ABSTRACT

Energy consumption in Indian buildings is expected to increase substantially due to economic growth, rapid growth in the construction sector and improvement in the living standard of the people. The demand for energy to operate the appliances such as televisions, air-conditioning and heating units, refrigerators, fans, etc. will increase substantially as the living standard rise in India. Also the growth in commercial sector and the shift from rural to urban living will continue to take place. This will also result in a substantial increase in energy demand from the buildings sector alone. Therefore, concerted efforts need to be taken for bring down the energy consumption by buildings through various measures.

Reducing operating energy significantly through use of passive and active technologies even if it leads to a slight increase in embodied energy can reduce life cycle energy demand for building. However, an excessive use of passive and active features in a building may be counterproductive. To implement the energy efficient technologies in existing buildings, one has to know about its thermal comfort conditions. It shows the need for thermal comfort studies to understand the comfort levels in existing buildings. Judicial use of passive techniques for providing thermal comfort to residents demands the need of thermal comfort standards. Thermal comfort standards in naturally ventilated buildings depend on several factors like, psychological, physiological and adaptive nature of residents. Further, it also depends on the climatic zone in which building is located.

Kozhikode district of Kerala, in warm-humid climatic zone, was considered for conducting detailed thermal comfort analysis of existing buildings. Three types of buildings were selected namely Asbestos cement roofed (ACR) house, Reinforced cement concrete (RCC) roofed house and Traditional mud tile (TMT) roofed house for quantitative analysis. Dwellings considered for the study were hostel rooms in National Institute of Technology (NIT) Calicut. To understand the effect of roofing on thermal performance of dwellings, study was carried out on rooms, which are similar in all construction features except roofing. Detailed thermal performance analysis of ACR dwelling was carried out during the end of summer season and onset of rainy season for the period of 15 days. Out of 15 days, analysis of first 3 days was during summer with near zero ventilation, next 2 days was during summer with night ventilation, next 4 days was during summer with ventilation, next 3 days was during rainy season with ventilation and last 4 days was during rainy season with near zero ventilation. Later similar studies were carried out on both RCC roofed dwelling and TMT roofed dwelling during summer with near zero ventilation conditions. Results obtained from the quantitative analysis shows that most of the time, inside temperatures of the RCC building are above the ambient and reached to a maximum of 40°C which is 4°C more than ambient. At the same time TMT roofing maintained the inside temperatures well below the ambient at peak time and reached a maximum of 33.6°C which is 2.4°C less than ambient. In case of quantitative analysis, the difference observed in inside temperatures of RCC roofed residential buildings when compared to TMT and ACR houses are huge and reached to a maximum of 7.5°C and 4°C respectively. This study highlighted the role of roof in providing thermal comfort in dwellings. Quantitative analysis showed that under non-ventilated conditions, TMT roofed room performed better than that of other types where as the performance of RCC roofed room and ACR room were comparable.

Reduced scale models of a prototype of typical living room of a residential building with dimensions 3 m x 3 m x 3 m have been designed. Five identical reduced scale models were fabricated with different roofing materials, which are commonly used in southern India viz., Reinforced Cement Concrete (RCC) block, Mud tile, Corrugated asbestos cement sheet, Metal deck and Flat asbestos cement sheet. Models were fabricated in such a way that only roof was exposed to sunlight. All the joints of models were sealed to maintain zero ventilation conditions. Experiments were carried out over fifteen days under sunlight to predict the thermal performance of each roof. Comparative analysis indicated that RCC roof was better than other roofs. Later, similar experiments were conducted with the help of an artificial heating arrangement and identified the input parameters for each type of roofing to replicate the experiments under sunlight. By utilizing the identified input parameters, a comparative study has been performed between RCC roof model and ventilated flat

asbestos cement roof model. Results showed that optimum air gap between main roof and false roof for roof ventilated model is 6 cm. Comparative analysis between RCC roofed model and ventilated roof model showed that better indoor condition than that of RCC roofed model is possible by providing suitable roof ventilation technique. Reduced scale model study upheld the results obtained from quantitative analysis.

Residential buildings were considered for subjective analysis in Kozhikode district, Kerala, India. Rooms with Traditional Mud Tile (TMT) roofing, Reinforced Cement Concrete (RCC) roofing and Asbestos cement roofing (ACR) were considered for subjective analysis. A total of 936 subjects were participated in survey, in which 402 subjects from TMT roofed residential buildings, 406 subjects from modern RCC roofed residential buildings and remaining 128 subjects were from ACR buildings. Thermal Sensation Vote (TSV) based on ASHRAE seven-point scale was collected for identifying the perception of occupants on thermal comfort of their dwellings. Subjective analysis was carried out in all three seasons namely, summer, monsoon and winter. Majority of subjects felt comfortable in both winter and monsoon irrespective of whether the roof was traditional or modern. In this study, rooms were selected in such a way that they were almost similar in all aspects except roofing. Based on subjective analysis, it has been found that residential buildings with TMT roofing were faring better in providing thermal comfort than that of ACR and RCC roofed buildings during summer. The percentage of satisfied residents were 41% and 34% in case of RCC roofed dwelling and ACR dwelling, at the same time mud tile roofed dwelling able to provide satisfaction to more than 52% subjects. Performance of RCC roofed dwellings was slightly better than ACR dwellings. Results obtained from subjective analysis indicated that, for the climatic conditions of Kerala, ventilation was playing major role in providing thermal comfort. At the same time the effect of roof on thermal comfort is negated by the effect of ventilation and adaptive nature of subjects. Subjective analysis upholds the adaptive thermal comfort theory, which suggests that thermal comfort not only depends on temperature, humidity etc. but also on factors like physiological, psychological and behavioral adaptations.

Thermal comfort study was carried out in differently roofed hostels in National Institute of Technology Calicut, Kerala, which is located in warm humid climatic zone of India. Measurements of ambient temperature, globe temperature, relative humidity and air velocity were carried out in eight hostels, and in parallel a paper based survey was conducted among students to know about their Thermal Preference Vote (TPV) and Thermal Sensation Vote (TSV) based on ASHRAE seven point scale. Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) have been evaluated based on Fanger's theory of thermal comfort by utilizing the field measurements. Preferred operative temperature, neutral effective temperature and neutral humid operative temperature were obtained based on the Predicted Mean Vote (PMV). Similarly the preferred operative temperature neutral effective temperature and neutral humid operative temperature were identified for both Thermal Sensation Vote (TSV) and Thermal Preference Vote (TPV). Thermal comfort conditions for 80% satisfaction were also determined in each case. A correlation between the Predicted Mean Vote (PMV) and the Thermal Sensation Vote (TSV), as well as between the Predicted Mean Vote (PMV) and the Thermal Preference Vote (TPV) were obtained. Results indicated that PMV is over predicting the thermal comfort conditions in naturally ventilated buildings and the predicted neutral temperature is 2 to 3°C more when compared to that of TSV and TPV. A linear relationship, PMV = 0.746* TSV + 1.454 and PMV = 0.852* TPV + 1.239 were developed based on the results for obtaining Thermal Sensation Vote (TSV) and Thermal Preference Vote (TPV) respectively in terms of Predicted Mean Vote (PMV). Based on this study, thermal comfort standards for the region of Kozhikode were proposed in this thesis.