© September 2021| IJIRT | Volume 8 Issue 4 | ISSN: 2349-6002

Impact of roof garden on Annual building cooling load

Viraj Purohit[1], Utsav Thakkar[2], Dhrumil Shah[3]
[1,2,3]*Civil Engineering, ITM Vocational University, India*

***Abstract* - Design builder simulation software was used to determine the effects of rooftop garden on annual energy consumption of cooling load of four-story commercial building in Ahmedabad. The thermal resistance of grass, Xps sheet, thermocrete were estimated using data from Software, and the effects on the building energy consumption of a roof garden with these methods were simulated. For roof garden different soil thickness on the building has been done & simulated. The results showed that the installation of roof garden on four story commercial building can results in saving of ₹ 1, 53,180in annual cooling load consumption, and garden was found to be the most effective in reducing building energy consumption. The results also revealed that the increase of soil thickness would further reduce the building energy consumption and the moisture content of soil can affect the outcome quite substantially.**

***Index Terms* - Design builder, Building Energy Consumption, Annual building cooling load, Urban heat island, terrace garden, xps sheet, thermocrete,**

1.INTRODUCTION

Urbanization has become a common feature of Indian society. Growth of Industries has contributed to the growth of cities. As a result of industrialization people have started moving towards the industrial areas in search of employment. This has resulted in the growth of towns and cities. Growth in buildings is effecting growth in number of roofs. Vast urbanization or aimless growth of cities may result in adverse effects like problem of over population, cost of living etc. All these lead to more energy consumption. Urbanization leads to Urban Heat Island phenomenon.

An UHI is a metropolitan area that is extremely warmer than its surrounding rural areas due to human activities. Many urban and sub urban areas doing lofty temperatures compared to their peripheral rural surroundings; this difference in temperature is what creates an urban heat island. Urban heat islands refer to the heavy temperatures in developed areas compared to more rural surroundings. UHI are caused by development and the changes in radiative and thermal properties of urban infrastructure as well as the impacts buildings can have on the local micro-climate for example tall buildings can slow the rate at which cities cool off at night.

Heat islands are fitted by a city‘s geographic location and by local weather adjustment, and their force changes on a daily and seasonal basis. UHI is a usual mode where urban temperatures are clearly greater than those of its enclosing suburban and rural areas in mid-summer time.

UHI can disturb a group by expanding summer time external temperature of building cowling and infrastructures; boosting thermal stiffness; promoting cooling energy use and carbon dioxide affixing air pollution; and erecting risks in heat associated fatality. A higher air temperature tends to enlarge cooling want and decrease working effectiveness of cooling systems to construct a environments, ensure a giant power call and energy use.

2.LITERATURE REVIEW

[1]They described about the Climate benefits like thermal insulation, Urban Heat Island (UHI) mitigation, avoided the emission of carbon dioxide and air pollutant, Co2 separation and removal in compact city of earth it is based on localized and experimental and modelling studies at IIT Delhi Campus.by five different scenario to reduce the Urban Heat island. They were evaluating the power consumption for space cooling and found that scenario 5 Bamboo-concrete composite (bam Crete) is more economical and effective to reduce the power consumption.[2]They described about the climate change intensify the heat islands effect, and lack of greenery in urban areas. This study compared the temperature reductions and heat amplitude reductions provided by four type of green roofing that can cover and bare rooftops. After resulting all the four plants the evaluation came out a perennial herbs more efficient

and has the highest magnitude of temperature reduction to bare the rooftop as compare to different plants.[3]These study assay the thermal properties and energy performance of the combination of green roof and night ventilation with making a model of office building. They conducted experiment into a three series first with and without night ventilation on summer and third was natural ventilation all day long on summer and rainy day. The assay shows that results while combining green roof and night ventilation can diminish the indoor air temperature and quality and heat procure on sunny day but have no effect on rainy day. [4] They develop innovative field-based analytical method to Quantify cooling energy saving resulting from the installation of cool roofs on commercial buildings. For building monitored in the Metropolitan Hyderabad region, the measured annual energy saving from roof whitening of previously black roofs ranged from 20 to 22 kW/h2 of roof area, corresponding to a cooling energy use reduction of 14-26%.[5] They compared insulating properties of green roofs and cool roofs. Results shows that cool roof combined with insulation provide great benefit in terms of Urban Heat Islands mitigation and energy transfer into building. The high the albedo of cool roof sustainability reduced net radiation, leaving less energy available at surface for sensible heating during the day.[6]They annualize the prospect with two comparisons (a) one with different types of roof (exposed roof, typical flat roof and rooftop garden with different level of vegetation-low, medium, high vegetation) and (b) the other comparison was made within the soil thickness on a rooftop. They annualize prospect with roof top and find the different R-values, K-values, U-values of rooftop with vegetation on the exposed roof and compare with rooftop garden with vegetation on the typical flat roof by considering turfing, shrubs and trees on both the condition. And they also measured the surface temperature at different points. 1st under the vegetation, 2ndunder the soil layer 3rd measured on soffit surface. They also tried the different species of plants and selected based on their density or leaf-area index.at the end the conclusion comes that installing the rooftop garden in a five-storey building could result in saving of 1-15% in the annual energy consumption and 17-79% in space cooling load while applying different thickness of soil (100-900 mm) they found that 1-3% of annual energy consumption and 2-64% in space cooling.[7]The two heat sources increase the temperatures of an urban area as compared to its surroundings, which is known as Urban Heat Island Intensity (UHII). The estimated three billion people living in the urban areas in the world are directly exposed to the problem, which will be increased significantly in the near future of UHI. [8]The result is searing summer nights, a drastic loss of insect and avian biodiversity, and a large increase in energy usage for interior climate control. The possibility of using recycled material as garden substrate was assessed; the effect of roof gardens on temperature variations below the roof was evaluated; and finally an assessment of whether enough water can be collected from air conditioner condensate to support a roof garden and whether the water is suitable for agriculture was performed. [9]Then a generic office building constructed with the green roofs was modelled using energy plus and its energy performance was evaluated under different future climatic conditions over future periods and two emission scenarios. [10]Heat transmission through the roof can be reduced by applying thermal insulation coating (TIC) on the roof and/or installing insulation under the roof of the attic. The experimental works were carried out indoors by using halogen light bulbs followed by comparison of the roof and attic temperatures.

3. DATA USED

3.1 Building Data

The present building study has been done for a 4 storied in Ahmedabad located in high dense urban shade of mega city Ahmedabad. Fig. 1(a) shows the Google image of the respective high dense urban shade in Ahmedabad along with the location of building.

The building has offices for commercial purpose. All the floors and rooms are fully air conditioned having fans for artificial ventilation. Fig (2) shows the respective schematic floor plan of building this building footprints were processed in design builder software. The floor wise detail of the air conditioned area of building are describe in Table-1 while in Table -2 it has been describe in detail the number of doors and window as well opening area of building. The door were of specified size 1.2 *2.1 m having wood has the construction material while the windows were of glass.

3.2 Meteorological Data

The site specific monthly meteorological data was available through energy plus, the monthly data for meteorological parameters i.e. dry bulb temperature, wind speed, wind direction relative humidity was used. The meteorological data was further used in design builder software.

3.3 Details of material used

The linchpin of the present research is to quantify the thermal performance (in terms of power consumption for cooling load and carbon production) of Terrace roof garden, XPS sheet and thermocrete. The salient aspects of this different methods are discussed below.

Terrace Roof Garden: -A Terrace Garden is the most idolize space of any Building. If given due consideration your terrace can be turned into your personal evacuation. A terrace design should involve more than just plain green grass or growing plants. From a viewpoint of terrace garden designers a lot of garden elements that can be incorporated into our terrace for a better space utilization and also for decreasing a cooling load of any Building. And which not very much costly as compared to other methods.

Xps Sheet: -A XPS sheet is also called as Extruded polystyrene (XPS) foam is a rigid insulation that's also formed with polystyrene polymer but manufactured using an extrusion process. The main pros of these method are durable, long term, and it can also stable the R- values so with greater R- values we can have cooling effect on the specified floor so there would be a decrease in cooling load of any building. but the main disadvantage of these method is if the temperature is above the 250° F will melt the polystyrene and also when the material is expose to sun it will Detroit the sheet.

Thermocrete:-The Theromocrete material is process in which the Water proofing material, fibre glass reinforcement, sand, cement, thermo coal balls and white cement are used. Initially, epoxy-based water proofing with fibre glass reinforcement is done over traditional RCC slab.

PCC bunds of 75mm height are prepared over water proofing in which thermo coal balls are filled. 25-40mm flooring is done with cement punning and white washing is done on a façade. then after simulating all these we would be stabilizing the R-values very well but there are very much corns in these method that the maintenance is more if the temperature is more than the thermos coal balls will be melt and the R-values will be more so that would give much more affect in cooling load of any building

4. METHODOLOGY

Fig.1 Represent the methodology adopted for the present study.

For the present study after preparing meteorological inputs in terms of monthly weather and basic building data in terms of building footprint, building material used and the other data such as maximum occupancy, average occupancy, for average occupancy the data has been procured from different offices of commercial building. From this detail the average occupancy of the people in the air conditioned room was computed. The working hours of building is from 9:00 AM to 8:00 PM were considered for simulating the energy consumption of building for the period of one year on a monthly basis. The good judgment of an energy building model is preferable for building actual data inputs to the BEM like (i) actual building data with the details of geometry and orientation (ii) realistic occupancy detail and working period of different offices. From the details given earlier in "Data use" seen that behavior of people using air conditioners, the present study represent this requirements.

To analyze the performance of model, comparison was done for exposed roof (Present condition) and Terrace roof garden, XPS sheet and Thermocrete for monthly building energy consumption for listed below methods from 01st January 2017 to 31st December 2017 was done. After validation of model, simulation was performed by changing the soil thickness and construction technique to see the impact of power consumption for commercial building. The present comparison for different soil thickness and different methods Scenarios were created which are frame in Table 1.

Table 1Different Material and Specifications

Scenarios	Material	Specifications
Scenario 1	Exposed Roof	6"inch thick rcc roof regularly made on usual bases
Scenario 2	Rooftop Garden	6"inch regular roof, waterproofing by china mosaic,100mm clay

		soil, clothing, drain board, 1*1 grass cubes
Scenario 3	Xps Sheet	6"inch regular roof, waterproofing by regular Indian style, xps sheet
Scenario 4	Thermocrete	6"inch regular roof, waterproofing by regular indian style, then thermo cool balls

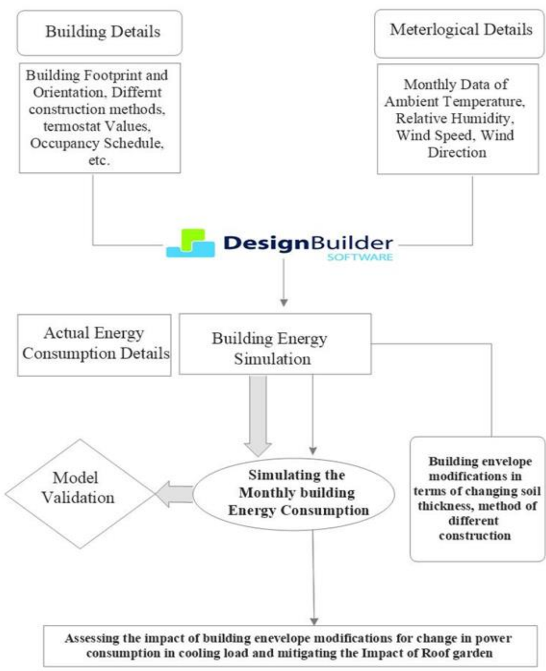

Figure 1 Methodology

Table 2Comparison of energy simulation results for different types of roofs.

Type of roofs	Annual Energy Consumption (MWh)
Exposed Roof	277.54
Rooftop Garden	244.61
Xps Sheet	244.90
Thermocrete	244.79

5.RESULTS AND DISCUSSION

5.1. Comparison of energy simulation results for different types of roofs.

A comparison between rooftop without Garden, rooftop covered with Garden and with Xps sheet, thermocrete for four story commercial building was carried out. Energy simulations were done for this commercial building with four types of roof and the simulation results are shown in table 2.

From this differentiation, it could be concluded that roofing material has a great impact on roof through heat transfer there is a large reduction in the energy consumption for different methods of roofs .the annual energy consumption has reduced by 32.98 MWH (11.98%) (Rooftop Garden) 32.74MWh (11.79%) (thermocrete) and 32.63MWH (11.75%) (Xps Sheet) for four story commercial building. The Reduction in annual building cooling load with the provision of rooftop garden on exposed roof shows that the cost of the building will decrease.

The simulation results shows that although the providing the rooftop garden and different methods would also results reduction in heat gain into the four-story commercial building, the reduction of heat done by the rooftop garden was more significant than other methods.

5.2 Comparison of energy simulation results for different soil thickness

A comparison of annual building cooling load between the different thicknesses of soil layer from 100 to 800 mm was carried out, and soil was taken as a clay soil with 30% moisture content were considered.

While comparing the different soil thickness we got a results as shown in table 3we found that while providing 100 mm soil thickness in roof top garden around 11.88% of reduction would be there comparing with not having rooftop garden now while providing 200 mm soil thickness around 6.35% of reduction would be there comparing with having 100mm soil thickness while for different thickness from 300mm to 800 mm around 0.01% of reduction is there comparing with 200mm soil thickness.

Table 3Comparison of energy simulation results for different soil thickness

Soil Thickness	Annual Energy consumption of cooling load (MWh)
100 mm	244.61
200 mm	244.55
300 mm	244.55
400 mm	244.54
500 mm	244.54
600 mm	244.53

700 mm	244.50
800 mm	244.52

The simulated results shows that an increase in soil thickness it would also results in reduction of energy when the soil thickness is increased and these is due to the higher thermal resistance of clay soil. With every 100mm increase of soil thickness thermal resistance of clay soil also increase by 0.633m2 K/W.

5.3 Comparison of cost of consumption

The annual energy cooling load consumption of the four story commercial building was converted into a specified unit to have a view in saving the installation of rooftop garden. The peak rate was IND₹4.50 was obtain from torrent power ltd was used for the calculations. The results shows in table 4 the simulated results shows that installation of rooftop garden on the exposed roof could results in saving upto IND₹ 1,48,164/ year.

Table 4 Comparison of cost of consumption

Types of roof	Annual energy consumption of cooling load (MWH)	Peak Rate (Rs/KWh)	Total Cost Consumption (Rs)	Saving (Rs)
Exposed roof	277.54	₹ 4.50	₹ 12,48,926	
Rooftop Garden	244.61	₹ 4.50	₹ 11,00,762	₹ 1,48,164
Xps Sheet	244.90	₹ 4.50	₹ 11,02,063	₹ 1,46,862
Thermocrete	244.79	₹ 4.50	₹ 11,01,565	₹ 1,47,361

The comparison also shows that the increasing the thickness of soil did not grant to the saving in the running cost. In the comparison for the rooftop garden with having different soil thickness, the saving were not much more. The topmost saving was IND ₹ 1,48,690in which the thickness of soil (30% moisture content) was 700mm total cost of consumption for different soil thickness on the roof of a four-story commercial building shows in table 5

5.4 Results of carbon production for different soil thickness

While having different soil thickness there would also be reduction in annual cooling load with that the carbon production also reduces from the building while not using very much of Air-condition through using the rooftop garden and from these also the we can save it to the money while converting it into the cost. The cost has been taken from the carbon credits 1 ton carbon reduction cost to 6 Euro if the is conversion is done in to INR we got a cost of ₹ 486 Rs/Ton shows in Table 6.

Table 5Comparison of total cost of consumption for different soil thickness on the roof of a four-story commercial building

Soil type	Thickness of soil	Annual energy consumption of cooling load (MWH)	Peak Rate (Rs/KWh)	Total Cost Consumption (Rs)	Saving (Rs)
No soil	0	277.539	₹ 4.50	₹ 12,48,926	
Clay Soil (30% moisture soil)	100	244.61	₹ 4.50	₹ 11,00,762	₹ 1,48,164
	200	244.55	₹ 4.50	₹ 11,00,492	₹ 1,48,434
	300	244.55	₹ 4.50	₹ 11,00,476	₹ 1,48,450
	400	244.54	₹ 4.50	₹ 11,00,452	₹ 1,48,474
	500	244.54	₹ 4.50	₹ 11,00,423	₹ 1,48,502
	600	244.53	₹ 4.50	₹ 11,00,404	₹ 1,48,521
	700	244.50	₹ 4.50	₹ 11,00,236	₹ 1,48,690
	800	244.52	₹ 4.50	₹ 11,00,352	₹ 1,48,574

Table 6Results of carbon production for different soil thickness

Soil type	Thickness of soil	Annual carbon production through A-C (Ton)	Peak Rate (Rs/Ton)	Total Cost Consumption (Rs)	Saving (Rs)
No soil	0	235.65	₹ 486.00	₹ 1,14,526	
Clay Soil (30% moisture soil)	100	225.32	₹ 486.00	₹ 1,09,506	₹ 5,020
	200	226.99	₹ 486.00	₹ 1,10,319	₹ 4,207
	300	226.99	₹ 486.00	₹ 1,10,318	₹ 4,208
	400	226.99	₹ 486.00	₹ 1,10,316	₹ 4,210
	500	226.98	₹ 486.00	₹ 1,10,314	₹ 4,212
	600	226.98	₹ 486.00	₹ 1,10,313	₹ 4,213
	700	226.96	₹ 486.00	₹ 1,10,302	₹ 4,224
	800	226.97	₹ 486.00	₹ 1,10,310	₹ 4,216

6.CONCLUSION

1. In India, urbanized population is taking is going very fast day by day. Cities are giving major role for high energy consumption. The high theusage of coal will causing more CO2 level in the environment. In the multi-story buildings, the thermal comfort has is going high by high every day sever problem for top high-rise buildings. So, the introduction of roof garden is needed to address the global climate problem from low level.
2. After analysis the experimental data; it is seen that during summer we can attain up to 4°C indoor temperature reduction will be there compared to the ambient temperature by using design builder software for analyze of roof technologies.
3. This study shows that the rooftop garden for a four-story commercial building would outcome in saving of 11-18% of yearly energy consumption of cooling load. The study shows that maximum saving of 2-64% on cooling load would be obtain by providing different soil thickness from 100mm to 800mm.
4. In terms of cost saving up to ₹ 1,53,180 per year in total cost of annual cooling load of four-story commercial building

7REFERENCES

[1] A. Kandya and M. Mohan, “Mitigating the Urban Heat Island effect through building envelope modifications,” Energy Build., vol. 164, pp. 266–277, 2018.

[2] Y. Y. Huang, C. T. Chen, and W. T. Liu, “Thermal performance of extensive green roofs in a subtropical metropolitan area,” Energy Build., vol. 159, pp. 39–53, 2018.

[3] L. Jiang and M. Tang, “Thermal analysis of extensive green roofs combined with night ventilation for space cooling,” Energy Build., vol. 156, pp. 238–249, 2017.

[4] T. Xu, J. Sathaye, H. Akbari, V. Garg, and S. Tetali, “Quantifying the direct benefits of cool roofs in an urban setting: Reduced cooling energy use and lowered greenhouse gas emissions,” Build. Environ., vol. 48, no. 1, pp. 1–6, 2012.

[5] A. M. Coutts, E. Daly, J. Beringer, and N. J. Tapper, “Assessing practical measures to reduce urban heat: Green and cool roofs,” Build. Environ., vol. 70, pp. 266–276, 2013.

[6] N. H. Wong, D. K. W. Cheong, H. Yan, J. Soh, C. L. Ong, and A. Sia, “The effects of rooftop garden on energy consumption of a commercial building in Singapore,” Energy Build., vol. 35, no. 4, pp. 353–364, 2003.

[7] A. M. RIZWAN, L. Y. C. DENNIS, and C. LIU, “A review on the generation, determination and mitigation of Urban Heat Island,” J. Environ. Sci., vol. 20, no. 1, pp. 120–128, 2008.

[8] L. Sisco, S. Monzer, N. Farajalla, I. Bashour, and I. P. Saoud, “Roof top gardens as a means to use recycled waste and A/C condensate and reduce temperature variation in buildings,” Build. Environ., vol. 117, pp. 127–134, 2017.

[9] A. L. S. Chan and T. T. Chow, "Energy and economic performance of green roof system under future climatic conditions in Hong Kong," Energy Build., vol. 64, pp. 182–198, 2013.

[10] M. C. Yew, N. H. Ramli Sulong, W. T. Chong, S. C. Poh, B. C. Ang, and K. H. Tan, "Integration of thermal insulation coating and moving-air-cavity in a cool roof system for attic temperature reduction," Energy Convers. Manag., vol. 75, pp. 241–248, 2013.