EFFECT OF LOW COST ROOF INSULATING MATERIALS ON INDOOR TEMPERATURE OF BUILDINGS IN LAHORE

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ABSTRACT: The aim of this research work was to investigate temperature effect of different materials on conventional concrete roofs for the buildings. Each material tested consists of a combination of materials that can reduce net heat load or temperatures inside the buildings. In Hot climates, the building having Reinforced Cement Concrete (R.C.C) roofs exhibit unfavorable thermal conditions resulting in uncomfortable indoor temperatures. In the absence of passive cooling techniques it also leads to increased cooling loads thereby increased electricity consumption. This study work reports for comparative analysis of different materials locally available for the roofing insulation. Therefore, small rooms already built at different orientations have been tested for studying the passive cooling effect of roofs. Three different materials were applied for the comparison of temperature effects. The analysis of results marked the minimum indoor temperatures for thermal comfort and also the respective insulation- mixture.

Key words: Roof, Insulation, Materials, Indoor Temperature.

INTRODUCTION

There is a worldwide growing concern over energy conservation. Insulating the buildings' envelope is an important strategy in achieving thermal comfort for the occupants at reduced energy consumption. The roofs of buildings are an important component of the envelope. In Pakistan people pay high charges for use of electricity in summer due to the excessive use of cooling devices. The reason is that the modern buildings are constructed with no regard to the local climate and the building modeling with energy simulation in modern houses investigated by Arif (2011), showed that the roof is the most important component of the buildings in the hotter climates and should have a time lag more than six hours and a thermal conductivity of less than 0.48W/m^2. As the passive strategies are highly sensitive to meteorological factors and, therefore, require a broader understanding of the climatic factors by a designer. There is always a need to work on prototype of building while application of certain techniques. The rooms in any building can face any orientation, therefore, this work was executed on the test structures already constructed by the corresponding author in her Doctorate Research. Therefore, three low cost materials, locally available, were tested along with the factory made product for the thermal indoor comfort at reduced temperature and the sustainability of application. Different insulation materials were applied over the roofs of these test structures to analyze the variations of indoor temperatures. The cost and applications were the main factors while selecting materials.

MATERIALS AND METHOD

Three locally made materials were tested on six test structures at six main orientations. Each material was applied over roofs of test structures for two weeks. Application of first insulating material polystyrene was started on 9th June, 2012. Then afterwards, insulating materials were replaced on all six test rooms. Device used for monitoring was Testo Saveries System having temperature probes with display Base unit; each probe was installed in the centre of each test room to measure indoor temperatures. All probes were connected to a recording Base unit which is further connected with Computer System. The other technical data include six test Rooms of 5'7" x 4'11" size and 21.58 ft² area. The materials include polythene sheet, mud with wheat straws and White Cement with Lime stone. The material selection was based on the economical local availability.

The Material -I (extruded Polystyrene Board), with the thermal conductivity of 0.18 Btu in/ft^2.hr.F^o (0.026 W/mk), was placed over the roof. The Polystyrene is a petroleum-based plastic made from the styrene monomer. Polystyrene is a light-weight material, about 95% air, with very good insulation properties.

For the Material-II (Mud wheat straw- mix), the mud was collected from ground in university campus and wheat straw (Bhoosa) was purchased from the market at very low price. Wheat straw was added in mud to avoid any kind of cracking, expected to appear on surface on drying. Cracks proceed deep inside which cause water leakage and damage to roof slab under by increase in moisture content. Mud is a dynamic medium made up of minerals, organic matter, water, air and living creatures including bacteria and earthworms.

The following Figures: 1, 2, 3 and 4 show steps involved in application of the Material II.

Fig. 1: Mud and wheat straw

Fig. 2: Polythene sheet laying

Polythene sheet was laid before application of Mud and Wheat Straw Paste over the roofs so to avoid any kind of water leakage that might lead to roof slab damage underneath. The thickness of mud plastered layer was kept between 25 mm to 30 mm.

Fig. 3 Roof while Preparation

Fig. 4 Finished roof

Third material, the cement and limestone were also purchased. Water was sprinkled over coarse Limestone particles so it released heat and turned to powder form whereas White cement was already available in fine form.

For the preparation for Material- III, the mix (white Cement and Limestone) was used as Insulating material. As white color has high reflecting intensity as compared to other colors, so limestone was added in white cement to enhance reflectance and also to economize the cost of application (Figure 5, 6 and 7).

Fig. 5: Limestone

Fig. 6: White Cement

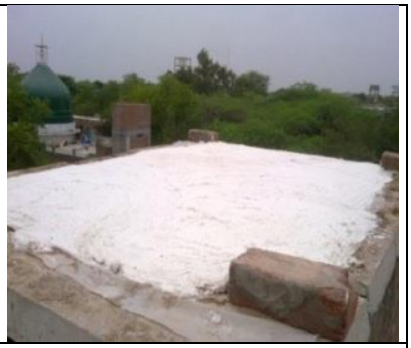

Fig. 7: Finish roof with the white

Similarly, Polythene sheet was also placed over the roofs before applying the mixture paste to avoid any kind of damage caused by water through cracks in paste layer at later stage. Proper slope was provided over layer to avoid any water deposition on layer in case of rain.

RESULTS AND DISSCUSSION

The recorded temperature of the test structures before and after the installation of the insulations showed temperature variations in this work. Similar experimentation conducted locally, at the Attock Refinery Limited, Rawalpindi, also showed similar results according to Ahmad (2010), to assess the performance of the anti-solar insulated roof system. Ong K.S (2011), also tested small scales test boxes for roof insulation system which reduced the thermal loads for indoor thermal comfort. Hamdan *et al* (2011) reported clay as thermal insulation over the roof to be the best material for cooling of buildings for better comfort in arid areas among passive techniques of painting with white cement, pieces of glass and clay layer over the four roofs; the test structures were made by using mild steel angle and galvanized steel sheet and had a 0.08m thick R.C.C. roof.

In this work, in the climatic context of Lahore, the monitored data of indoor as well as outdoor temperature was continuously recorded with all local materials' application and compared for the analysis. The results with 50 mm polystyrene sheet (material –I) are shown in Figure 8.

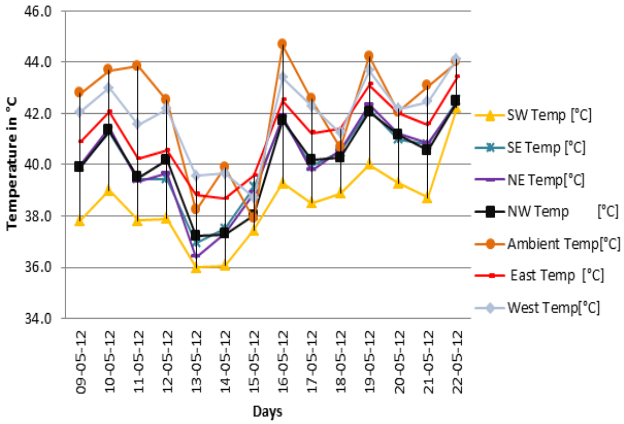

Figure 8: Temperature profile with material-1 at 4 p.m.

All the results were analyzed for the lowest temperature effects among all the test structures. The maximum temperature difference was found (6 °C) between SW and ambient temperatures on 11th May, 2012. The data recorded for the material-II comprising of mud and wheat straw (Bhoosa) were plastered over roof (25mm) is shown below in Figure 9.

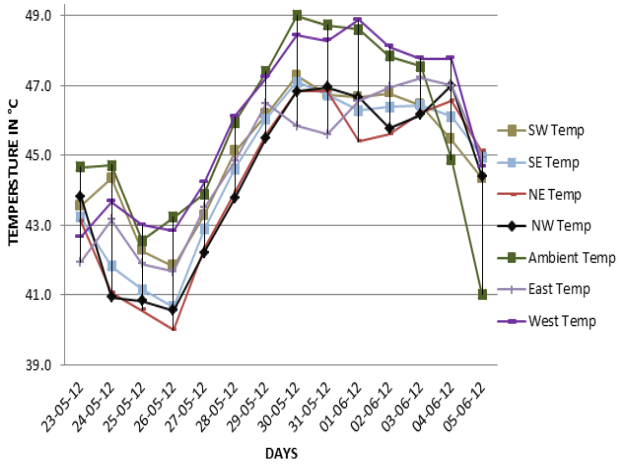

Figure 9: Temperatures monitored with the material II at 4 p.m.

The maximum temperature difference of 3.9°C was observed between East test room and the ambient temperature probes on 5th June, 2012, while on the overall NE showed minimum temperature profile. The test results for the material III comprising of White Cement and Limestone at 4 p.m are shown in Figure 10.

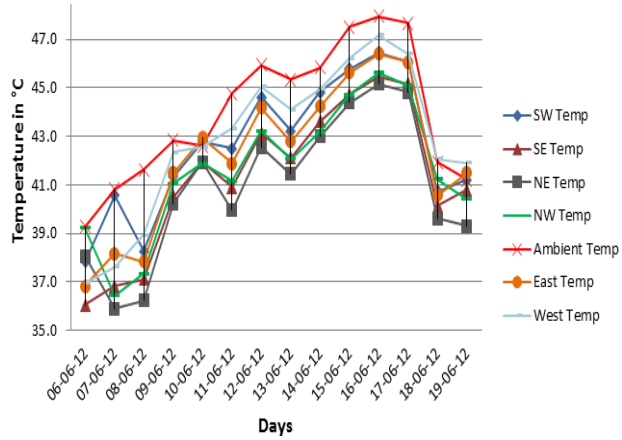

Figure 10: Temperature profile monitored with material III.

The maximum temperature difference of 5.4°C was found between NE and Ambient temperature probes on 8th June, 2012 at 4. p.m. The comparisons of average temperatures along with their respective differences are shown in table 1.

White Cement and Limestone mix over the roofs has proven to be the best material for passive cooling of building for thermal comfort while the extruded polystyrene, which is rather expensive insulation but showed good results in SW oriented test structure. Although Polystyrene board carries thermal conductivity of 0.18 Btu in/ft^{2}hr.F^o (0.026 W/m^{2}k), which lower than the referred value of 0.25 W/m^2 K by Erell *et al*. (2006)

Table 1: Average Indoor and Ambient Temperature differences

Insulation Technique	Av. Ambient Temperature [°C]	Av. of max. Temperatures [°C]	Difference[°C]
Jumbolon Insulation Board	42.1	40.32	1.78
Mud Wheat Straw Mix	45.7	44.84	0.86
White Cement Limestone Mix	44	41.90	2.10

for roofs of new buildings; the analysis of average temperatures of all the test rooms at different orientations has shown the potential lower than White Cement and Limestone Mix. Whereas, the passive low cost materials reported by Nahar *et al*. (2003), also showed similar indoor temperature results but with the lesser potential for cooling than the material tested with the White Cement and Limestone mix. The roofs of test structures treated with Mud and Wheat straw mix, was concluded to be at the lowest potential and also at the lowest cost. Likewise, the differences in average ambient and average Indoor temperatures at 4.00 p.m. were 1.78 °C, 0.86°C and 2.10°C insulated with polystyrene board, mud wheat straws mix and white cement limestone mortar respectively. The materials investigated by Ong K.S (2011) are expensive materials; likewise, the results demonstrated by Jorge (2008), with the aluminum- poly-urethane insulation with an optimal orientation are less applicable in our environment of new housing developments. Therefore, the experimented results of low cost tested material for cooling have significance in climatic condition of Lahore. Deficiencies during application must be avoided to get the effectiveness of insulation and even better efficiency.

Conclusion: It is concluded that all the insulating materials have their respective cooling effect on the indoor temperatures. By the application of all three materials, W oriented test structure showed the least temperature differences between indoor and ambient temperatures with all the insulation materials while the maximum temperature differences were analyzed for the NE test structures with the material II and III. Only the SW test structure showed a minimum average with the material I. Therefore, it can be concluded that the White Cement with Limestone over the roofs have shown best results in achieving thermal comfort with the lower cost as well while the polystyrene showed lesser indoor temperature differences in one orientation only and is rather expensive. More thicknesses of the tested materials may reduce the indoor temperature as they are cheaper and locally available. However, deficiencies during application must be avoided to get the effectiveness of insulation and better efficiency.

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REFERENCES

Ahmad, I. Performance of anti solar insulated roof system, Renewable Energy vol. 35, pp 36–41. (2010).

Arif ,S. "Energy Efficient House Design, Effect of Orientation on indoor temperature profile", unpublished PhD Thesis, University of Engineering and Technology, Lahore, Pakistan, (2011).

Erell E., S. Yannas, J. L. Molina, Roof Cooling Techniques, PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland, (2006).

Hamdan, A., M. Yamin, and J. M. E. Abdel Hafez, Passive cooling roof design under Jordanian climate. Sustainable Cities and Society, (2011).

Jorge ,L., A. Alvarado, and E. Martı, Passive cooling of cement-based roofs in tropical climates, Energy and Buildings, vol. 40, pp 358–364, (2008).

Jorge, L; A. Alvarado; W. Terrell; D. Michael and Johnson, Passive cooling system for cement – based roofs, Building and Environment, Vol. 44. Pp 1869-1875 (2009).

Nahar, N.M., P. Sharma, and M.M. Purohi, Performance of different passive techniques for cooling of buildings in arid regions, Building and Environment vol. 38, pp 109 – 116, (2003).

Ong, K. S. Temperature reduction in attic and ceiling via insulation of several passive roof designs, Energy Conversion and Management vol. 52, pp 2405–2411, (2011).

Suresh, B.; M. Sadineni; S. Robert and F. Boehm, Passive building energy savings: A review of building envelop components, Renewable and Sustainable Energy Reviews 15, pp 3617-3631 (2011).