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Comparative Energy Analysis of Vegetative Flat Roof, Cool Flat Roof and Standard Flat Roof in a Office building at Nagpur, India

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Abstract: ***Vegetative roofs are a passive cooling technique that stop incoming solar radiation from reaching the buildingstructure below.In particular, the roofs of buildings have been identified as a possible field of intervention that could contribute to provide significant energy savings and environmental benefits. This paper deals with the comparativeenergy analysis for an office space in Nagpur, Maharashtra. As in the current scenario the reductionof energy demand for space cooling, requires adequate solutions at building level and urban scale.***

Keywords: Vegetative Roofs, Solar Radiation, Energy, Office Space

1. Introduction

The roofs of buildings have been identified as a possible field of intervention that could contribute to provide significant energy savings and environmental benefits. The roof of a building can be fully or partly be covered with a layer of vegetation known as a green roof or vegetative roof. A green roof is a layered system comprising of a waterproofing membrane, growing medium and the vegetation layer itself.

A green roof offers a building and its surrounding environment many benefits. These include stormwater management, improved water run-off quality, improved urban air quality, extension of roof life and a reduction of the urban heat island effect.In summer the solar radiation that hits a roof causes the increase of the outer surface temperature by several degrees generating need for provision of cooling to enhance the overall energy consumption requirements.

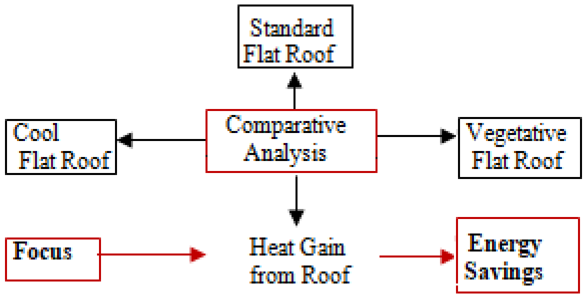
One of the most adopted strategy to reduce the heating and cooling loads of buildings is the increase of the thermal insulation of the envelope components, including the roofs.A comparative study was done to analyze the discrete amount of electrical energy required to attain desired cooling in an office space.

2. Methodology

Quantitative information from measurements or simulations of heat gain from vegetative, cool and standard flat roof is very useful to analyze the performance and energy required to maintain the indoor air temperature in design. The comparative study helps in understanding and promoting the use of vegetative roofs instead of standard flat roofs. The qualitative and quantitative data comprising of type and thickness of vegetative layer, thermal insulation are considered with reference to specified standards and literature reviewed papers.

3. Focus of the Paper

The paper focuses on comparison between electrical energy consumed to achieve stipulated indoor air temperatures and reduce the overall cooling load demands of a building by adopting alternative thermal insulation methods for a roof, rather than having a standard conventional flat roof.



4. Heat Gain from Roofs

Heat gains and heat losses through building surfaces are the main factors that determine the building's cooling and heating loads. The more solar radiation received in the surface area of building fabric (roof, walls, windows, and floor), the more heat gains will be produced. Roof as a building surface that has the most exposed area to the sun, contribute most of heat gains in the building. Therefore, the amount of solar heat gains received by roof need to be minimized by combining the possibility of roof structure. The impact the roof has on energy use depends on the climate, the orientation of the roof, the thickness and quality of insulation, the reflectivity of the roof's surface, and how well the roof has been maintained.

5. Vegetative Flat Roof

A vegetative or green roof consists of a vegetation cover on top of a roofsurface. The two types of green roofs are generally identified: extensive green roofs, whose soil thickness is below 15 cm, andintensive green roofs, with a soil thickness above 20 cm. The energy balance of a green roof is governed by radiant and convective heat exchange, evapotranspiration from soil and plants, evaporation/ condensation of water vapor, as well as heat conduction and storage in the soil layer. Generally, a green roof is subdivided into three main layers for modeling its energy balance: structural support, soil and canopy (leaf cover).

The soil component contains a solid phase (mineral and organic material), a liquid phase (water) and a gaseous phase (air and water vapour). The canopy is composed by the leaves and the air within the leaf cover. The height of the plants and the leaf area index, which is the total one-sided area of leaf tissue per unit ground surface area, are two of the fundamental characteristics of the canopy. Other characteristic parameters are the emissivity, the reflectivity, the absorptance and the transmissivity of the leaves, and the minimum stomatal resistance, which governs the flow of water vapor through the stomates.The evaporation from the ground surface and the evapotranspiration from the vegetation layer strongly depend on the moisture content of the soil layer.

Vegetative roofs greatly reduce the proportion of solar radiation that reaches the roof structure beneath as well as offering additional insulation value.

6. Cool Flat Roof

A cool roof is substantially a roof with a highly reflective material (cool material) on its outermost surface. Cool materials are characterized by high values of solar reflectance, whichstrongly reduces the amount of solar radiation absorbed by the roof outer layer. Furthermore, cool roofs are also characterized by high infrared emissivity, which contributes to dissipate the heat accumulated during the day through an intensive radiant heat exchange at night .A wide range of cool materials is commercialized: paints, coatings, membranes, tiles and pre-painted steel panels .Cool roofs usually show lower values of the surface temperature if compared with a traditional roof, and they reduce the roof daily heat gain.

Cool flat roofs and standard flat roofs mainly differ for their surface reflectivity.The upper surface of the roof,assumed as a gray body, is exposed to the following thermal fluxes: incident short-wave radiation from the sun, long-wave radiation exchanged with the sky, convective heat exchange with the outside environment and heat exchange with the indoor environment.

7. Application Case

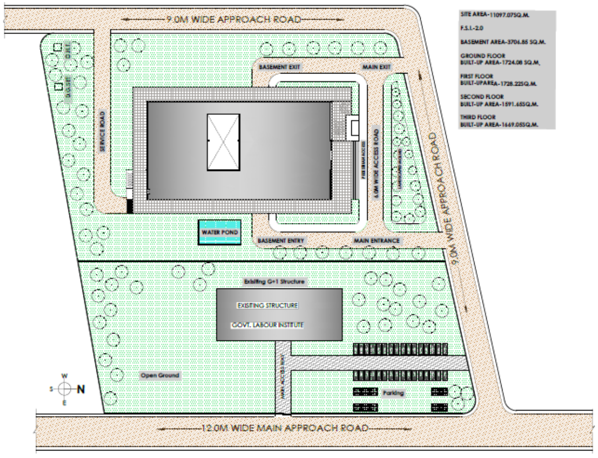


Figure 1: Base Case for Simulation

The base case used for comparative simulation is the above depicted office space, the office is located in Nagpur lying in the state Maharashtra in India having 1724 sq. floor area and the same case has been considered for all the three genre.The geographic coordinates of Nagpur are Latitude: 21.15 and Longitude:79.08.

8. Simulation Software

The software used for conducting simulations in order to access heat gain from roof on the energy parameter was design builder.The Application of Design Builder includes Building Energy Simulation,Visualization,Internal Heat Gains,Solar Shading, Natural Ventilation, Hourly Weather Data,Heating and Cooling, Equipment Sizing and Daylight Simulation. It operates on self-simulation engine.

9. Base Case Results

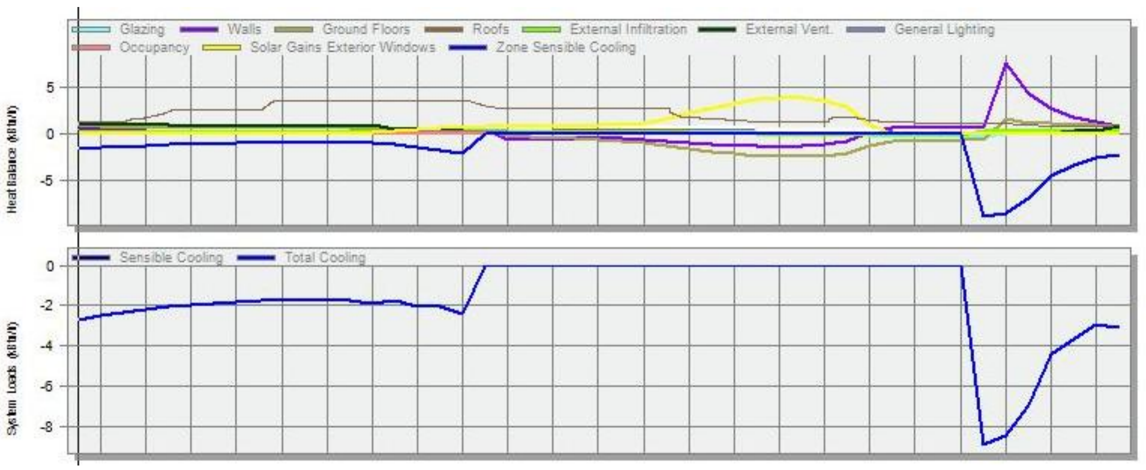


Figure 2: Energy Requirements for Cooling Using Standard Flat Roof

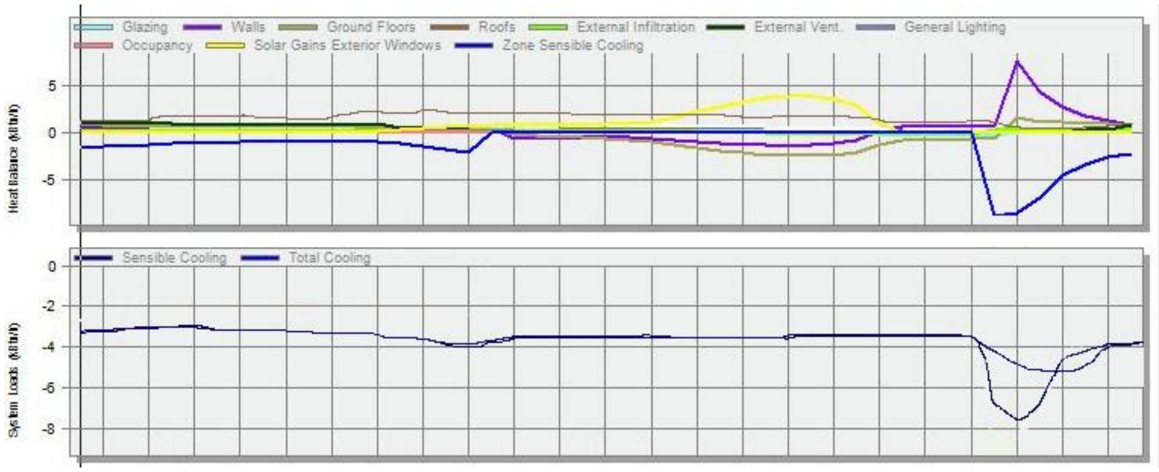


Figure 3: Energy Requirements for Cooling Using Cool Flat Roof

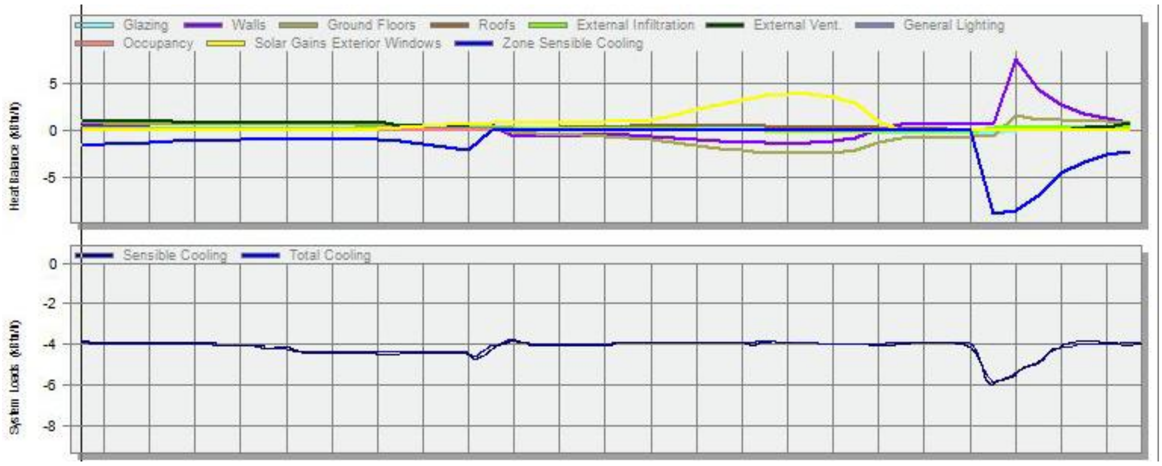


Figure 4: Energy Requirements for Cooling Using Vegetative Flat Roof

10. Simulation Analysis

In Fig.2.Simulation Analysis for Roof Gains from Standard Flat Roof, The light-brown band depicts the general heat gains from the roof and the graph below with the blue band depicts the cooling requirement for the office space.

In Fig.3.Simulation Analysis for Roof Gains from Cool Flat Roof, The light-brown band depicting the general heat gains from the roof can be seen posing reduction in the overall gains and the graph below with the blue band depicts the cooling requirement which is further lower than a standard roof.

In Fig.4.Simulation Analysis for Roof Gains from Vegetative Flat Roof, The light-brown band is optimum depicting the diminished amount of heat gain. This is further aiding in optimizing the overall energy consumption requirements for cooling the office space.

11. Conclusion

The work presented in this paper aimed to contribute the understanding of the energy requirements for adopting different approach for flat roof structures. The simulation results depict that vegetative roofs prove to be the most effective technique used within the flat roofs to reduce the energy requirements for cooling the built-space. The cooling load requirement can be seen maximum in the standard untreated concrete flat roof, while it can be seen diminished by 30 percent within cool flat roof and further reduced in the vegetative flat roofs. Hence, the vegetative flat roofs aid in optimizing the energy requirements and enhance the thermal mass.

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