

Green Roof System

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Abstract - Urbanization has promoted fast urbanization with high surface temperature, stormwater runoff, and consumption of energy in cities. Traditional concrete roofs trap too much heat and also contribute to urban heat island effect. This paper is directed towards the design and analysis of a Green Roof System as a green solution to the present-day buildings. The system comprises of several layers such as waterproof membrane, drainage layer, filter fabric, light weight growing medium, and appropriate vegetation.

The approach was site selection, structural load analysis, selection of materials and plants selection, and performance testing. It was observed that the green roof had lower surface temperatures than a normal roof, and stored more rainwater that otherwise would have been washed away in rainfall. Structural safety and adequate conditions of growth of the plants were checked by soil and load checks.

The findings show that the green roofs have a beneficial effect on the thermal insulation, energy consumption, air quality, and environmental sustainability. That is why green roof systems can be regarded as a solution to environmental-friendly and sustainable urban development.

Key Words: Green Roof System, Urban Heat Island, Stormwater Management, Thermal Insulation, Sustainable Development

1. INTRODUCTION

The process of rapid urbanization has changed the natural landscapes greatly as the permeable soil surfaces are replaced with concrete buildings and impervious surfaces. The change has led to the

rising surface temperature, storm water runoffs and the energy used in buildings is on the rise. The Urban Heat Island (UHI) phenomenon is one of the most significant environmental impacts of urbanization where cities will have a higher temperature compared to rural areas because of the construction materials being used to absorb heat. Traditional concrete roof systems are significant contributors of heat, as they absorb and retain the solar radiation throughout the day and absorb it gradually, therefore, raising the temperatures indoors and elevating heating energy requirements. Furthermore, the conventional roof constructions fail in terms of supporting precipitation, thereby straining the city drainage systems during excessive rain. Green Roof Systems has come up to provide solutions to such problems because it is both sustainable and environmental friendly. A green roof is composed of several fabricated layers such as waterproof membrane, root barrier, drainage layer, filter cloth, lightweight growing soil and plants. Fig. 1.1 illustrates the materials used in the current study and consists of drainage cells, geotextile filter fabric, growing material and irrigation pipe as well as selected vegetation. All the parts are very essential in maintaining structural protection, water treatment and plant development. The given study is devoted to the design and performance analysis of a Green Roof System aimed at determining its effectiveness in terms of thermal insulation, stormwater runoff decrease and sustainable urban development.

2. LITERATURE SURVEY

In the article, Thermal Performance of Green Roofs in Hot Arid Climates (El Menchawy et al., 2025), the authors examined how the intensive and extensive application of green roofing affects the thermal comfort of the interiors of educational

institutions. The parameters that the study examined, using simulation tools and climatic data in desert areas, included surface temperature, heat flux, humidity, or Predicted Mean Vote (PMV). The findings indicated that intensive green roofs with high substrate depth had a serious effect on the reduction of the surface temperature of the roof and enhanced the thermal comfort relative to the traditional roofs.

Green roofs have been assessed through the environmental lens in the paper Green Roofs as Nature-Based Solutions to Urban Sustainability (Mihalakakou et al., 2023). The research mentioned that cooling load demand was low, the air quality was improved as the pollutants were absorbed, the urban heat islands effects were eliminated, and the biodiversity was enhanced. It highlighted that the vegetation type, soil depth, and the irrigation plan have a strong impact on the performance of the system.

In Stormwater Detention Modeling of Green Roofs (Peng et al., 2022), the two-stage physically based hydrological model was constructed by using the Richards equation and Saint-Venant equation to model the water flow under substrate and drainage layers. The results verified that proper characterization of substrate hydraulic conductivity and water retention curves are the key in predicting the runoff detention performance.

In the article IoT-Based Monitoring of Green Roof and Solar Systems (Tseng et al., 2020), Narrowband IoT was used as a part of the study to observe temperature, humidity, and soil conditions on-demand. The findings proved that there were some quantifiable changes in the indoor temperatures and also in the photovoltaic efficiency because of the cooling effect of vegetation.

Likewise, in the article by Andric et al. (2020), the authors measured the energy savings and impacts of green roofs and green walls on the microclimate using both simulation and empirical evidence. The experiment had recorded a decrease in maximum indoor temperature and yearly energy usage, which emphasizes the significance of the selection of plants and management of irrigation in harsh climates.

In general, literature that has been reviewed confirms the existence of quantifiable thermal, hydrological, and environmental benefits of green roofs. Nevertheless, they can only be as effective as they are well designed structurally, their substrate properties, their vegetation attributes, and their acclimatization to the local climatic environment.

3. PROPOSED SOLUTION

In a bid to eliminate the ecological problems that come with the traditional roofing system, a sustainable Green Roof System has been suggested in this paper. The aim of the proposed solution is to decrease the surface temperature of roofs, to regulate rainwater, and to enhance the overall performance of the buildings.

The suggested system is in the form of a layered construction that is installed on the available reinforced concrete roof slab. The lowest layer is made up of a high quality waterproof membrane to avoid infiltration of water into structural slab. Most importantly, there is the installation of protective root barrier to prevent plant root damage. This is followed by the provision of a light weight drainage layer, which will enable the excess rain to drain to outlets and the necessary moisture to support plant growth. An overlapping of a non-woven geotextile filter fabric is laid on top of drainage layer to avoid the blockage of the drainage path by small particles of soil.

The system has been developed in consideration of the calculations of the loads, the properties of the soils, slope requirements, and the local climatic conditions. The intended solution will be to increase thermal insulation, minimize runoff, improve the quality of the air, and ensure sustainable urbanization in a practical and efficient way.

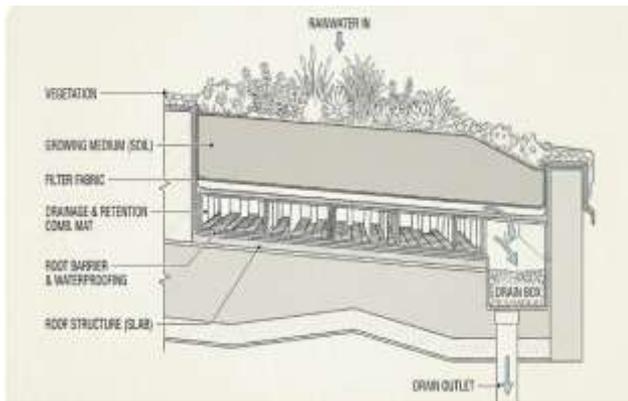


Fig -1: Green Roof

4. METHODOLOGY

The research design of this study is systematic in design, installation and appraisal of the Green Roof System proposed. The process incorporates site exploration, material choice, structural evaluation and performance test in order to ascertain technical feasibility and environmental efficiency.

4.1 Problem Identification

The paper started by discovering the key urban challenges in the form of an elevated roof surface temperature, surplus stormwater drainage, and the absence of greenery. On the basis of these challenges, it was intended to come up with a sustainable roofing solution that enhances thermal performance and water management.

4.2 Literature Study

To have an idea of the various forms of green roofs, structural needs, drainage, soil content, and plants used in green roofs, it was necessary to critically review research articles, journals, and technical reports of the past to acquire an idea about the various types of green roofs. This assisted in choosing an appropriate system set up.

4.3 Site Choosing and Preliminary Study.

The roof was reviewed based on strength, inclination, drainage, accessibility to sunlight and drainage. The available surface was checked on cracks, leakage and the condition of waterproofing. The local climatic conditions (temperature, rainfall, and humidity) were also examined in order to provide adequate selection of the plant and longevity of the system.

4.4 Structural Load Assessment

The roof slab was tested in terms of its load-bearing capacity. The load in kilograms of each layer of the green roof in such a condition as saturated soil were estimated per square meter. Maintenance live load was also taken into consideration to provide a safe condition during service.

The selection of material and plant used will be determined as per the final decision.

The choice of material was due to its durability, lightweight properties, and environmental friendliness. The system consists of no fewer than a water proof membrane, root barrier, drainage layer, geotextile filter cloth and light weight growing medium. Maintenance was kept to the bare minimum with drought resistant and shallow rooted plants that were able to cope with the local climatic conditions.

4.5 Installation Process

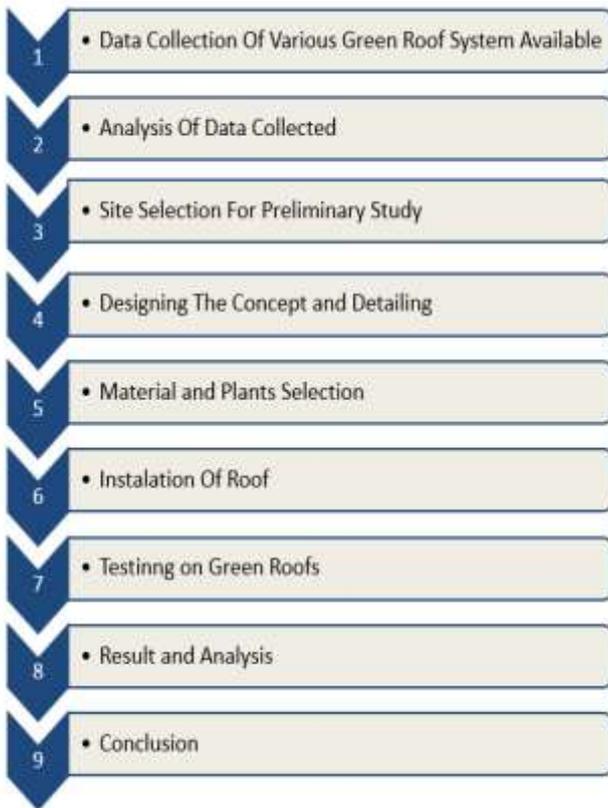
The dry roof was cleaned and repaired then installed. Root barrier was first laid and then the waterproof membrane. Then the drainage layer and filter fabric were arranged one after another. The growing medium that was ready was uniformly spread and vegetation planted uniformly on the surface. The slope was well anchored to allow proper drainage.

4.6 Testing and Performance Evaluation.

Performance testing was done after the installation to test its ability to reduce temperature, water retention capacity, and the conditions under which the plant grows. Initially, soil tests were conducted to detect the content of moisture, pH level, porosity, and nutrient availability. Load tests were done to ensure structural safety.

The data obtained was evaluated to determine the effectiveness of Green Roof System in enhancing thermal insulation, mitigating runoff and sustainable building performance.

➤ **FLOW CHART :-**



5. RESULT AND ANALYSIS

5.1 Thermal Performance

The temperature measurements were done through comparing the green roof surface to a traditional concrete roof in the same climatic conditions. It was noted that the green roof had a significantly low surface temperature on hot sunny days. The growing medium and vegetation layer minimized the amount of direct solar heat absorption and minimized the amount of heat transferred to the building interior. This translates to better thermal protection and lesser cooling energy requirement, which can result into energy conservation.

5.2 Stormwater Retention Performance Stormwater retention is a performance measure that evaluates how much water is absorbed by the ground surface instead of washing it away into a drainage system only to be discharged into the environment without beneficial use. 4.2 Stormwater Retention Performance Stormwater retention is an evaluation of performance which assesses the degree to which the ground surface captures water rather than sweeping it off into a drain system, which is then released into the environment with no useful

purpose.

The system proved to be effective in terms of rainwater retention because the growing medium and drainage layer were present. When it was raining, the water was taken up in large amounts and stored temporarily in the substrate. The drainage layer was gradually emptied and decreased the surface runoff. This managed release assists in reducing the pressure on the urban drainage systems and reducing chances of floods.

4.3 Soil and Vegetation Analysis.

The soil analysis showed that the growing medium was of adequate moisture content, proper porosity, and acceptable pH to enable the growth of plants. There was sufficient nutrient supply that did not necessitate the overuse of fertilizers to sustain vegetation. The plants chosen were also suitable because they could grow in the environment of a roof and required low maintenance to stay in a healthy condition.

The structural safety assessment pertains to the safety of the structure or the safety of individuals within it. 4.4 Structural Safety Assessment Structural safety assessment relates to the safety of the structure or the safety of the people in the structure.

The calculations done in loads, such as saturated and maintenance load, were within the allowable limit of the roof slab. After installation did not show structural distress, excessive deflection or leakage. This proves the fact that the system is structurally safe when it is done with right load considerations.

The performance measured by the results in the evaluation is satisfactory. 4.5 total performance assessment based on the outcome of evaluation is satisfactory.

The general discussion has shown that the suggested Green Roof System is effective in terms of thermal comfort, decreasing runoff, improving air quality, and increasing the functional life of the roof structure. The findings confirm the technical feasibility, environmental friendliness, and sustainability of urban development of the system.



6. APPLICATION

6.1 Residential Buildings

Green roofs may be implemented on houses, apartments and housing complexes to decrease the internal

Fig -2: Testing

temperature, decrease the use of energy to cool houses, and enhance the comfort of living in general. They are also beneficial in aesthetics and also offer extra usable green cover.

6.2 Commercial and Institutional Buildings.

Green roofs can be implemented in office buildings, shopping malls, schools, hospitals and government buildings to enhance thermal efficiency and lower the operational energy costs. Green roofs may be recreational or relaxation spots in the institutional buildings as well.

6.3 Stormwater Management in the City.

Green roofs are very effective in the management of rain water run-off in urban cities with high population density. They absorb and temporarily store rainfall which lowers pressure on the drainage systems and limits the occurrence of urban flooding.

6.4 Architecture in Response to Climate.

Green roofs are considered natural insulation systems in areas that have elevated temperatures. They aid in

alleviation of Urban Heat Island effect and assist in climate resilient building design.

6.5 Biodiversity and Environmental Betterment.

Green roofs also create a habitat to birds, insects and small plant species enhancing urban biodiversity. They also aid in the improvement of air quality due to the absorption and release of carbon dioxide and oxygen respectively.

As a country, Australia has been actively involved in adopting renewable energy systems.

Solar panels may be used with the green roofs (bio-solar roofs) to enhance photovoltaic performance because vegetation cools the building. This improves the general building sustainability and regenerable energy capacity..

Despite its advantages, however, it does have a number of limitations:

7. LIMITATION

Green Roof System has certain limitations. The initial installation cost is higher compared to conventional roofing systems. Additional structural load due to soil and water retention requires careful structural assessment before implementation. Regular maintenance is necessary to ensure healthy plant growth and proper drainage performance. In extreme climatic conditions, irrigation may be required, which can increase water usage. Improper installation may also lead to leakage issues.

CONCLUSIONS

This current research paper shows that Green Roof System is an effective and viable solution to traditional roofing applications. The proposed system was able to cut down the surface temperature of the roof, enhance thermal insulation as well as rainwater holding ability. When the system is well installed and designed it was confirmed that it is safe through structural load assessment.

The findings have shown that green roofs have a positive impact on saving energy, improving air quality, and preventing the urban heat island effect. The system increases the longevity of roofs and enhances urban biodiversity besides environmental benefits.

All in all, it is possible to state that the Green Roof System is a viable and environmentally friendly method of sustainable urban development, as long as correct materials, selection of plants and structural factors are taken into consideration.

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