Smart GHAR III Post Occupancy Evaluation: A Report on User Perception Survey in the context of Thermal Comfort

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION

FUNDED BY

INDO-SWISS BUILDING ENERGY EFFICIENCY PROJECT

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Indian Project Management & Technical Unit

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About INDO-SWISS BEEP

The Indo-Swiss Building Energy Efficiency Project (BEEP) is a bilateral cooperation project between the Federal Department of Foreign Affairs (FDFA) of the Swiss Confederation and the Ministry of Power (MoP) of the Government of India.

The first phase of the project was from 2012-2016. The follow-up phase of the project spanned over 2018-2023. The overall goal of the project was to reduce energy consumption in new commercial, public and residential buildings in India through energy-efficient and thermally comfortable (EETC) design. The follow-up phase of BEEP has the following outcomes:

- **Building Design**: A critical mass of Indian building sector professionals have adopted Energy-Efficient and Thermally Comfortable (EETC) building design as standard practice.
- **Building Technology**: External Movable Shading Systems (EMSYS) have been established in the market in 1-2 urban clusters in India.
- **Building Policy**: Measures for Energy-Efficient and Thermally Comfortable (EETC) buildings have been integrated into the regulatory framework at the national and sub-national levels.
- **Outreach**: Knowledge of EETC buildings has been effectively delivered to targeted stakeholder groups.

About CARBSE:

The Centre for Advanced Research in Building Science and Energy (CARBSE) is one of the centers comprising the CEPT Research and Development Foundation (CRDF). CARBSE aims to provide an impetus for research in energy efficiency in the built environment, and energy–resource management at large. Its objective is to carry out in-depth research in the fields of energy-efficient building design, construction process, environment-friendly construction materials, and resource audit and management. CARBSE, (http://carbse.org/), is the frontrunner in the field of sustainability from varied dimensions; it interacts with industry, government organizations, and the public at large, to generate and disseminate knowledge about building a sustainable habitat.

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Executive Summary

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The Rajkot Smart GHAR (Green Homes at Affordable Rates) III project, called Lakshman Township now, was an effort to combine affordable and sustainable housing holistically; the project comprises eleven seven-storeyed building blocks, amounting to 1176 dwelling units. The project was executed under the Pradhan Mantri Awas Yojana (PMAY) by the Rajkot Municipal Corporation (RMC). Its design stage involved conducting a “design charrette,” a 3–4-day integrated workshop involving all stakeholders; the Indo-Swiss Building Energy Efficiency Project (BEEP) provided technical assistance for rendering the building energy efficient. This project employs many passive strategies to achieve a significantly lower indoor air temperature for enhanced occupant comfort.

The current study aimed to understand the occupants’ satisfaction with their indoor environment and essentially validate if and to what extent the deployed strategies successfully achieved a thermally comfortable indoor environment. This study involved conducting a post-occupancy evaluation in the context of thermal comfort by means of the following surveys:

a. User Perception Survey – This survey aimed to understand the occupants’ perspective of their indoor environment ***across the year***. This survey involved asking the occupants about their satisfaction with the Indoor Air Temperature, Relative Humidity, and Air Movement. Additionally, background questions were asked concerning their reason for moving, electronic appliances owned, door window operation schedule, etc.
b. Thermal Comfort Right Now Right Here (RNRH) survey – The RNRH survey encompassed questions concerning the occupants’ perspective of their ***current environment***. The occupants were asked about their i) thermal *sensation*, ii) thermal *acceptance* – how acceptable they found their thermal environment to be, iii) thermal *preference* – preference for their current environment in comparison to a colder or warmer environment, iv) air movement *acceptance*, v) air movement *preference*, and vi) overall comfort. Moreover, their clothing items/attire and metabolic activity were noted. The survey also involved measuring the environmental parameters such as the Indoor Air Temperature (T_a), Relative Humidity (RH), Indoor Air Velocity (V_a), and Globe Temperature (T_g) using hand-held equipment.

The surveys were conducted during April 2023, i.e., the summer season. One user perception and RNRH survey response, each, were gathered per unit; however, if more than one occupant was available for the survey, more than one survey response was collected from that dwelling unit. One hundred twenty-two dwelling units were surveyed; 124 User Perception Survey and 134 RNRH Survey responses were gathered. However, after data quality assurance checks, 123 User Perception Survey and 130 RNRH Survey responses were used for analysis. It was common for only one family member/occupant, mostly female, to be available during the survey, as most of the family members were involved in economic activities.

Females made up 73% of the responses, and males 27%. The User Perception Survey responses indicated that most respondents had previously lived in a rented space, thus stating "having own house" as the leading reason for moving here. Most of them liked the amenities of the lift, garden, parking, etc. The most commonly stated cause of dissatisfaction amongst respondents was not related to the indoor environment or thermal comfort; but to the unavailability of water and the distance between the Township and their livelihood activities, schools, and/or vegetable markets. The majority (86%) of the respondents reported that their allotted dwelling unit was up to their liking. While a few mentioned that they would prefer to live in a dwelling unit opposite theirs or one on another floor – for better daylight and ventilation.

Figure 1 [a], [b], and [c] illustrate the variation in respondents' degree of satisfaction with their Indoor Air Temperature, Air Movement, and Relative Humidity, respectively, across summer, monsoon, and winter. Most respondents reported that the Indoor Air Temperature and Air Movement were "Neutral" or on the "Satisfactory"-spectrum during summer and monsoon. However, the proportion of respondents finding those parameters to be on the "Dissatisfactory"-spectrum increased during the winter. Moreover, most of the respondents found the Relative Humidity in their space to be "Neutral" or on the "Satisfactory"-spectrum across all seasons; however, the respondents were found to be less "Dissatisfied" with it during winter (11%) as compared to the summer (25%) and monsoon (24%) seasons.

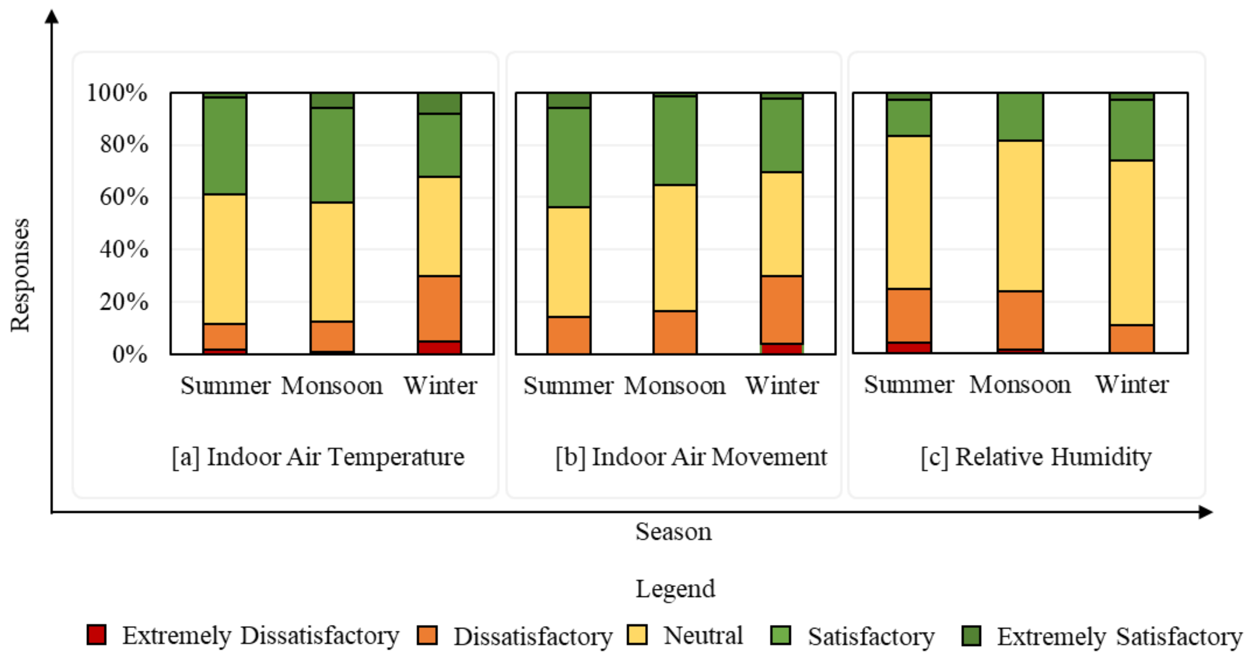

Figure 1 Respondents' satisfaction with their [a] Indoor Air Temperature, [b] Air Movement, and [c] Relative Humidity across seasons

When the respondents were asked about their door/window operation schedule, most reported varying the schedule according to the season – saying they kept their windows open during summer and closed in winter. The majority of the respondents reported feeling less hot in summer and colder in winter in their current dwelling unit than in their previous living space. A significant proportion (20%) of the respondents had closed off or removed the ventilators provided atop the main door due to the unwanted ingress of cold air into the dwelling unit; noise and dust were other issues leading to this change. The responses mentioned above and the inferences from Figure 1 [a], [b], [c] point to the fact that the respondents did not have the means to control the ventilation within their space. Moreover, a significant proportion of respondents said they refrained from opening their main doors due to noise from or uncordial relationships with their neighbors. Thus, they could not use that avenue to achieve adequate comfort and ventilation.

Figure 2 [a] to [f] illustrate the respondents' RNRH responses. From Figure 2 [a], [b], and [c], it can be seen that the majority of the respondents reported their thermal *sensation* to be "Neutral" while simultaneously considering their indoor thermal environment to be on the "Acceptable"-spectrum. Nevertheless, the majority of the respondents still reported to "Want a cooler environment." This was indicative of their aspirations for a cooler environment, regardless of them finding their thermal environment to be "Acceptable." Interestingly, most respondents reported that they were unwilling to install an Air Conditioner (AC), stating they did not feel the need. However, a small proportion said they would install AC within a few years.

Figure 2 [d] and [e] illustrate the respondents' air movement *acceptance* and *preference* vote. Clearly, most of the respondents found their air movement to be on the "Acceptable"-spectrum and preferred "No change" in their air movement. However, a significant proportion (43%) reported to "Want more air movement." Figure 2 [f] depicts the variation in respondents' overall comfort votes; essentially, the majority of the respondents reported to feeling "Comfortable" about their indoor environment.

The environmental parameters measurements showed that the Indoor Air Temperatures in the North- and South-oriented dwelling units were in the same range. Interestingly, the maximum Indoor Air Temperature recorded in the South-oriented dwelling units was lower than in the north-oriented ones. Moreover, no trends were found in the clothing insulation and metabolic rate amongst occupants from different orientations and floors. Similar was the case with Air Velocity – no trends could be established because the fan was operational in all but two dwelling units.

Only ten percent of the surveyed dwelling units had a presence of AC, and the presence of an air cooler was found in even fewer dwelling units. Noteworthy, neither AC nor air cooler was operational in any dwelling unit during the RNRH survey.

The Indoor Air Temperatures at which the respondents' found their thermal environment to be "Acceptable" and "Unacceptable" were superimposed on the neutral temperature chart from Rawal et al. (2022). It was found that the majority of the Air Temperatures at which the respondents felt

"Acceptable" were within the 80% acceptability range, establishing that the dwelling units were thermally comfortable.

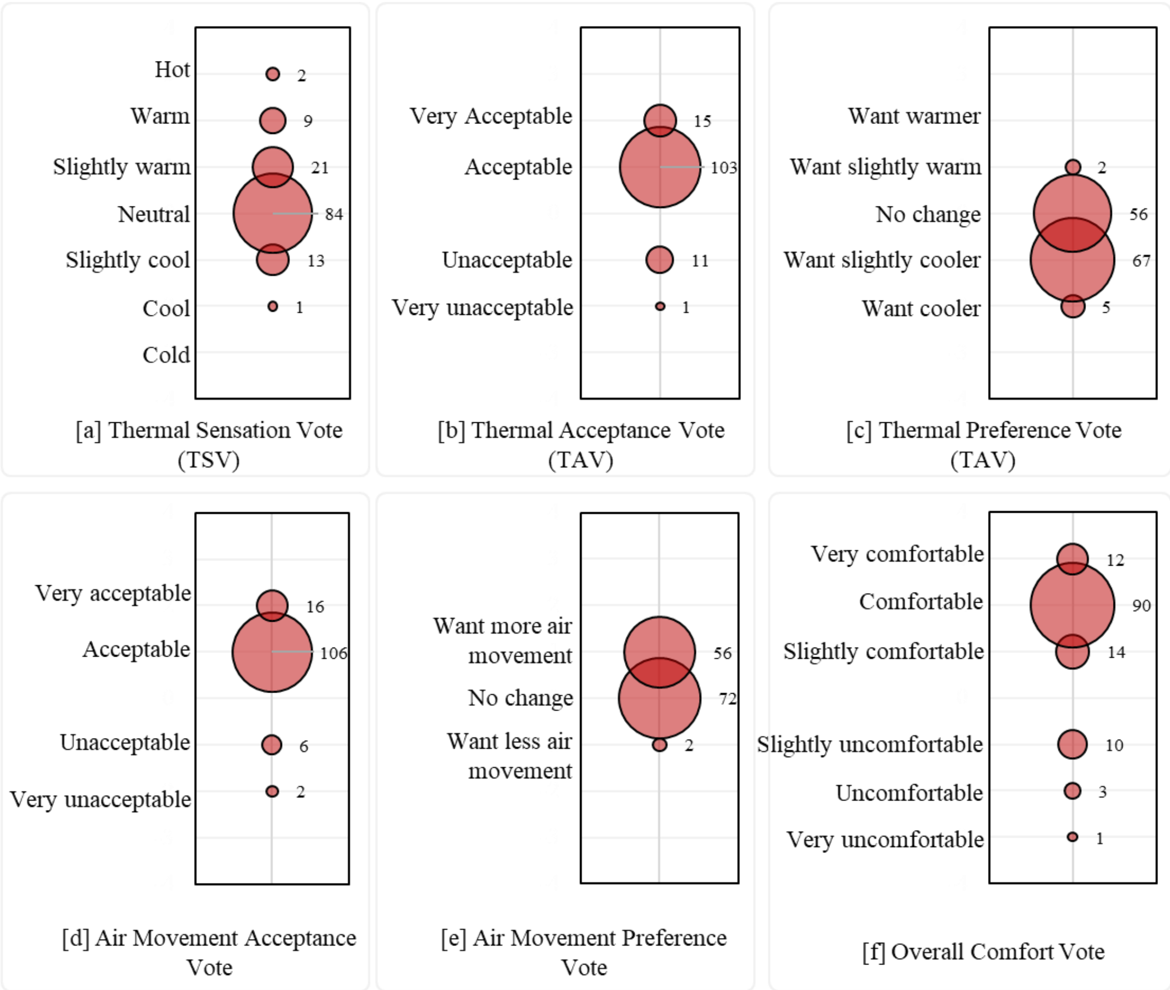

Figure 2 RNRH responses: Distribution of [a] Thermal Sensation Votes, [b] Thermal Acceptance Votes, [c] Thermal Preference Votes, [d] Air Movement Acceptance Votes, [e] Air Movement Preference Votes, and [f] Overall Comfort Votes

Most of the respondents from Wing D, regardless of the floor, stated that they did not receive adequate daylight or ventilation. This issue was prevalent among respondents from Wings C, E, F, and G as well, but only among the first to fourth-floor dwelling units.

The learnings from this study may be applied to upcoming projects aspiring to be holistically sustainable across their lifespans. Recommendations include deciding the distance between two buildings to allow for maximum daylight and ventilation while being considerate of the site-related constraints; designing the building envelope to be thermally comfortable, in accordance with the adaptive thermal comfort model presented in and as IMAC-R (Rawal et al., 2022). Moreover, it is recommended that the ventilators be flexible, and made of a sturdy material that does not shudder when hit by strong winds or rain. Over and above, providing the occupants with an operational schedule of doors and windows, appropriate for various seasons, to help them achieve a thermally comfortable indoor environment may be beneficial.