ISSN 2229-5518

The Energy Consumption Performance of Roof Garden

Shailendra Kasera, Ashish Nayyar, Dr. Dilip Sharma

Abstract—Green roofs are a passive cooling technique that stops incoming solar radiation from reaching the building structure below. Many studies have been conducted over the past 10 years to consider the potential building energy benefits of green roofs and shown that they can offer benefits in winter heating reduction as well as summer cooling.

Statistics have confirmed that a lawn placed on a roof top can reduce the cooling load. In this study, the eQUEST energy simulation program was used to determine the effects of roof gardens on the annual energy required for cooling, and annual electrical usage in a computer based model. In this case study two different cases were considered first one of only roof garden, later with 2inch XPS (Extended Polystyrene). It has been found that 3.79% of cooling load can be reduced by best case.

Index Terms—Green Roof, Building Energy Simulation, eQUEST, Energy Saving

———————————— ◆ ————————————

1 INTRODUCTION

A green roof is a roof that contains a soil (growing media) and vegetation layer as its outermost surface. Green roofs have been recognized as a great means of removing heat from the air through evapotranspiration of the plants, which leads to a reduction of the temperatures of the roof surface and the surrounding air.[1] The roof of a building can be fully or part covered with a layer of vegetation known as a green roof. A green roof is a layered system comprising of a waterproofing membrane, growing medium and the vegetation layer itself. Green roofs often also include a root barrier layer, drainage layer and, where the climate necessitates, an irrigation system.[2]

Environmental problems, especially in urban areas, have become a serious issue. The increasing numbers of buildings in cities causes a loss of green areas, resulting in the Urban Heat Island effect (UHI), which makes temperatures increase and causes uncomfortable conditions for human living. The reduction of heat coming into buildings is very important with respect to thermal comfort and saving energy. Thus the need for vegetation in urban areas is increasing.[3]

- *Mr. Shailendra Kasera is Research Scholar, Dept. of Mech. Engg at Poornima College of Engineering Jaipur, India*
- *Mr. Ashish Nayyar is Associate Professor, Dept. of Mech. Engg at Swami Keshvanand Institute of Engineering, Technology, Management & Gramothan, Jaipur, India*
- *Dr. Dilip Sharma is Associate Professor, Dept. of Mech. Engg at Malviya National Institute of Technology Jaipur, India*

2 BUILDING ENERGY BENEFITS

Buildings account for around half of primary energy consumption, hence CO_2 emissions. A large proportion of this energy is used to maintain internal building temperatures through heating and cooling systems. This section of the report will therefore address the potential building energy reduction benefits arising from the enhanced thermal properties of a green roof.[4]

2.1 Reduction of Heat Flux and Solar Reflectivity

In summer the exposed area of a black roof can reach 70-80 ◦C when the equivalent area beneath a green roof is only 27 -30◦C. Green roofs cool through latent heat loss and improved reflectivity of incident solar radiation. The ratio of total reflected to incident electromagnetic radiation is defined as albedo. Green roofs cool as effectively as the brightest possible white roofs, with an equivalent albedo of 0.7–0.85, compared with the typical 0.1–0.2.[4,5]

The hard ground reradiated the stored heat, increasing the ambient air temperature. However, planted roofs suffered less heat gain during the day. By measuring the air temperature at various heights above the green roof it was found that after sunset the ambient air temperature above the vegetation was reduced significantly and continued to cool the ambient air throughout the night.

ISSN 2229-5518

2.2 Thermal Mass

The addition of a green roof can improve the insulation properties of a building, that' why annual energy consumption can be reduced. Not only does the roof act to reduce the heat loss from the building in winter and heat gain into the building in summer, it also adds thermal mass to help stabilize internal temperatures year round. Many studies exist that assess the potential energy savings of green roofs when added to buildings. This suggests that green roofs are predominately seen as a passive cooling technique, rather than as a thermal insulator in the winter. Potential winter heating savings have however been investigated, although not to the extent of summer cooling.

2.3 Local Temperature Effect on Air Conditioning

Air conditioners cool interior spaces by discharging heat to outside. This process therefore raises the surrounding temperature and even costs of neighboring air conditioning as HVAC efficiencies depend on input air temperature. The lack of heat build up on a green roof has therefore been suggested to increase the efficiency of air-cooling and ventilation systems. A free cooling system, which can be incorporated into a conventional chiller, can reduce energy consumption when cooling a building. Free cooling can operate when the ambient (outside) temperature falls 1 ◦C below the cooling fluid returning to the chiller. The cold outside air is then used to further cool this returning fluid, replacing the need for electrical input. Free cooling is most useful for cooling in office buildings in autumn/spring when there are lower external temperatures, but still high internal heat gains from occupants and equipment. It can be deduced that the local cooling effect of a green roof could therefore enable free cooling to operate for a greater proportion of the year, harnessing further energy savings.[6]

3. METHODOLOGY

3.1 Building Energy Modeling

eQUEST was chosen for this study because of its comprehensive yet very easy-to-use features and interface. eQuest's simulation engine is derived from the latest version of DOE-2, one of the most widely recognized and respected building energy analysis program in use today.

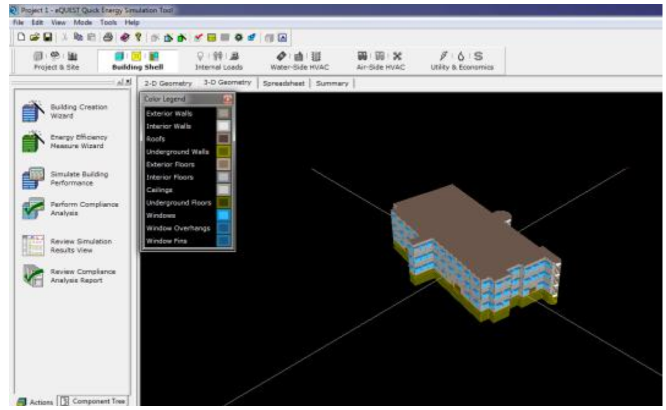

Fig. 3.1 Modeling of Building

The key to optimized energy performance is use of an accurate, detailed building energy model. eQUEST allows quick construction of building energy models with options that allow the level of detail to evolve with the design. The model includes a graphical interface that allows a quick visual check of the building geometry and also HVAC system arrangements.

3.2 Building Details

The experiment model consists of a 250000 sq ft of institutional building. This multi storey building has three floors above the grade and one below. Floor to floor height is 13 ft and floor to ceiling height is 10 ft. Construction of roof surface is of 8 inch concrete along with light and no insulation. Similarly brick with white plaster is used as a construction material for above grade wall. Maximum no of door 12 is in west direction while no door at south direction. North and east is occupied with 2 and 6 no. of doors respectively. The dimension of the door is 7 X 4 ft. 35 % of window is retrofitted at south and west direction of dimension 7 X 6 inch with 3 mm clear glass.

4. CASE STUDY OF GREEN ROOF

4.1 Case 1: Without Green Roof

U value: 0.439 Btu/h- ft^2-°F

TABLE 4.1

ENERGY CONSUMPTION WITHOUT GREEN ROOF (KWH X 000)

	Jan	Feb	Mar	Apr	May	Jun
Space Cool	0	0	4.32	8.43	2.18	2.18
	Jul	Aug	Sep	Oct	Nov	Dec

	8.06	9.3	7.46	7.41	0	0
	Total		49.34			

kWh x 000

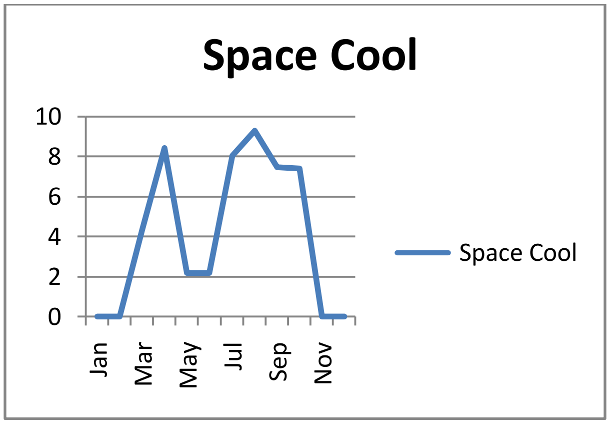

Fig. 4.1 Energy Consumption without Green Roof (kWh x 000)

4.2 Case 2: Roof Garden

U Value: 0.135 Btu/h- ft^2-^{o}F

TABLE 4.2
ENERGY CONSUMPTION WITH GREEN ROOF (KWH X 000)

Space Cool	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
	0	0	4.28	8.37	2.14	2.14
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	8	8.96	7.44	7.38	0	0
	Total		48.71			

kWh x 000

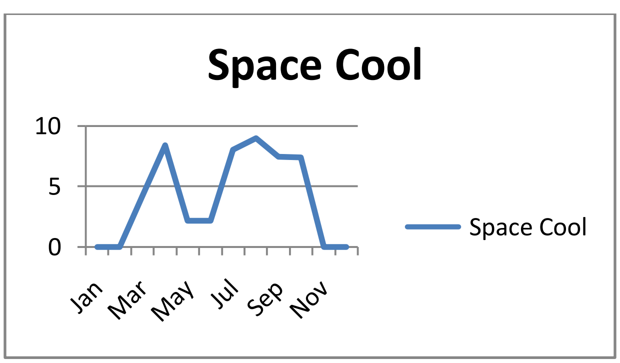

Fig 4.2 Energy Consumption with Green Roof (kWh x 000)

4.3 Case 3: Roof Garden with 2 inch XPS (Extended Polystyrene)

U Value: 0.057 Btu/h- ft^2-^{o}F

TABLE 4.3
ENERGY CONSUMPTION WITH GREEN ROOF+ 2 INCH XPS (KWH X 000)

Space Cool	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
	0	0	4.26	8.35	2.12	2.12
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	7.96	8.92	7.41	7.34	0	0
	Total		48.48			

kWh X 000

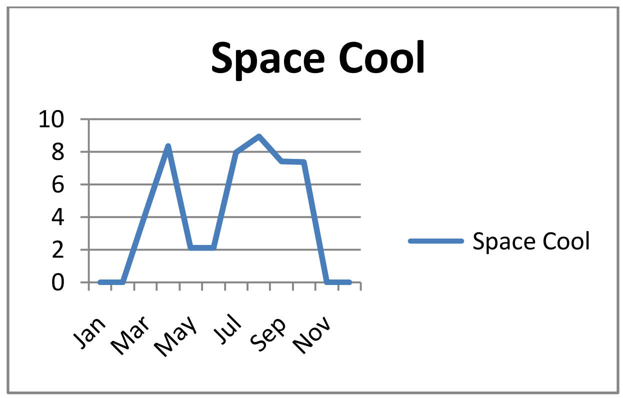

Fig 4.3 Energy Consumption with Green Roof+ 2 inch XPS (kWh x 000)

4.4 Comparison of Types of Roofs

TABLE 4.4
COMPARISON OF ENERGY CONSUMPTION (KWH X 000)

Annual Energy Consumption (kWh x 000)	**Base Case**	**Green Roof**	**Green Roof + 2 In XPS**
	49.34	47.77	47.47

ISSN 2229-5518

kWh x 000

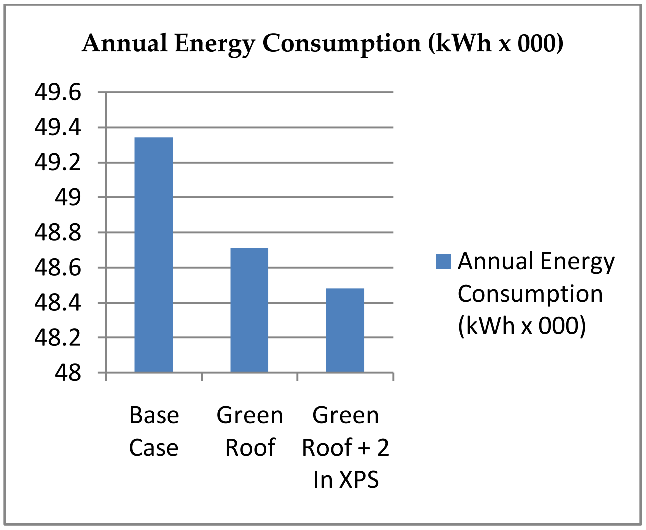

Fig 4.4 Comparison of Energy Consumption (kWh x 000)

kWh x 000

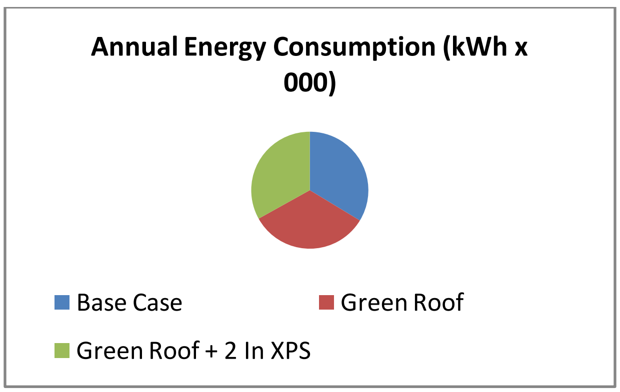

Fig 4.5 Annual Energy Consumption (kWh x 000)

5. Discussions

Enormous use of ground for various purposes has lead to disappearance of green planted surfaces. In order to prevent dangerous and uncomfortable urban heat island effects the indispensable need of planted surfaces is quiet inevitable as is confirmed by many researchers viz. Space constraints have further reduced the applicability of green surfaces in various areas surrounding the building envelope. Consequently, planted roofs become the only promising and stabilizing choice in the present scenario.

Good thermal protection can greatly reduce the high thermal loads that badly affect the comfort conditioning of building during summers. Planted roofs contribute not only in reducing the thermal loads on the building's shell but also in reducing urban heat island effects in densely built areas having a little natural environment. It has described the cooling energy potential of shade trees by reduction of the local ambient temperature.[7]

References

[1] D.J. Sailor, A green roof model for building energy simulation programs, Journal of Energy and Buildings 40 (2008) 1466–1478

[2] Georgios Kokogiannakis, Annegret Tietje, Jo Darkwa;, The role of Green Roofs on Reducing Heating and Cooling Loads: a Database across Chinese Climates, Procedia Environmental Sciences 11 (2011) 604 – 610

[3] Sittipong Permpituck, Pichai Namprakai, The energy consumption performance of roof lawn gardens in Thailand, Journal of Renewable Energy 40 (2012) 98-103

[4] H.F. Castleton, V. Stovin, S.B.M. Beck, J.B. Davison, Green roofs; building energy savings and the potential for retrofit, Journal of Energy and Buildings 42 (2010) 1582–1591

[5] Rakesh Kumar, S.C. Kaushik, Performance evaluation of green roof and shading for thermal protection of buildings, Journal of Building and Environment 40 (2005) 1505–1511

[6] Fabricio Bianchini, Kasun Hewage, How "green" are the green roofs? Lifecycle analysis of green roof materials, Journal of Building and Environment 48 (2012) 57-65

[7] Issa Jaffal, Salah-Eddine Ouldboukhitine, Rafik Belarbi, A comprehensive study of the impact of green roofs on building energy performance, Journal of Renewable Energy 43 (2012) 157-164