU_new_build houses (Type-2). When asked about the 'overall living quality of the houses' 100% people in the Type-1 and Type-2 houses expressed satisfaction. Respondents in the Type-3 Old_houses, on the other hand were fully dissatisfied. Undoubtedly, the environmental conditions with an average temperature of 40.6^{0}C were unacceptable to most of them. Furthermore, the residents are mostly involved in outdoor-type professions such as auto or manual rickshaw driving, road cleaning, begging or factory work which indicates their acclimatisation to high air temperatures. Figure 5 shows how probability of thermal acceptability decreases with the increase of instantaneous indoor air temperature.

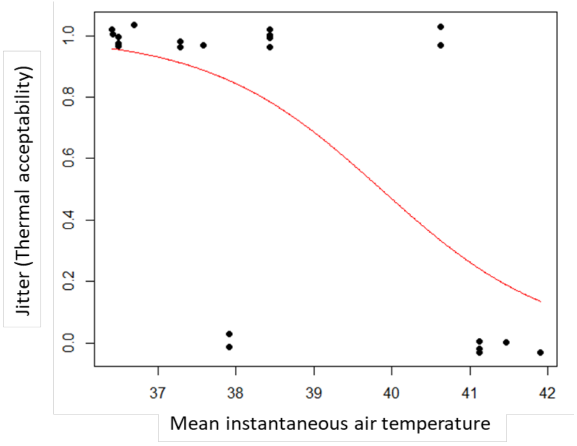

Figure 5: Thermal acceptability against instantaneous temperature during comfort survey across the houses

4. DISCUSSION

As discussed above, in order to deal with the extreme heat in summer, the architect incorporated front and backyard in the designed houses. The design strategy also evolved from the social need of the local community as realised from their lifestyle. However, from the interviews, none of the residents were happy about the courtyard spaces even though they appreciated the social and functional value of the courtyard spaces. To them it was more important to have additional indoor space rather than a semi-outdoor space where they could store more personal belongings.

The natural ventilation strategies adopted in the design such as cross ventilation and stack ventilation could not be utilised for night ventilation which is the most effective ventilation strategy for this climate as the windows did not have safety grills and therefore, could not be kept open during nights. Furthermore, the foldable panels were somewhat inflexible, heavy, and impractical (size unsuitable for a residential scale) and did not follow ergonomic design. Therefore, their performance to facilitate natural ventilation was somewhat reduced.

Culturally and traditionally, the people in the region are accustomed to stay outside throughout the most part of the day and sleep in the courtyards or terraces at night. The reason behind this mainly climatic as it is not possible to fully modify the indoor environment through design and building material. Therefore, people take it very naturally to come out of the house and stay outside in a nearby open field, under the shade of a tree, whenever it is uncomfortable inside the house. Even at night, it is completely normal for men and women to sleep in the open premises outside their house, for thermal reasons. In the questionnaire survey, 86% respondents chose to 'go outside' as the first option while feeling hot indoors. Other options mentioned were 'turning on ceiling fans' and 'opening or closing of windows and doors'.

4. CONCLUSION

Analysis of the thermal comfort performance of the three different house-types for a low-income community shows that people in the architecturally designed houses (Type-2) were fully comfortable even when the temperature ranges were above the prescribed comfort ranges. The average indoor air temperature in the Type-1 and Type-3 houses was 1^{0}C higher than the Type-2 houses. Consequently, all inhabitants (100%) in the Type-3 houses were found uncomfortable and only, 33.3% people in the Type-1 houses were found comfortable during the survey period. This implies that passive design strategies as implemented through architectural design has an important role to play for ensuring thermal comfort in low-income housing.

The residents, however, have little knowledge about the adverse effects of poor indoor thermal comfort. Therefore, they could neither fully appreciate nor exercise the full potential of the applied passive strategies. For example, use of courtyards in the design was considered to be a waste of space considering the acute space shortage and high number of occupants. Similarly, full natural ventilation potential could not be achieved during nights due to impractical window design and lack of safety features in them. It indicates that future design needs further exploration of practical aspects, usability of spaces and privacy requirements of the occupants in residential spaces to ensure passive design strategies are more effective in practice. If the drawbacks can be overcome, the passive ventilation and cooling strategies can be successfully incorporated into the design of new homes to make them less dependent on artificial cooling.

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