Experimental Investigation of the Thermal Performance of Silica gel-Soil Roof

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***Abstract*— Global warming refers to increasing average surface temperatures of earth and it has become a threat to biota. Increase in the ambient temperature increases indoor and outdoor temperature level of the houses which augments the usage of mechanical air-conditioning systems. This paper investigates the impact of silica gel-soil roof on the cooling potential of residential buildings in Oman. Experimental analysis shows that compared to the standard bare roof, the room air and roof surface temperature of the silica gel-soil roof were reduced by a maximum of 8.08ºC and 19.43ºC respectively.**

***Keywords*— Cooling potential; Energy conservation, Silica gel, Thermal Performance**

I. INTRODUCTION

Silica gel is a highly porous solid adsorbent material that structurally resembles a rigid sponge. It has a very large internal surface composed of myriad microscopic cavities and a vast system of capillary channels that provide pathways connecting the internal microscopic cavities to the outside surface. The amount of water adsorbed rises almost linearly with increasing relative humidity until RH reaches about 60%. It then plateaus out at about 40% adsorbed as relative humidity approaches 100%. Silica gel has superior characteristics for the recovery of space conditioning energy from exhaust air. When the airstream with the higher relative humidity passes over the silica gel, moisture is adsorbed from the airstream into the silica gel. This will help in evaporative cooling and hence the total amount of heat transferred to the room can be reduced. In this ventilation energy recovery application, the silica gel has all of its surface area covered with at least a monomolecular layer of water because it has a greater affinity for water than any other chemical species. In the study carried out by Chiara Ferrari et.al [1], an innovative approach is tested to achieve roof tiles with high capacity of rejecting solar radiation. It consists of using a cool-colored tile with relatively high solar reflectance, combined with a thin insulating layer attached below the tile and made of a silica-gel super-insulating material. An aluminum foil with very low thermal emittance is also applied below the insulating layer. Along the perimeter of each tile, line brushes were attached in order to enclose an almost sealed air space between the aluminum foil and the roof slab below when the tiles are supported on wooden battens. Studies have shown that composite tiles like that outlined here provided a strong increase of roof thermal resistance, helpful to control either heat loss in winter, or building overheating in summer.

The study performed by Anna Laura Pisello et.al [2] concerns the year-round analysis of the thermal-energy performance of a typical 16th century historic residential building located in central Italy where an innovative cool clay tile was installed in a continuously monitored two-floor residential unit. The results showed that the proposed tiles, having good visual similarity with respect to the classic tiles, represent an effective solution to improve building energy efficiency during the cooling season and, if applied at larger scale, they could represent an effective UHI mitigation technique. In particular, maximum primary energy saving for cooling was 51%, while heating energy penalty was lower than 2%. The combined multi-scale analysis finally showed how these tiles represent an effective non-invasive strategy to (i) optimize thermal-energy performance of historic buildings even in temperate climate, and to (ii) mitigate urban climate.

II. METHODOLOGY

A. Experimental Set-up

The experiment was performed in two symmetrical rooms of area 1.6 m^2 each (figure 1) during the peak season in Oman. The interior walls of the rooms are insulated by polystyrene foam of thickness 4.5cm to avoid any heat conduction thorough the walls so that the heat transfer will be through the roof of the rooms. The rooms are constructed in such a way that their shadows will not cross each other. One room is the standard (reference) room and the other is covered with soil and silica gel to study its effect on thermal behavior of buildings.

Fig.1 Experimental roof covered by silica gel and soil mixture

The schematic diagram of the experimental set-up is shown in figure 2. The humidity retained by the silica gel absorbs heat and evaporates the moisture there by stopping the heat in leak into the roof. The concrete roof slab is covered with Polyethylene sheet of 2 mm thickness and silica gel mixed with soil for a height of 10 cm (figure 2). The temperatures were recorded at every 5 minute intervals by a computer assisted automated system.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 01, January-2018

Fig.2 Schematic of the Experimental set-up

B. Instruments

- Thermocouples (Type T) for measurement of Temperature at various points in the silica gel roof and on the concrete slab.
- Temperature data logger (TC-08) to record the temperature

The properties of silica gel used are shown in Table 1

Table 1

Size of Beads	2-5 mm
Bulk Density	700-800 g/l
Adsorption capacity	80% RH: 37%
Average pore diameter	2-3mm.
Surface Area	650-800 m^2/g.

III. RESULTS AND DISCUSSION

C. Room Air Temperature of standard and silica gel-soil roof

The temperature of room air was measured automatically for a period of 5 days in March 2017 using thermocouple connected in Silica gel with Soil roof as well as normal roof rooms. Figure 3 shows the room air temperature profile of the experimental rooms. The maximum difference occurred during the midday afternoon. From the studies it is evident that the room air temperature of silica gel with soil roof shows a much lower temperature profile in comparison with the standard bare roof. Tallest temperature peaks were obtained with the standard bare roof. The effect is most pronounced in the extreme regions of temperature, especially the temperature peaks. The conventional roof quickly responds to the ambient temperature.

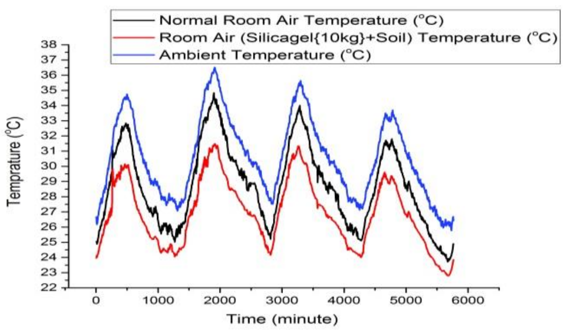

Fig.3 Room air temperature profile

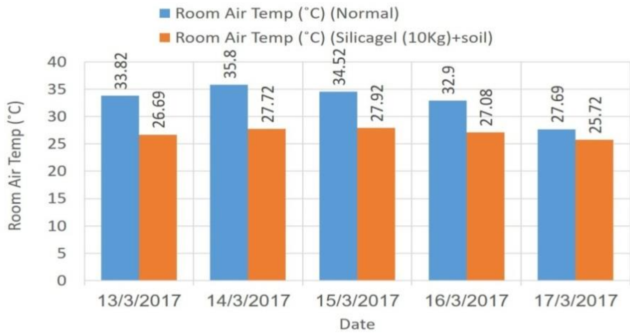

Fig.4. Maximum Room air temperature of reference and silica gel-soil roofs

The temperature profile follows the same pattern for both the study rooms. The maximum difference occurred during the midafternoon. A maximum reduction of 8.08°C (29%) have been obtained for Silica gel-soil roof over the conventional roof as shown in figure 4. The reduction of temperature is due to evaporation, increase of roof thermal resistance and insulating capacity of silica gel with soil roof layers.

D. Exterior Roof Surface Temperature

The temperature profile of the exterior surface the concrete roof slab is shown in figure 5. The data have been recorded continuously for a period of 5 days in March 2017. A higher reduction in exterior roof surface temperature was obtained for silica gel-soil roof in comparison with the standard bare roof. The main impact was upon the maximum and minimum values of the external surface temperature of the silica gel-soil roof slab. It was found that silica gel with soil roof caused the maximum external temperatures to drop. Overall the effect was that of reducing the extremes of temperature swings.

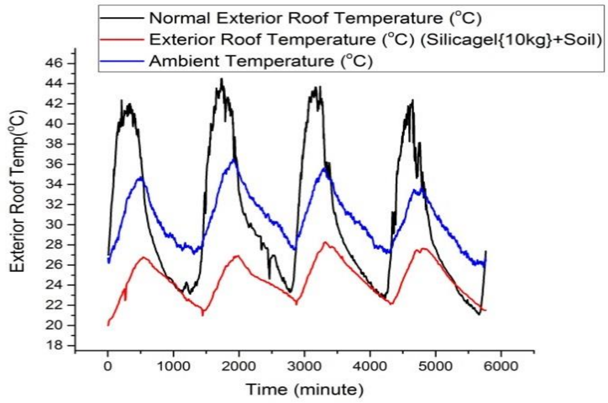

Fig.5 Exterior roof slab temperature profile

The temperature of the exterior surface of the roofs have been measured continuously for a period of 5 days in March using thermocouples and recorded by data logger. A higher reduction in exterior roof surface temperature was obtained for Silica gel and Soil roof surface. A maximum difference of 19.43°C (84.74%) have been obtained as shown in figure 6. It has been confirmed from the above studies that the Silica gel-Soil mixture roof showed much lower peaks and lower thermal profile of surface temperature compared to a conventional roof. The effect is most pronounced in the extreme regions of temperature, especially the temperature peaks.

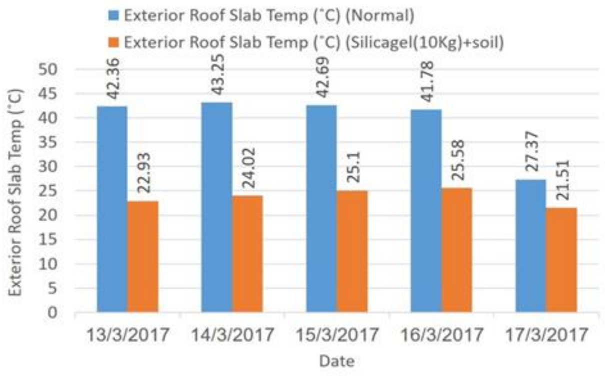

Fig.6 Maximum Exterior roof slab Temperature of reference and silica gel-soil roofs

E. *Interior surface temperature of the roofs*

The interior surface temperature of the roofs has been measured continuously for a period of 5 days in March 2017. Similar to the Exterior roof, a higher reduction in roof surface (Interior) temperature was obtained for Silica gel -Soil roof surface.

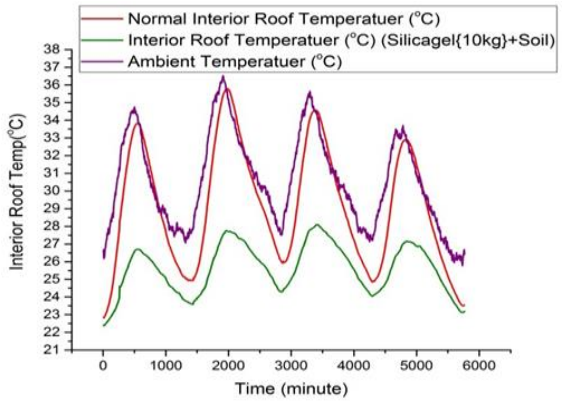

Fig.7. Temperature profile of bottom face of green roof

A maximum difference of 6.66°C (24.89%) has been obtained as shown in figure 7. It has been confirmed from the above studies that the Silica gel and Soil roof showed much lower peaks and lower thermal profile in comparison with a conventional bare roof.

IV. CONCLUSIONS

The study shows that silica gel-soil roof can be an effective tool to save energy and cost of air conditioning. The experimental studies indicate that compared to a normal bare roof, the indoor air and roof slab surface temperature of the silica gel-soil roof was reduced by a maximum of 8.08°C and 19.43°C respectively. The results reveal that the significant reduction in silica gel-soil mixture was due to the improved thermal resistance. The cooling potential of Silica gel-soil roof in hot arid climate of Oman was experimentally and successfully demonstrated.

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