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Seasonal evaluation of adaptive use of controls in multi-storied apartments: A field study in composite climate of north India

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Abstract

A Class II level field survey is conducted in five naturally ventilated multi-storied apartments in the composite climatic zone of north India. A total of 984 data-sets were collected for the whole year, involving over 82 subjects and 55 apartment units. This paper highlighted the season-wise behavioral change in the usage pattern of controls and the resultant thermal response of the subjects. It is observed that at extreme weather conditions, subjects are switching to 'seasonal controls' (i.e. fans, A/C's and heaters/hot blowers) as oppose to the 'designed controls' (i.e. windows, balcony doors and blinds) or personal controls (i.e. changing 'clo' and 'met' levels). The study concludes that if designed controls are efficiently incorporated in the building the thermal perception of the residents and the resultant energy consumption can be improved.

Keywords: Thermal comfort; Adaptive behavior; Control-use; Naturally ventilated apartments; Seasonal variation

1. Introduction

The fundamental assumption of adaptive model of thermal comfort is: '*if a change occurs, such as to produce discomfort, people react in ways which tend to restore their comfort*' (Nicol and Humphreys, 2002). It embraces the notion that people play an important role in creating their own thermal preferences through the way they interact with the environment or modify their own behavior, or gradually adapt their expectations to match the thermal environment (Brager and de Dear, 1998). Adaptive behavior as a response to the thermal discomfort has a huge implication on the energy consumption of any building (Murakami et al., 2007 and Yang and Su, 1997). Steemers and Manchanda (2010), in their study, has justified this point with the detailed monitoring of 12 case studies (office buildings) in U.K. and India. The study proved that the key link variable between energy consumption and occupant's happiness is the degree of control available on the adaptive opportunities. It is a well acknowledged fact that indoors with high adaptive opportunities are likely to prove more comfortable than one with the low

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opportunities (Zain et al., 2007). Brager and de Dear (1998) reported a link between personal control of environmental conditions (temperature and ventilation) and work performance. Raja et al. (2001) also inferred that the change in indoor temperature is about one-third of the outdoors when occupant controls the indoor. Therefore, it is necessary to understand and quantify the adaptive measures taken by the occupants so as to avoid any conflicts between user behavior, in terms of thermal expectations and the resultant energy consumption.

Previous studies (Raja et al., 2001; Rijal et al., 2008; Baker and Standeven, 1996; Peeters et al., 2009) have proved that the temperature (indoor/outdoor), among all other parameters, strongly influences the control use behavior of the respondents. It suggests that the seasonal variation has a huge repercussion on the way occupants perceive and respond to the environmental changes. Due to its geographical position India witnesses different climatic seasons in a year (Library of Congress-Federal Research Division) and is divided into six climatic zones (Nayak and Prajapati, 2006), with its maximum coverage falling under composite climate. This seasonal and climatic diversity makes it quite essential to revise the operational thermal comfort standards in India. On the contrary, National Building Code (NBC) follows a narrow comfort range for air-conditioned buildings (Indraganti, 2010a,b, c; BIS, 2005; Pellegrino et al., 2012) irrespective of the climatic zone it falls under.

Leen Peeters et al. (2009) has inferred that the adaptive measures in a residential building vary within a small time scale, which consequently affects the indoor environment. Residential buildings in India are, predominantly, naturally ventilated with the occasional use of heating and cooling appliances at extreme weather conditions. This makes the indoor conditions quite dynamic and unpredictable, which not only exhilarates the energy consumption but also affects thermal comfort. This paper has highlighted the findings of the field survey in Chandigarh and Roorkee (both falls under composite climatic zone as per classification given by NBC; BIS, 2005) with the main focus on the seasonal variations in the use of adaptive measures in naturally ventilated apartments. The most common means of controlling the indoor environment in summer, winter and monsoon are studied. Windows (W), blinds (BL), balcony door (BD) were found to be used at varying scale in all the seasons. The use of fan, air conditioner (A/C) and heater/blower is also explored. For analysis, 'window open', 'door open', 'blind drawn', 'fan on' and 'A/C on' were coded as '1' and otherwise as '0'. The relative frequency of "open" and "close" events for each of the controls is calculated separately for indoor globe temperature (Tg). Objectives of the paper:

- To explore the adaptive approach in naturally ventilated buildings.
- To analyze the impact of seasonal changes on the thermal perception and control the use of occupants.

2. Materials and methods

Adaptive controls are employed by the subjects to restore comfort conditions and the decisions are partially based on outdoor/indoor temperatures (Raja et al., 2001) and partially on personal expectations (Brager and de Dear, 1998). People, consciously and sub-consciously, respond to discomfort either by changing activity (Indraganti, 2010b; Darby and White, 2005), clothing/posture (Indraganti, 2010b,c; Fishman and Pimbert, 1982 and Nicol and Raja, 1996) or thermal environment. In naturally ventilated buildings, the usual controls available to regulate the thermal environment are doors, windows, blinds, doors, however, fans, A/C's and hot air blower have also been used in this study at extreme weather conditions of the year. Opening of doors or windows enhances natural ventilation, fans provide forced convective cooling and blinds/curtains reduce the heat gain from direct solar radiation as well as the glares (Raja et al., 2001).

Temperature (outdoor and indoor) is the key statistical variable in predicting the use of control. But studies have confirmed that it is the immediate environment that stimulates the instincts of the subject to use the available controls (Rijal et al., 2008). The relative frequency of the control-use during the survey period is plotted against indoor globe temperature (Tg) using regression analysis.

2.1. Survey

A field survey is conducted for the year of 2012 in five naturally ventilated (NV) multi-storied apartments. The aim of the survey was to establish the temperature, which people find comfortable in a composite climate of north India The selection of the case studies was solely made on the basis of factors like climate zone, building type, income group, no. of floors, floor areas/dwelling unit (DU) and most importantly clearance from the concerned authorities i.e. President of the societies and approval from the occupants of the buildings to be surveyed. Two buildings i.e. Hill View Apartments (HV) and Canal View Apartments (CV) are located in Roorkee and three buildings i.e. Grow-more Society (GMR) and Bhaimata Das Society (BMD) and Trishla (TR) are located in Chandigarh. As per climate classification proposed by Bansal and Minke (Nayak and Prajapati, 2006), Chandigarh and Roorkee both fall under composite climatic zone.

Survey sheet included interviewee's demographic information, comfort vote on seven point ASHRAE's thermal sensation scale or 'TSV' (−3 to +3), the preference vote on a five-point thermal preference scale or 'TP' (−2 to +2), clothing worn, activity level, adaptive use of environmental controls at the time of voting. Besides this, questions related to the tenure of stay, number of family members, household appliances and the hourly consumptions of fans, A/C's, heater/blowers etc. are also included in the questionnaire. The questions were put in English and were explained in regional languages, when required.