

Research highlights from monitoring efficiency of High Albedo white roofs in improving thermal comfort of occupants of EWS residences in India



Science

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ABSTRACT

Economically Weaker Sections (EWS) household in India are those section groups with annual earnings up to two lakhs. (GOI, 2013). Generally in India, EWS homes are built which are smaller in size with a carpet area of 21 to 27 Square meters and 28 to 60 Square meters respectively with average occupancy of 2 -5 occupants per homes throughout the year. Thermal comfort is an important aspect of the building design process as modern man spends most of the days indoors. Thermal Comfort – the state of mind, which expresses satisfaction with the thermal environment (Joost Van Hoof, 2010). High Albedo white roof is one such emerging technology that is becoming popular in developed countries experiencing tropical warmer climate. High Albedo white roofs are like thermal insulation that reflects the solar gain before it is absorbed by roof surfaces, reducing the intensity of heat transmitted through roof surfaces to living spaces. The study has been specially concentrated on the analyzing the impact of High Albedo roofs technologies on improving thermal comfort of occupants of economical weaker section households in India. For this purpose, two identical economically weaker sections houses oriented in same direction located in warm dry climate of Ahmedabad, Gujarat were monitored to understand the impact of High Albedo roofs on improving thermal comfort.

1. INTRODUCTION

A policy that will pave the way for allotment of low cost houses to economically weaker sections (EWS) has been cleared by the central government of India. The housing and urban poverty alleviation ministry has drafted the policy in view of a report that said that India was falling short of nearly 19 million houses, with approximately 1.8 million of them in EWS (Low Income Group) categories. The policy allows households with an annual income of up to Rs 2 Lakh to apply for the subsidized houses. The houses with proposed carpet area of 21 to 27 sq m for EWS categories would be developed in partnership with either state housing boards or private developers. Such low cost houses will cost Rupees 4 to 10 Lakh, with center providing Rupees 75000 per dwelling unit to project developer. With such upcoming densely occupied buildings, the thermal comfort of occupants is bound to be affected.

Thermal comfort is an important aspect of building design process as modern man spends most of the days indoors. Thermal Comfort – the state of mind, which expresses satisfaction with the thermal environment (Joost Van Hoof, 2010). A typical summer day in Ahmedabad can have average maximum temperature ranging from 23°C to 44°C and relative humidity of about 60 RH%. Such high temperature and humidity leads to a need to cool and de-humidify spaces to create comfortable conditions for occupants. However, the need for such climatic modification of spaces within a building consumes much energy. Under such rapid growing electricity tariff regime, the occupants of economically weaker section residential cannot afford electricity bills for space cooling. Occupants of such residential live in houses with either tin sheet or asbestos roofs or thin concrete roofs without sufficient ventilation. Moreover occupancy density in such residential is comparatively higher as compared to other income group residential, thereby affecting their thermal comfort levels which in turn reduces their work efficiency. The periods of high temperatures inside residential complex associated with urban heat island (UHI) can cause discomfort, weakness, disturbance of consciousness, cramps, fainting, and heat stroke and even exacerbate pre-existing chronic diseases such as diabetes, respiratory failure, and cardiovascular, cerebrovascular, neurological and renal diseases, to the point of causing death (Besancenot, 2002) (G. Luber, M. Mc Geehin, 2008).

In a hot climate, excessive heat gains in a residential building can also be reduced by means of high albedo roofs. The amount of energy that is reflected by a surface is determined by the reflectivity of that surface, called the albedo. A high albedo roof means the roof surface which reflects the majority of the radia-

tion that hits it and absorbs the rest. Such techniques ultimately aim to promote human comfort for building users. The relationship between occupant's comfort/ productivity and building design is complicated. The productivity of occupant can be related to indoor environmental quality of the building. Improved thermal comfort can be related to improved health, resulting into improved productivity (Kats, 2003). The research study at Ahmedabad includes analysis of thermal insulation provided by High Albedo Roofs and its findings supported the hypothesis that High Albedo Roofs technologies improve thermal comfort, improve health of the occupant and thus demands less demand on health services.

2. RESEARCH OBJECTIVE AND METHODOLOGY

The objective of research study is to quantify the effect of High Albedo white roofs on improving internal thermal environment of economical weaker section buildings. The field trials were carried out during a summer period. Two identical rooms were identified, constructed oriented in same direction in the city of Ahmedabad. The selection criterion for the research study were due to warm dry climate of Ahmedabad. The chosen site has maximum exposure to solar radiation. The cells under monitoring were completely separated from each other. As per Indian housing guide lines, the rest rooms in EWS residential houses were built with a carpet area of 9 sq. meters which perfectly fitted into the selection criterion. Figure 1 shows orientation of test cells. Glass windows were used in the experiment. The roof of both room is a galvanized Iron sheet roof. The test cell 1 roof is treated with High Albedo white roofs paint whereas test cell 2 room roof is untreated.



Figure 1 Orientation of monitored test cells

At both the cells, data were collected at 10-min intervals and stored in data logger. Comparative analysis was adopted for research study to quantify in terms of mean radiant temperature (MRT), internal room temperature, over/under roof temperature and heat flux variation of both test cells to analyze the effect of High Albedo Roofs technologies in improving thermal comfort i.e. lower the MRT better the thermal comfort.

3. ANALYSIS AND RESULTS

The first step in the analysis was to convert the validated 10-minute data into hourly data by summing various monitored variables and averaging the remainder of the variables. From these data, average daily data were obtained for over/under roof temperature, air temperature, cell's room temperature, cell's globe temperature, cell's mean radiant temperature, relative humidity, wind speed, cell's roof heat transfer rate and roof's reflectance. Figure 3 shows treated and untreated roof test cell's monitored hourly data over the study period. There were noticeable differences in monitored variables of both cells. The maximum over roof temperature of test cell 2 and test cell 1 observed is 60.5°C and 43.3°C respectively, therefore the maximum temperature difference between over roof surfaces is 17.2°C. The maximum under roof (plenum) temperature of test cell 2 and test cell 1 observed is 57°C and 41.9°C respectively, therefore the maximum temperature difference between under roof surfaces is 15.1°C. The heat flux of test cell 1 is lower by a factor of three as compared to test cell 2. Noticeable difference were also observed in ambient temperature and mean radiant temperatures of both cells. As seen in figure 4, the difference (test cell 2 minus test cell 1) in mean radiant temperature of both cells is in the range of 1.2°C to 2.5°C.

Roof surfaces are subjected to radiative exchanges. These radiative exchanges play an important role in building envelop heat gain. The concept of sol-air helps to illustrate this impact. Sol-air is the fictitious temperature of outdoor air, in absence of radiative exchanges on outer surface of the roof. The heat gain due to the heat flow through the roof or wall is easily determined by using sol-air temperatures. Positive extreme sol-air temperatures can accelerate heat exchanges, thereby negatively affecting thermal comfort of occupants of building.

for a dark roof. The effect of solar radiation on heat gain through building structures with dark roof is more as compared to high albedo white roof. This effect can be related to reduction in heat flux in cell 1. Hence as result, cell 1 is subjected to lower heat stress as compared to cell 2

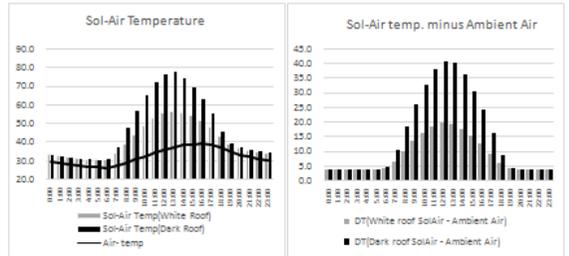


Figure 3 Sol-air temperatures

4. SUMMARY AND CONCLUSION

This study arises from the need to put forward High Albedo Roofs technologies solutions for improving indoor thermal conditions in economical weaker sections buildings. Environmental parameters were monitored and compared in two economical weaker section homes in Ahmedabad. The buildings were monitored for a period of about 2 ½ months of summer. The original roof reflectivity of test cell 2 is about 30 percent whereas after application of High Albedo roof paint the roof reflectivity of test cell 1 were increased to 70 percent. It was found that an increase in solar reflectance by 40 percent from the application of high albedo roof coating improves indoor thermal comfort condition and reducing internal room temperatures by 1°C to 4.8°C. Improved indoor thermal comfort condition can reduce heat stress thereby increasing occupant's productivity and living standards. The use of high albedo roof coating is an inexpensive and passive solution that can contribute to improvement in indoor thermal comfort by decreasing hours of discomfort. The result of this study can contribute to adoption of high albedo roof technologies in economical weaker sections and low - income group's buildings constructions and urban planning regulation. Envisaging the potential benefits of high albedo roof technologies, for occupants of EWS houses, who can't afford to have conditioned space, government should adopt such roofs technologies while designing low cost houses for such groups.

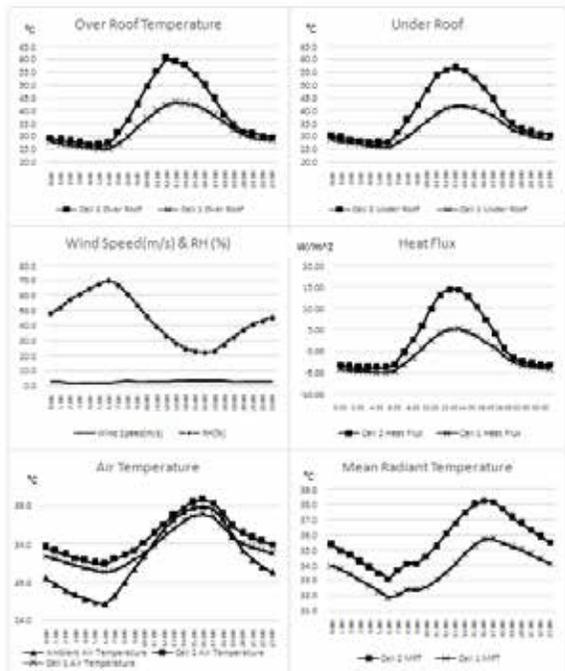


Figure 2 Time of day: Over roof temperature, Under roof temperature, Heat flux, Wind speed, RH, Air temperature and Mean Radiant temperature

Figure 4 shows graph of ambient air temperature and sol-air temperature for high albedo white roof and dark roof. As seen in figure 4, the difference between sol-air temperature and ambient temperature is 19.4°C for a high albedo white roof but 40.4°C

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