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Performance Evaluation of Green Roof

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Abstract—*A green roof is a roof which is covered with vegetation and soil, planted over a waterproof layer. Generally the green roofs are used to provide insulation to a room from the surrounding condition. The most of the population in India particularly in rural areas are facing bad comfort condition in the room during summer, particularly in the absence of electricity. If the green roofs are made then the human comfort may be increased even in the less availability of electricity. In order to check the feasibility of green roof in Eastern Uttar Pradesh, India, an experimental study has been carried out. A prototype of a room was fabricated with reinforced cement concrete (RCC) roof at KNIT Sultanpur. A green roof was developed over RCC roof in order to investigate the reduction in the inside room temperature. The temperatures of top surface, inside roof surface, inside air and ambient air were recorded at an interval of 15 minutes for all the roofs. From the experiments, it is revealed that, there is a decrease in inside temperature of the room due to green roof as compared to RCC roof. This reduction in temperature is due to evapotranspiration, lower thermal conductivity of green roof and low absorptivity of white painted roof.*

1. INTRODUCTION

In the present scenario, the population of world is increasing very fastly, especially in India; increasing rate of population is resulting in the deterioration of our non-renewable resources and our environment. From the last few decades, there is a lot of variation in the climate of earth. This is due to the man made activities such as pollution, deforestation, increasing population load etc. all these things are contributing in the ecological unbalance which is resulting in the global warming, variation in the monsoon, increased global mean temperature etc. The development activities of human being are resulting in the uncontrolled growth in transport facilities (increased motor vehicles) and construction of buildings. These activities are mainly contributing in the increased CO_2 emission. This CO_2 entraps the solar radiation which again results in the green house effect. This results in the increased global mean temperature of earth which is worsening indoor thermal condition for human comfort. There are many ways for maintaining the indoor thermal condition for human comfort such as fan, desert cooler, air- conditioning equipments etc. Thus for maintaining the thermal comfort, large amount of electricity is required by the many countries (India is one of them). This again results in the increased emission of CO_2 due to the burning of fossil fuel such as coal, diesel etc in the power plants and also depletes our non-renewable energy resources. Thus for the sustainable development, it becomes necessary to achieve indoor thermal comfort condition by reduction in CO_2 emission along with reduction in energy demand. This can be done by installing the P-V module for production of electricity and green roof for thermal insulation. Though the installation of solar panel is the best alternative but it has large installation and maintenance cost and becomes in-effective towards recovery of our environment as it is not able to decrease the CO_2 emission, particulates, noise pollution etc. So the green roofs become one of the best alternative among all possible alternatives, which not only reduces the electrical demand but also helps in saving of our environment.

2. GREEN ROOF

A green roof is a roof which is covered with vegetation and soil, planted over a waterproof layer. It is formed by placing a number of layers such as plants, growing media, filter fabric, drainage layer, retention layer, insulation layer, root barrier, waterproof layer and substrate one over the other. Green roofs are of two types: intensive and extensive. The green roofs having substrate thickness greater than 150 mm are termed as intensive green roof while others are termed as extensive green roof. These green roofs have many advantages such as thermal advantages, storm water retention, decreasing noise pollution etc. According to the **Magill et al [1],** thermal advantages are mitigation of urban heat island, enhanced thermal insulation and increased life of roof etc**.**

From the previous few studies it is observed that green roof reduces the heat gain during summer, temperature of top roof surface, inside roof surface and inside room air. **Celik et al [2]** performed experimental and theoretical analysis for insulation properties of different green roof systems. They used 12 different green roofs in which there were three species of sedum (sedum kamtchaticum, sedum spurium and sedum sexangulare) and four types of growing media (Arkalyte, Pumice, Lava and Haydite) and concluded that Haydite and sedum sexangulare combination shows the best insulation. **Wong et al [3]** performed a field measurement with six vegetation species (Heliconia, Spider lily, Ophiopogon, Raphis Palm, Pandanus and Erythrina) They observed that the maximum temperature of hard surface reaches around 57^oC while the maximum temperature for the bare soil surface was

around 42°C and the maximum surface temperature for planted roof was not more than 36°C. They also concluded that bare hard surface shows heat gain of 366.3 kJ/m^2, bare soil gave heat gain of 86.6 kJ/m^2 while bare soil with turf showed heat gain of 29.2 kJ/m^2.

In India, if green roofs are proposed over the RCC roof then these will reduce the electricity consumption and save the environment. Thus in this paper an effort has been done to investigate the feasibility of green roof in Indian climate.

3. PROBLEM FORMULATION

From the literature, it has been observed that green roofs help in the reduction of heat gain inside the building which further reduces the temperature of top roof surface, bottom roof surfaces and inside air of room. The place of research is Sultanpur, Uttar Pradesh, India. The most of the population of Sultanpur is facing bad comfort condition in the summer, particularly in the absence of electricity which availability is very poor in this region. If the green roofs are made in this region then the human comfort may be increased even in the less availability of electricity. In order to check the feasibility of green roof in Eastern Uttar Pradesh, India, an experimental study is required. The green roof will be constructed on a prototype of a room on the top floor of KNIT Sultanpur, Uttar Pradesh, India.

4. METHODOLOGY

An experimental set up has been prepared which involves fabrication of a model of a room, preparation of green roof, measurement of temperature. A prototype of a room was constructed which has dimensions of 1 m × 0.5 m × 0.9 m with traditional RCC roof of thickness 0.1 m as shown in Fig. 1. There are three side walls (east, west and south walls) which are formed with lateral single brick with mixture of cement and maurang in the ratio of 1:3 along with water. A layer of plaster of thickness 1 cm was placed over the brick walls with the same mixture. The traditional RCC roof layer was formed by the mixture of cement, maurang and aggregate in the ratio of 1:2:2 along with water while 5.8 kg of TMT rods were used.

Following assumptions have been considered:

- Heat flow is uni-directional that is heat is flowing only in vertical direction. For this purpose, all the side walls are insulated with the help of thermocol sheet.
- Steady state heat flow that is heat is flowing steadily. In actual practice, the heat flow is not flowing steadily as solar radiation is varying all the time so an average of all the temperatures have been taken from the reading of that day during 10:00AM- 4:00PM.
- In order to achieve uni-directional heat flow, all the walls were insulated by placing a sheet of thermocol internally as well as externally. A layer of greenery was prepared over the 0.1 m thick soil layer with organic material in the ratio of 2:1 over a plastic sheet. Measurement of temperatures was carried out with the help of four temperature sensors. These temperature sensors were measuring the temperature of top surface, bottom surface, inside air of model and ambient air.

Fig. 1: Model with thermocol covers

5. RESULTS AND DISCUSSION

Temperatures of top surface (T_1), inside roof surface (T_2), inside air for RCC roof (T_{iRCC}), inside air for green roof (T_{iG}) and ambient air (T_0) were recorded from 10:00 AM to 4:00 PM at an interval of 15 minute. For RCC roof and green roof, the temperatures were recorded on March 1, 2 & 3, 2016 and March 7, 9 & 10, 2016 respectively.

Fig.2 shows the variation of top roof surface temperature (T_1) with respect to the time on these days. From Fig. 2, it is observed that, the top surface temperature was the highest in case of RCC roof and the lowest for green roof (GR). Some of the absorbed energy (solar radiation) by the RCC roof convected and radiated to the atmosphere and remaining is conducted through the roof to the room. **Lazzarin et al [4]** has investigated that 25 % of the solar radiation was used to evaporate the moisture in green roof in addition to convection, radiation and conduction as in the case of RCC roof. Therefore, the temperature of top surface of green roof is lower than that of RCC roof.

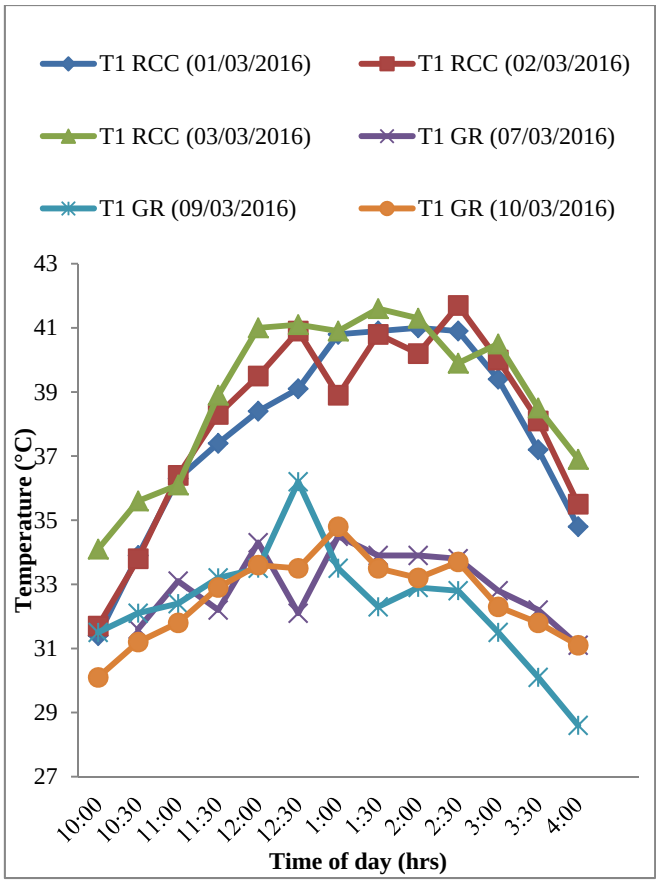

Fig. 2: Variation in top roof surface temperature with respect to time on respective days

From top surface of the roof, heat is conducted through the roof to inside surface of the roof and then it is convected and radiated inside the room. The variation in the inside roof surface temperature (T_2) was plotted with time for all the 6 days as shown in Fig.3. From Fig.3, it is seen that inside roof surface temperatures (T_2) were lower for green roof than that for RCC roof. The rate of increase of temperature is very less in case of green roof while it is very high in case of RCC roof.

The inside room temperatures (T_{iRCC} and T_{iGR}) are plotted with time (Fig.4). From Fig.4, it is observed that inside temperatures are increasing with time with nearly same rate. The temperatures for green roof (T_{iGR}) were lower than that for RCC roof (T_{iRCC}).

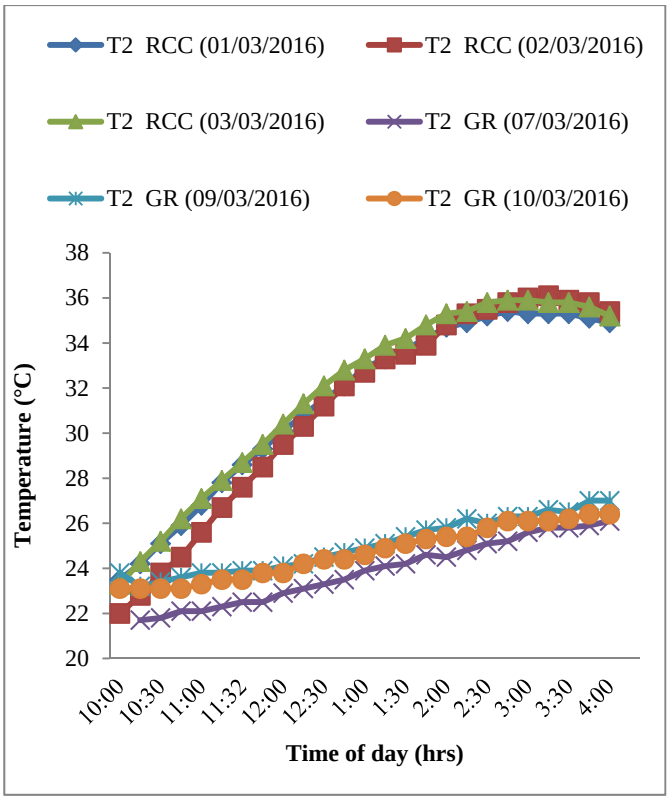

Fig. 3: Variation in the inside surface temperature of roof with respect to time on respective days

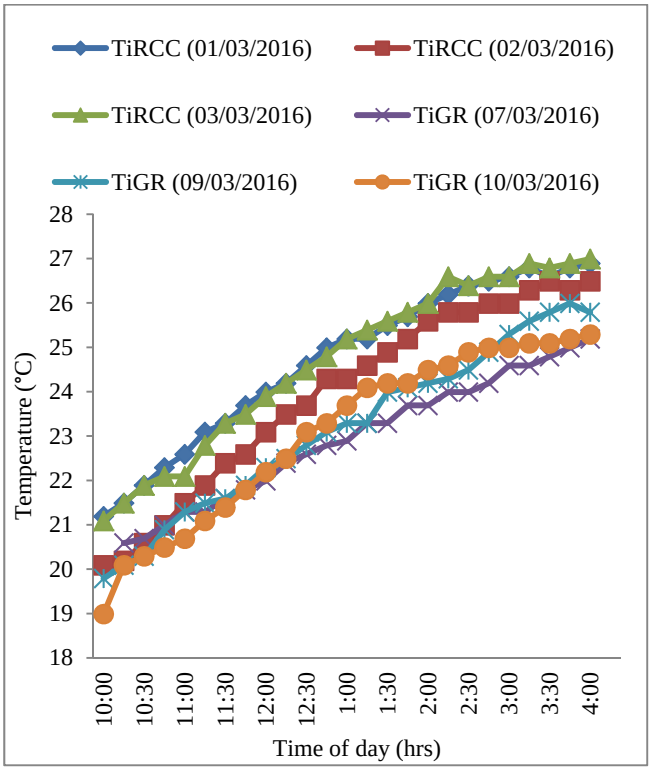

Fig. 4: Variation in the inside air temperature with respect to time on respective days

The temperature is one of the parameters which must be lower for better comfort inside the room. The inside room temperature is mainly due to convection and radiation from the inside surface of the roof i.e. it can be said that inside room temperature is function of inside surface temperature of the roof (T_2). For green roof, the slopes of the inside surface temperature (T_2) with time is smaller than those for RCC roof which indicates that in case of green roof the environment inside the room is more comfortable than in case of RCC roof.

6. CONCLUSION

In this investigation, a model of room with RCC roof was made. A green roof was developed on the RCC roof. After recording the temperatures with RCC roof, again that were recorded for green roof and it was observed that there is decrease in temperature of the inside room when green roof was present and these green roofs reduces the fluctuation in the top roof surface temperature which increases the life of roof.

From this experiment it is advisable to develop green roof on the upper surface of the RCC roof to maintain the lower temperature inside the room which is one of the parameters required for comfort environment.

7. ACKNOWLEDGEMENT

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