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A Study on Green Roofs: Benefits, Challenges and Possibilities

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Abstract: ***Green roofs are considered to be a sustainable approach to mitigate the negative effect of urbanization. Due to rapid building construction activities, infrastructure development and increased land costs, green areas are reducing at a fast pace in cities. To cater to this situation, people are turning towards the usage of green roofs. It has the potential for increasing urban green footprint thereby directing towards sustainability. It is also easier to cater to roof surface for greening, than to vertical surfaces of buildings. In this paper, a systematic bibliographic study has been done to trace the benefits that green roof provides in an urban setting. Literature review suggests the benefits of green roofs are spread across a large canvas, which has been tried to streamline and summarized in this paper. The paper primarily focuses on thermal comfort, economic and environmental benefits of green roofs apart from other benefits.***

Keywords: Green roof benefits, thermal comfort, passive cooling

1. Introduction

Modern Green Roofs also known as vegetative roofs are essentially installed on roof slab or the roofing sheet. It typically consists of different layers or components comprising of a waterproofing membrane, drainage layer, and root barrier or filtering membrane geotextile, substrate or growing medium and vegetation [1], [2] (Figure 1). Looking into the numerous benefits of green roofs, a huge amount of research has been done particularly in the past decade in various parts of the world having different geographical, climate, social and economic background.

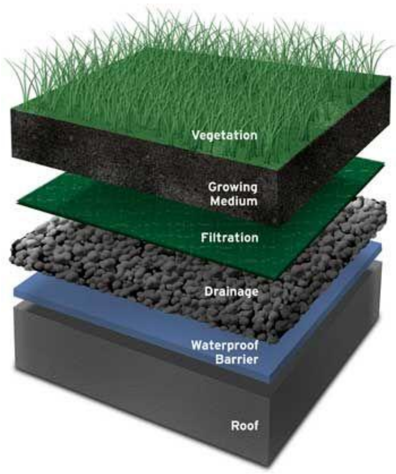

Figure 1: Typical green roof layers

This concept of green roof is getting popular due to multiple benefits such as thermal comfort, economic and environmental.

2. History

Historically green roofs date back to the Neolithic age, showing archaeological remains over a long duration with a lot of advancement till date [3], [4], [5]. It also finds mention in hanging gardens of Babylon of 5th century BC [6]. Although green roof components are getting changed it continued to be in practice. Sod roof or turf roof which is predominantly practiced in the Arctic region is one of the good examples of a locally adopted building practice (Figure 2). Available building materials could not provide sufficient insulation against the extremes of weather in the Arctic region. Sod roofs provide thermal insulation and benefits from the thermal mass effect [7]. The basic notion of green roof structures over centuries of practice has persisted in modern times; yet, the techniques and materials have been restructured since the 1960s.

Figure 2: An example of a turf roof (www.pexels.com/photo/house-on-green-landscape-against-sky-314937)

Green roofs are also referred to as vegetated roofs [8], eco-roofs (due to ecological benefits) [9], [10], roof garden or living roofs [1]. Due to multiple benefits, green roofs are being implemented in many countries. More research is being done on the implementation and performance of green roofs in different regions around the world [11].

3. Types

Green roofs are generally categorized into two types:

a) Extensive green roofs and
b) Intensive green roofs [12].

Extensive green roofs are those having 150 mm or less substrate layer with having limitation to plant size but having the advantage of less weight which can even be retrofitted to an existing roofing system. This type of green roof system is also economical as compared to that of intensive type green roofs [13].

Intensive type green roofs have substrate more than 150 mm and larger plants or trees can be planted over it. These types of green roofs need special considerations on the structural part as it imposes heavy loads on the structural roofing system, thus needing structural design at the initial stage itself or requires retrofitting. This system generally requires more care including irrigation. For these reasons, these types of green roof prove to be costlier than that of extensive green roofs.

Although some literature also highlights an intermediate category of green roofs know as semi-intensive green roofs [14].

4. Challenges in green roofs application

Although the green roofs provide many benefits yet, its application possesses certain challenges. Its initial retrofit cost is at the higher side, which is a hindrance for green roof usage [12]. For retrofitting into existing roofs, structural consideration has to be looked into as it would often stand as a limitation. For new green roofs, roof structure support needs to be designed accordingly [15], [16]. Specialized systems for green roof layers like waterproofing, drainage layer, root barrier needs to be installed, which will add further costs.

In many places, the green roof practice is not common. Lower awareness regarding green roof usage and its benefits is an obstruction towards wide application [17]. It's important to select appropriate plant species with respect to geographical location as it may require more water for irrigation purposes. Literature review suggests higher usage of drought-resistant plants like sedum etc. for the limited requirement of water with lesser frequency [18], [19]. Also, plants with limited height can be used in extensive type green roofs. Whereas intensive type green roofs support larger plant growth but pose a limitation of higher structural loads, higher costs and more maintenance.

5. Benefits of green roofs

Green roofs have numerous primary or secondary benefits. Although green roof benefits encompass various fields, in this paper benefits like thermal comfort, economic and environmental benefits are discussed.

5.1 Thermal comfort

Thermal comfort is considered to be important towards making a space habitable. Green roof adds to the temperature reduction inside buildings [20], [21] [22], [20], [23]. Vegetation layer of green roofs helps the roof absorb less solar energy by evapotranspiration [24] and providing a thermal mass layer thereby reducing the flow of heat into a building. In hotter days it reduces the temperature inside buildings. In cooler days it contributes towards warmer temperature. So, green roofs can be suggested for hot climates as well as cold climates. Green roofs also maintain the inside temperature. It also contributes to the reduction of diurnal temperature fluctuations [7]. It also absorbs lower irradiative temperature in comparison to other roofs [25]. Broadly, green roofs are being advocated as an important passive cooling system [22], [26].

Various studies have been done globally in order to find out the temperature reduction or thermal comfort properties of the green roofs. A few of them are being discussed here.

In a research output in Melbourne, Australia results in 3.8°C reduced temperature for the substrate of a green roof as compared to that of the roof with soil alone [27].

Another experimental and simulation study done in south India results in 4°C and 3.1°C lesser temperature respectively when averaged for a green-roofed room and a bare roofed room [28].

An experimental study was done in the Mediterranean climate of southern Italy, where different green roof rooms were observed with a reference room. All the green roofs having different layers showed temperature reduction with a maximum reduction of 2.3°C in one of those [29].

In a study done in Shanghai, China, green roof proved to be more efficient for temperature reduction when used along with intermittent ventilation. This was compared with an insulated roof. The maximum temperature reduction noted was 2.7°C [30].

A field experiment was done in central Taiwan resulted in a maximum temperature reduction of 3.98°C when bare soil roof was compared to the roof with vegetation [31].

These studies clearly suggest that green roofs reduce temperatures in spaces underneath thereby help achieve thermal comfort and also create microclimatic effects due to a temperature reduction of the surroundings. Literature review majorly suggests that due to the benefit of temperature reduction possibilities of green roofs, it stands as an important passive design measure in buildings to achieve sustainability.

5.2 Economic

Green roofs provide individual and socio-economic benefits over the life cycle [32]. Economic and cost-benefit assessment on green roofs did by Feng and Hewage highlights various individual and public benefits like cooling costs by energy use reduction, stormwater management, better air quality and reduction of urban heat island [33].

Green roofs are useful in extending the durability of the roof by becoming an insulation layer between roof and environment. Vegetation protects the existing roofs waterproofing membranes and reduces damaging effects due to exposure to direct ultraviolet rays and extremes of expansion and contraction because of temperature fluctuations thereby extending roof life or structural longevity [34]. This property of green roof is leading to lesser replacement and maintenance cost.

Green roofs have investment and financial benefits as highlighted by [32], [35]. To make it a common practice, some countries and cities offer benefits and incentives. It saves in terms of tax credits, incentives or rebates for using green roofs in buildings [36], [37], [38].

Certain green roof regulations count green roofs as a non-paved area, (for e.g. Fairfax Virginia), which allows building more on the same property, thereby increasing the property value thus making the green roof as an important trade-off [39].

On the lines of air conditioning usage, for each degree (in °F) being raised in the thermostat, about 3 to 5% could be saved on air conditioning costs [40]. In a simulation study for a typical office building in Hong Kong, for every 1°C increase in temperature setting, the reduction of electricity consumption in the air-conditioning equipment was about 3% [41]. As per the Ministry of Power, India, with a 1-degree increase in temperature set point of air conditioners, energy consumption decreases by 6 percent [42].

Since green roofs have been proven for temperature reduction and energy savings, these studies clearly show green roofs would further prove to be a cost-saving strategy.

5.3 Environmental

Green roofs contribute to numerous environmental benefits which are proven by various researchers. In this section, various such benefits are discussed.

Economic and thermal comfort benefits are directly or indirectly associated with environmental benefits and contribute to it. For instance, green roofs reduce energy consumption and add to thermal comfort which leads to cost benefits and in turn contributes to environmental benefits.

Green roofs contribute to the local environment by reducing temperature and achieving microclimatic benefits [20], [43]. It reduces energy usage during peak demands [26]. It provides space for plants, birds and other invertebrates etc. thereby creating habitat [43], [44],[45], thus improving the urban environment by enriching the biodiversity [46].

Green roofs contribute in pollution control. It purifies the air pollutants [18], [47]. It also helps in Carbon sequestration [48], [49], which further helps in reducing global warming. Plants in green roofs generate oxygen [18].

Green roofs cut off noise by providing acoustic insulation [50], [51], [52]. It absorbs pollutants from rain and cleans the rainwater and improves water run-off quality.

It contributes to water management and maintains stormwater drainage by delaying at the storm peak. By absorbing and holding water, it further reduces run-off volume [53], and because of reduction in rapid run-off, reduces flash floods in an area [54].

It Improves or enhances site aesthetics and livability benefits [55], [56]. Green roofs help in achieving green building certification like Leadership in Energy and Environmental Design (LEED®), developed by the United States Green Building Council (USGBC). LEED is the most used rating system for green buildings in the world [57], [58], [59].

Green roofs absorb 60% solar radiations through photosynthesis thereby act as an impediment to reduce solar radiations [25]. It further helps in reducing urban heat island effect [26], [60]. A research done by Berardi et.al. confirms environmental sustainability benefits of green roofs [61].

6. Conclusion

In this paper, various aspects of green roofs have been discussed highlighting the green roof benefits. Literature review clearly suggests that various researchers working on the lines of the common goal of achieving benefits from green roofs are successful to a greater extent. Literature suggests that research on green roofs is restricted to only a few countries [8], which advocates that there is a wide scope of studies and research in the area of green roofs. Research is needed on the effect of green roofs on achieving human comfort and energy conservation. A green roof can be implemented in various parts of the globe with different geographical backgrounds and diverse climatic conditions.

Research informs that various countries provide incentives, direct tax rebates and financial support for the usage of green roofs. This may be adopted by developing countries where such policies do not exist. This will also highlight green roofs as an environment-friendly construction practice. Due to rapid urbanization and shrinkage of green areas, urban roof greening comes as an important strategy to increase green cover and various other associated benefits from it.

To combat the energy crisis, carbon emissions, increasing global warming and ozone layer depletion, people must move to practical approaches which provide sustainable solutions. Green roofs prove to be one such strategy, which will serve communities for years to come. Green roofs are also important in terms of social, architectural and aesthetic aspects. When implemented at a large scale, it may transform the dying urban ecosystem and expand the public benefits.

Though it poses an initial challenge of higher incurred cost and other constraints, its overall benefits outweigh the cost and other hinderance factors.

In this paper, an effort was made to understand the know-how of green roofs and their benefits. From the study, it is apparent that future research and development is impertinent and green roof could be used widely as an integrated part of nature in buildings. In the long run, it will prove very beneficial for better human comfort, social, economic and sustainable development.

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