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Green Roof Methodology: Remedy for Urban Heat Islands

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Abstract:-Construction activity, method or technique consumes large amount of energy, first in form of non-renewable resources like material at time of construction and secondly at post construction period in the form of operation energy.

One of the major component responsible for enhancing material demand is roof .non reflective roof absorbs and retains solar energy as heat, which contributes not only to hotter roof, but also uneven thermal expansion / contraction of the roof. Creating either discomfort for the building inhabitants or increased local cooling loads. This increased absorption of solar energy by present concrete roofing system is causing heat island effect.

Researchers found that city is warmer than the surroundings remote or village areas. The average temperature in large cities can range from 5 to 10 ^{o} c warmer. , this phenomenon, know as the urban heat island effect. As thermal conductivity of concrete is high as compared to other materials, the amount of thermal flux or heat transfer further increases demand for consumption of operational energy in form of fan, air cooling devices etc.

Thus, to make living environment sustainable, alternative techniques should be adopted.

The experimental work done over here is to check out the feasible usage of green roof concept in construction methodology, by creating model and finding out cooling effect of green roof as compared to other roofing system and further thermal analysis is done by process of simulation using Ansys Fluent Flotran.

This experimental work lead to following benefits:-

Reduce in heat transfer rate and thus thermal flux below roof.,Overall reduction in room temperature in day time.Reduction in material consumption, i.e resources.Environmental friendly construction techniqueReduction in operation energy consumption of house & thus making living environment healthy and economical for inhabitants.

Key words:- non renewable , resources ,urban heat island , thermal flux, green roof.

I. INTRODUCTION

Unstoppable growth of urbanisation is leading to change in mode of living style of people. In the last two decades, diversion and adaptation towards more comfort and less time consuming practises has been marked globally as well as nationally. According to the census record of India, the change in mode of construction material and methodology is also remarkable.

The statistics of housing show the change in trend of construction. Survey done for the type and material used for roof, wall, flooring is highlighted below:-

Indian Scenario:

Population: 1,210,193,422 (2011- 16.7 % World Population),Total annual Utilization of water: 1086 Km3(9 % world water resource),Estimated need of water : 1450 Km3 (year 2050)Total solid waste : 12 million tones / annum,In rural India proportions of households using different materials are: Grass/ Thatch/ Bamboo/ Wood/ Mud, etc.: 20% (declined from 27.7% in Census 2001); Plastic/Polythene: 0.6% (increased from 0.4%),Tiles: 28.7% (declined from 37.5%),Burnt brick: 7.2% (increased from 5.6%) ,Stone/Slate: 8.9% (increased from 7.3%),G.I./ Metal/ Asbestos sheets: 15.9% (increased from 9.8%); Concrete: 18.3% (increased from 11%) Only 3.3 crore(16 %)

households in India live in houses with Grass/ Thatch/ Bamboo/ Wood/ Mud, etc. type construction The number has reduced substantially since 2001 by about 49 lakh.

(Source: censes of India 2011)

When the study is done , it is clear that roofing pattern from natural system like bamboo, wood ,mud has decreased from 21.4 % to 15.4 % where as roofing of concrete has increased from 21.1 % as in 2001 to 29.5 % in 2011.This change in construction mode is showing adverse effect on environment and human health. Even though, these materials like cement and concrete boost construction speed but increases the need of external energy too in form of operational energy for developing thermal comfort to the habitants in the houses. This high need for thermal comfort is leading to high rate consumption of non-renewable energy sources, creating scarcity for generations to come. Thus needs to balance and can be achieved with the concept and application of sustainable or cool roofing systems like 'Green Roof'.

A Green Roof is the sum of more than just plants. Following figures shows a Green Roof component. A key component to successful Green Roof implementation is the waterproof membrane that protects the roof from excess moisture. Similarly, a growing medium that provides proper drainage and aeration is essential.

Classification of Green Roofs can be divided into two main categories – extensive and intensive.

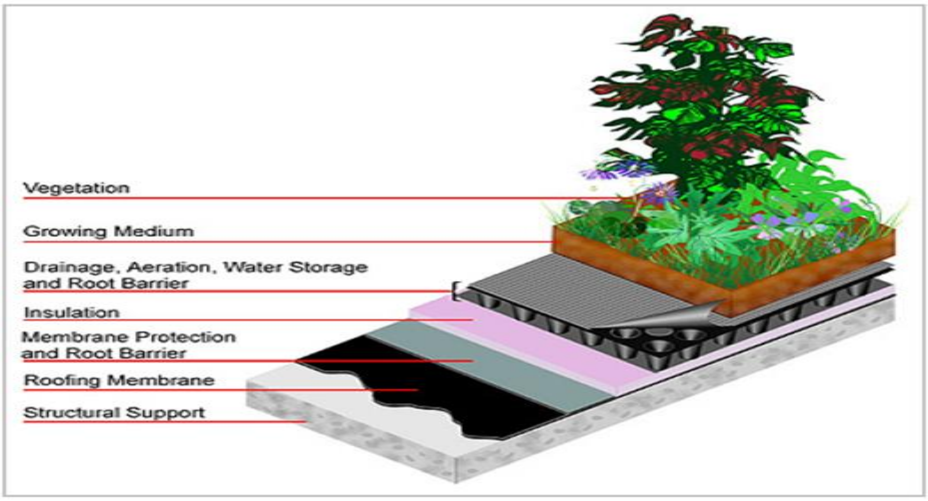

Fig.1 : Components of green roof

II. LITERATURE REVIEW

A healthy building can be defined which having sound designing and planning for heat, ventilation and air is conditioning. The improper design of illumination or ventilation leads to poor indoor air quality and may lead to serious health problem of habitants. John D. Spengler (1) studied the various rules and regulations that are to be followed for having good HVAC system. The IAQ factor needed and the present ventilation system is also specified. Further the study was done for changing construction material used and its effect in indoor air quality, emissions from surfaces and its potential harmfulness.

It is essential to quantify the Embodied Energy of House, depending upon the geographical location, material used and purpose of building the value of EEV changes.This evaluation of EEV is done for green building material by D.Bansal (2). Building envelop insulation is another approach for sustainability in housing is suggested by H. Agrawal (3). Building across the globe consumes 60 to 70 % of energy and building envelops contributes 75% of energy consumption out of it for heating and cooling effect .This huge amount of energy can be saved by insulating this envelops with provision of roof insulation, Brick bat coba , Tar felt membrane , mud Phuska technique , wall insulation techniques like double brick wall with cavity etc.Y.P.Kajale (4) suggested prefabrication of concrete elements as sustainable approach for future green construction. 3-s prefab for housing sector includes precaste RCC dense concrete slabs , autoclave light weight RCC slabs, floor and roof , light weight cellular building blocks , precast dense cement concrete columns , beams ,stairs , galvanized powder coated iron frames , door and windows etc. All this methodology leads to speedy, safe and strength construction practice. J.S.Chauhan (5) studied and presented various sustainable materials that can be used in buildings like solid concrete blocks fly ash mixed, hollow blocks, calcium silicate bricks and their adoptability in construction. K.D Sadhale , K.A.Sahakari & N.Dias (6) studied the use of precast technology for low cost housing.

B.W.Olesen,(7) conducted study of various International codes and found that the development of codes should be done on the basis of classes. O.Boccia,et.al (8) compared the experimental and numerical results for the natural ventilation and energy efficient design of window with the name ventilated illuminating .The numerical analysis considers steady state condition however, the simulation model benefited with dynamic mode consideration too.Alexander Kayne(9) carried out research work on computations fluid dynamics modeling of flows in buildings , as it has become matter of concern from last few decades. In 2009, buildings wee the second largest energy consuming sector in U.S, using upto 33.9% and 77.8% of electrical energy consumption. Similar work is done by A. Peri. Et,al.(10) by carrying simulation of various models with air flow and boundary parameter were designed and with concept of moving wall the thermal , air velocity pattern and graphs are obtained using CFD FLUENT simulation techniques so as to find most efficient ventilation design.

III.DESIGNING AND MODELING

Pitch green roof model in prepared. The model has dimension of 2*2*1 feet. In the model there are two sections within room, one having normal roof and other having green roof. The room area is 2*1 feet. A truss with sloping roof inclined to 35° act as supporting base. The model is built in the iron frame. Wall is made of asbestos or cement sheet. We provide two thermometers in the two sections, one for temperature observation under normal roof and another for green roof. The small gaps are filled with white cement for correct temperature reading. The model is kept in open surrounding and temperature is recorded with the help of thermometer. The temperature readings were taken at morning, noon and by the evening. The temperature in morning is normal temperature and in the noon is the peak value temperature obtained. The model is shown below:

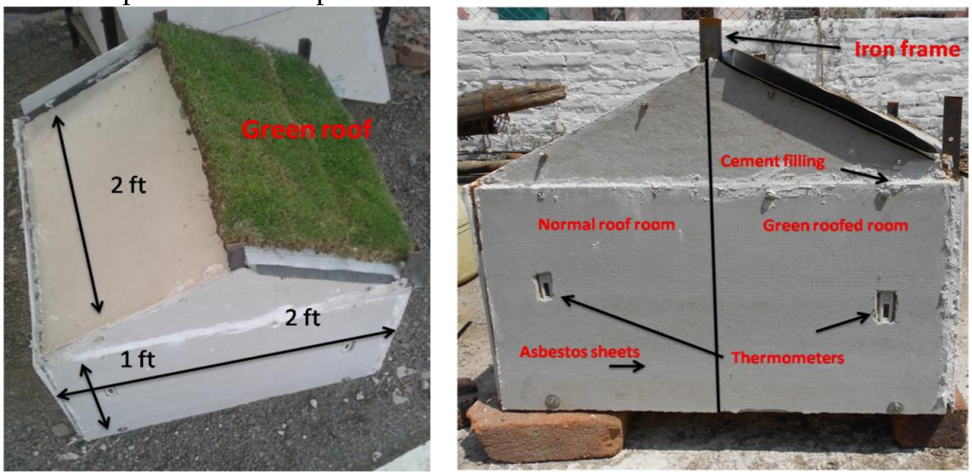

Fig. 2 - Green roof model

Various layers used in the green roof (Total Dept = approx. 50 mm)

1. Base cover layer (4 mm thick) - There is asbestos sheet fitted on the angle frame for structural support as shown in figure. It is main layer and carries all loads on it. Thermal Coefficient K= 0.245 $W/m^o c$.

2. Water proofing layer (2 mm thick) - The second layer is bituminous or tar coating which will not allow the water leakage in the roof. It acts as water proofing membrane. For provision of water proofing we use bituminous coating as shown in fig. Thermal Coefficient K= 0.17 W/m ^{o}c.
3. Root barrier and drainage provision (4mm thick) - For root barrier we use undulated AC sheet. The layer allows extra water to drain. The layer is fitted with gutter at the bottom as shown in figure. Thermal Coefficient K= 0.245 W/m ^{o}c.
4. Drainage Layer (20 mm thick) :-Provision of sand layer is made over AC sheet , so that excess of water can drain out easily though it. Thermal Coefficient K= 1.74 W/m ^{o}c.
5. Green layer (20 mm thick) - The topmost layer of the roof consisting of vegetation and soil. It only act as resisting medium and controls the temperature. It is shown in fig. Thermal Coefficient of soil, K= 0.73 W/m ^{o}c. Thermal Coefficient of vegetation K= 0.1 W/m^{o}c.

IV.OBSERVATION

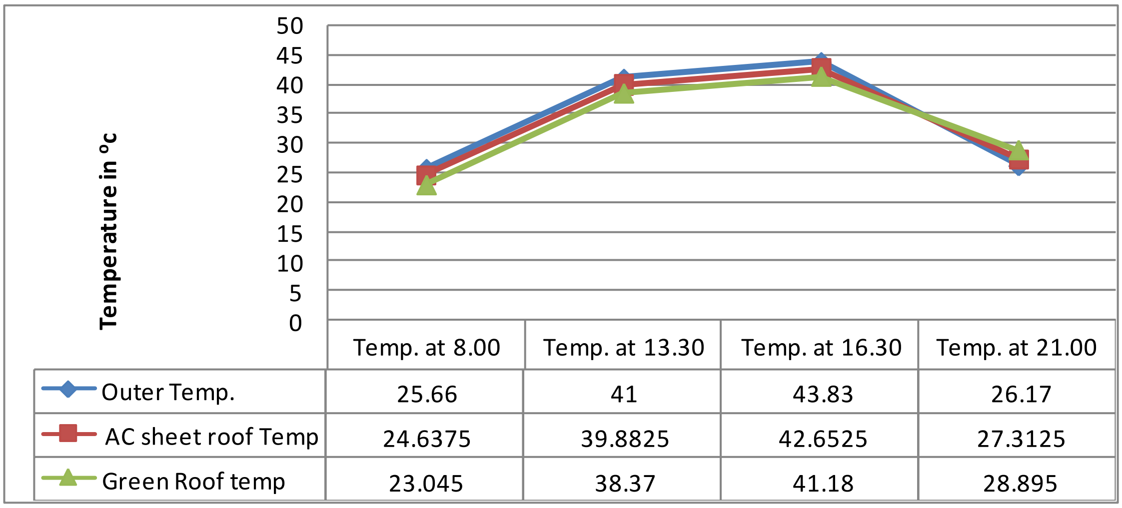

Fig 3 : Graph comparing temperature at different timing for outer and inner roof temp.

Model is being made with AC sheets and Green roof, however in practise green roof are suggested replacement for RCC slab. Thus, computational analysis and comparison for thermal parameters or heat is done for all three roofs namely:-

- AC sheet roof
- Green Roof.
- RCC roof

Table 1: Thermal Properties calculation considering mean thermal temperature values sets:-

Sr. no	Type of Roof	At time	I/OTemp. difference	Area (m^2)	L (m)	Resistivity)	Q (W)	q(W/m^2)
1	AC sheet Roof	8.00 a.m	1.023	0.147	0.004	0.11	9.20	62.628
	Green roof		2.615	0.147	0.05	1.15	2.266	15.418
2	AC sheet Roof	1.30 p.m	1.125	0.147	0.004	0.11	10.129	68.906
	Green roof		2.638	0.147	0.05	1.15	2.286	15.550
3	AC sheet Roof	4.30 p.m	1.185	0.147	0.004	0.11	10.669	72.581
	Green roof		2.658	0.147	0.05	1.15	2.303	15.668
4	AC sheet Roof	9.00 p.m	-1.14	0.147	0.004	0.11	-10.264	-69.825
	Green roof		-2.723	0.147	0.05	1.15	-2.360	-16.051

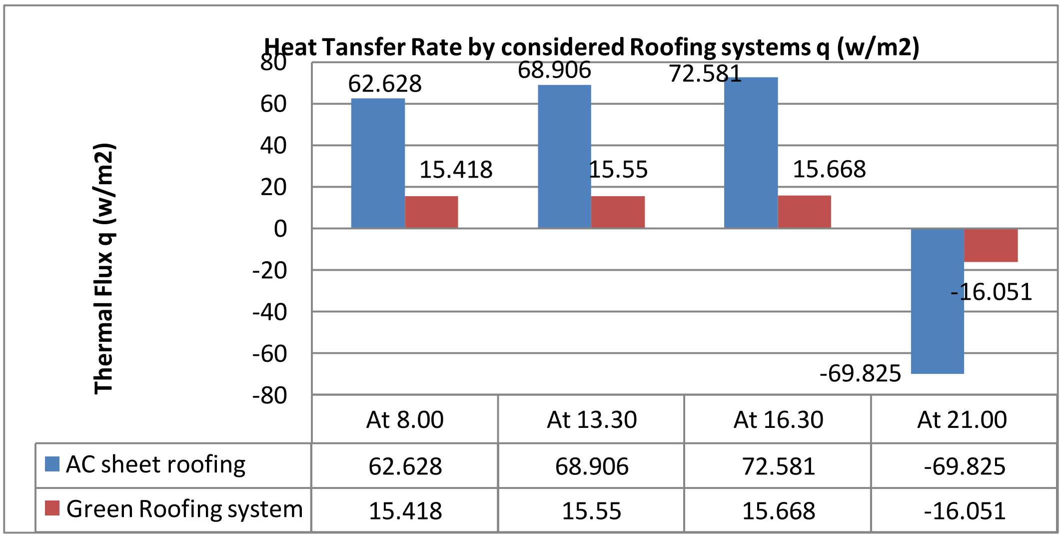

Fig 4 : Comparative chart showing Heat transfer rate for AC sheet and Green Roofing system.

From above information and calculation done it can be marked that max heat transfer rate is 72.581 w/m2 of AC sheet Roofing system where as that of Green roof is 15.62 w/m2 . This means that AC sheet roof system transmits heat more than 4 times that of Green roofing system.
In the model made, along with the roof covering, wall are also made up so as to avoid direct effect of outer air , thus the readings of temperature for inner sections are affected by heat transfer by that wall surface too, however both roofs were subjected to same surroundings and geometry thus , that part of error is common and can be neglected for comparison.

Comparison with RCC slab:-
Rate of thermal heat or flux is given as 'q= K. dt/L '. Thus it can be seen that 'q' is directly proportional to temperature difference 'dt' thus will increase with increase in difference and it is inversely proportional to resistivity 'R', thus more resistivity less will be heat transformation.
Set of Constants:-
Area of Slab:- 3.6*4.2 m2
Thickness of Green Roof = 0.05
Sample calculations for 1 °C I/O temperature difference.

Table 2: Equivalent RCC slab thermo effective design consideration and values :-

Material	Cond. k	Thick. L (m)	Area a(m^2)	Resistance of layer	Total Resistance	Temp. Diff.	Q (W)	q(W/m^2)
G.Roof 1	0.245	0.004	15.120	0.001	0.011	1.000	89.145	**5.896**
2	0.170	0.002	15.120	0.001				
3	0.245	0.004	15.120	0.001				
4	1.740	0.020	15.120	0.001				
5	0.730	0.010	15.120	0.001				
6	0.100	0.010	15.120	0.007				
Equivalent RCC slab								
1	1.580	0.267978	15.120	0.011	0.011	1.00	89.145	5.896

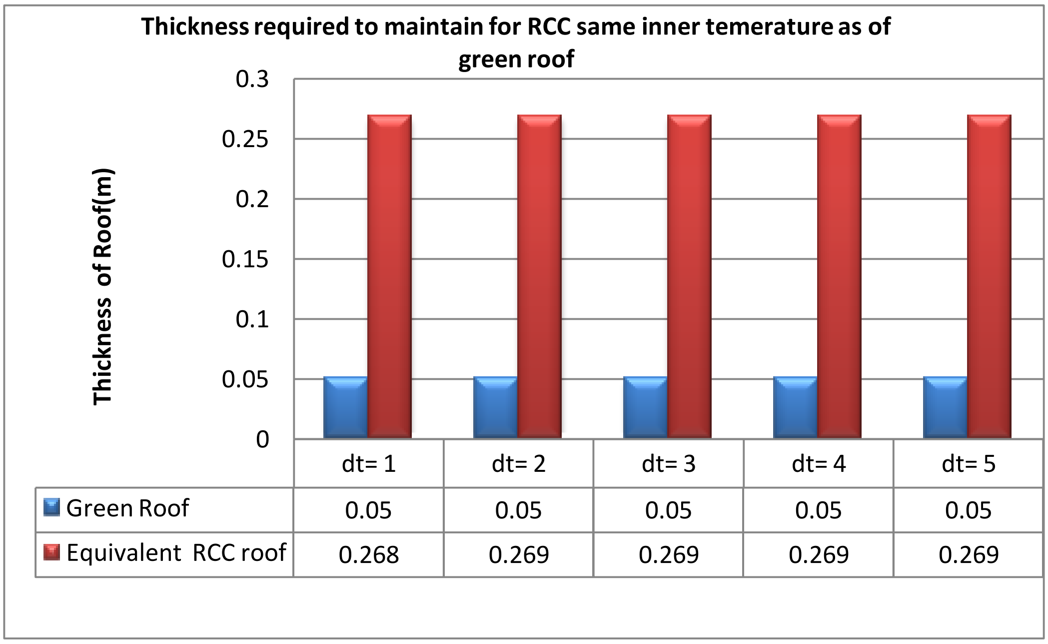

Fig 6. : Comparative chart showing Heat transfer rate for RCC slab and Green Roofing system.

From above considered case ,calculations and analysis it can be observed that the inner cooling done by providing 0.05 m thick green roof will be equivalently given by RCC slab of thickness 0.27 m. Along with that, further increase in this thickness defiantly increases the self weight of structure and thus, the safe design load considerations too.

V. ANSYS MODELING AND RESULT

1. Green Roof:

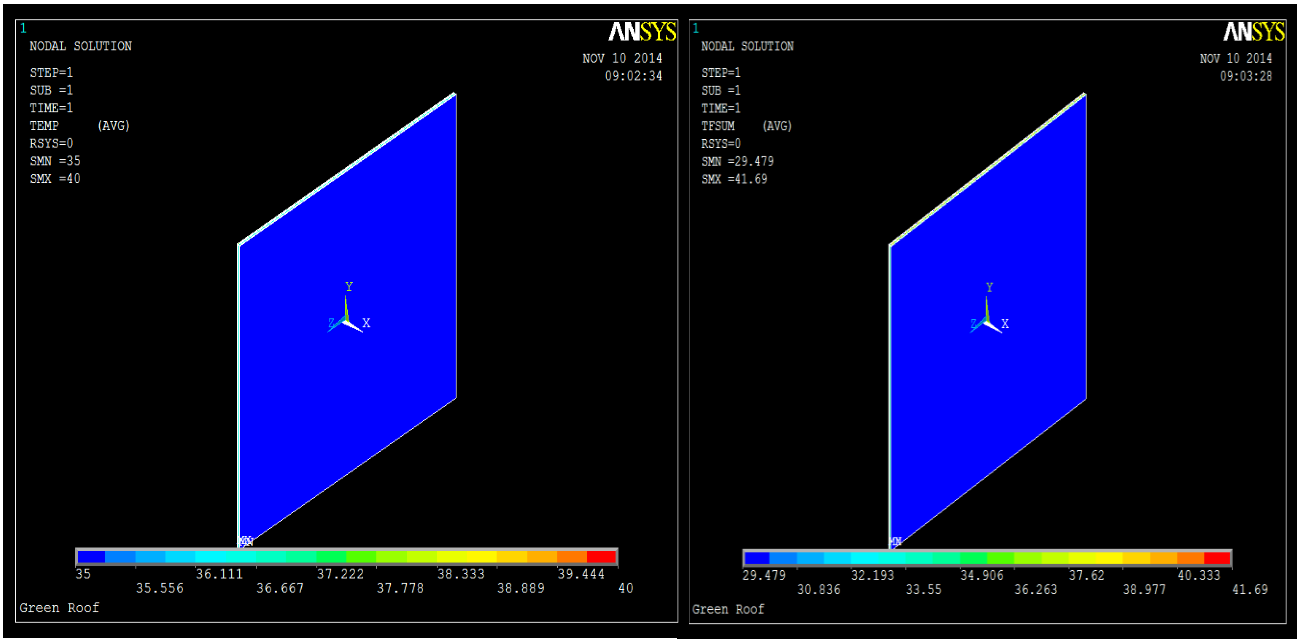

Fig 7. : a) Temperature Gradient in Green Roof b) Thermal Flux value Green Roof

2. Equivalent RCC Slab

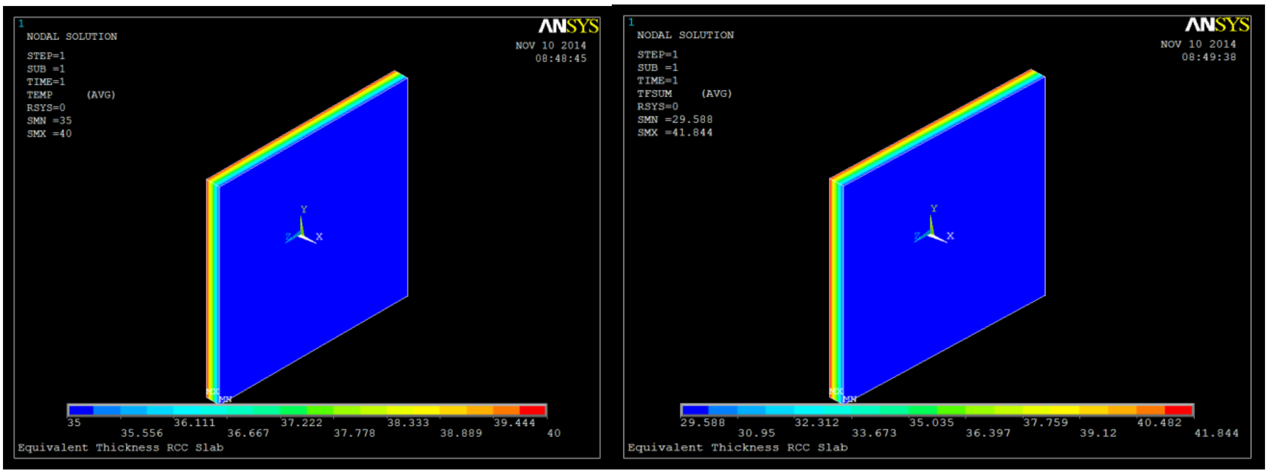

Fig 8. : a) Temperature Gradient in RCC roof. b) Thermal Flux value Green Roof

VI. CONCLUSION

The simulation modeling and analysis done using Ansys software clearly reflects the efficiency of green roofing system against thermal flux gradation and temperature reduction values in inner room space as compared to outer face. The calculations and simulations done for equivalent thermocooling effect using conventionally and commonly use material RCC and AC sheets shows that green roof of specified layers above of thickness 0.05 m is equivalent to 0.250 m of RCC roof. Perception for high installation cost and skilled maintenance requirement for green roofing system can be justified with its thermocooling effect and considerable decrease in operational energy consumption for thermal comfort of the building for its complete life span. Further , the alarming problems of green house gases, CO2 emission , urban heat islands necessitates the demand to adopt such alternative roofing system which will prove favorable and effective to mitigate such global issues of environmental problems.

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