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A REVIEW ON GREEN ROOF BENEFITS, OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Over the last decade, research on green roofs has progressed quickly. Green roofs have been suggested as a long-term solution for mitigating the negative impacts of urbanization. The history of the green roof, green roof components, and various advantages (environmental, social, and economic) connected with green roof technology are all covered in this review article. This article also discusses how green roofs function in many areas, including its effectiveness in lowering storm water and energy costs, as well as enhancing air and environmental quality. The advantages of a green roof demonstrate that it may help cities become safer, more sustainable, and more robust to climate change. As a result, several nations provide financial incentives to homeowners who install green roofs. The major difficulties connected with the use of green roofs are the initial high construction costs, high maintenance expenses, and roof leakage concerns. These obstacles may be addressed with the development of a revolutionary low-cost green roof design that can function more effectively and efficiently in any location. This article also covers advanced modifications and green roof application trends. The article also discusses the green roof's research difficulties and research gaps. Finally, several suggestions are made in order to improve the performance of green roofs.

KEYWORDS: *Advanced modification, Evolution Retrofitting, Green Roof, Promotional Policies, Roofs.*

1. INTRODUCTION

The current hot issues include climate change and urbanization. In wealthy nations, urbanization is expected to reach about 83 percent by 2030. Urbanization is growing in many nations as a result of fast economic development, degrading the natural landscape as well as the surrounding environment. Green storm water infrastructure solutions may be used to address these issues. Rain gardens, green roofs, green walls, and bio retention systems are examples of innovative urban development techniques that may help to offset the negative impacts of urbanization and enhance an area's environment. Green roofs are also known as vegetated roofs, cool roofs, eco roofs (owing to their environmental advantages), roof gardens, and living roofs. Green roofs are essentially roofs with various types of vegetation/plants growing on top of a growth medium (substrate). This idea was created to promote the growth of plants on the roofs of buildings in order to reap many social, economic, and environmental advantages. Vegetation, substrate, filter layer, drainage material, insulation, root barrier, and water proofing membranes are all common components of a green roof[1].

To obtain the greatest results from green roofs, it's critical to choose the finest components for each component. Each component is equally essential and plays a critical role in improving the performance of a green roof in a specific region. Green roofs are being adopted in several nations due to their many advantages. More study is being conducted on the installation and performance of green roofs in many parts of the globe. The 2016 green roof for excellence in buildings awards are shown in Figure 1. Green roofs have acquired a lot of popularity across the world in recent decades since they have shown to be sustainable practices. Green roofs provide many social, environmental, and economic advantages, according to research. Significant evidence suggests that green roofs can provide a variety of benefits, including storm water management, reduced urban heat island, increased urban plant, wildlife habitat, and roof life, improved air and water quality and quality of life, lower building energy costs, reduce noise pollution, promote re-creational activities, and increase green areas. Green roofs reduce the strain on local water treatment facilities as a consequence of improved water quality. Because of the advantages listed above, several nations have begun to install green roofs on buildings. As a consequence, more and more green roofs are being built across the world every day[2], [3].

Figure 1: Represents the Green Roof selected for 2016 Excellence Awards in buildings: green roofs on residential buildings[1]**.**

Green roofs are often divided into four types. Intensive, semi-intensive, single-course extensive, and multi-course extensive are all options. Intensive green roofs are distinguished by a thick substrate (> 12 in.), a vast diversity of plants/vegetation that resembles ground-level landscapes, a high water holding capacity, high capital and maintenance expenses, and a heavier weight. Because of the wide soil depth, it can store more water and the plant selection may be more diversified, including tiny trees and shrubs. This necessitates a greater focus on the building structure's ability to support big loads.As a result, this sort of roof needs a lot of upkeep in the form of irrigating, weeding, and fertilising.

Semi-intensive green roofs are those with a substrate thickness of 6–12 inches. Semi-intensive green roofs have a medium substrate thickness and are typically planted with tiny plants, shrubs, and grass. For optimal performance, these roofs demand frequent maintenance and significant capital expenses. Single-course extensive roofs, on the other hand, have a substrate thickness of 3–4 in. Sedum is commonly used as the plant layer in single-course extensive roofs, and watering is generally not required. In comparison to other roofs, it had low capital and maintenance expenses.. These roofs are generally quite light weight and come in handy when there are weight limits on the structure. Multi-course extensive roofs have a substrate thickness of 4–6 inches. This style of roof is often low in weight and is popular in the United States. Single and multi-course extensive roofs are the most popular of the four varieties since they are lighter, don't require watering, and have lower capital and maintenance expenses[4], [5].

2. EVOLUTION OF GREEN ROOF

Green roofs on building rooftops are a time-honored method. People built green roofs atop rooftops as rooftop gardens in ancient times to provide insulation and to mitigate the negative impacts of urbanization. The Hanging Gardens of Babylon, built about 500 BCE, are one of the most renowned ancient green roofs. During severe climate circumstances, several nations (Sweden, Finland, Iceland, Denmark, Norway, Greenland, Vinland, and the Faeroe Islands) have begun to cover their roofs with sod. However, because of the correct design and standards, today's green roofs are more efficient and effective.

When energy problems emerged in Germany in the early 1960s, contemporary green roofs were born. Green roofs were first built in Germany to decrease building energy use. In today's world, Germany is recognized as the global leader in green roofs due to the large-scale development, design, and implementation of green roofs. Fig. 1 discussed the history of green roofs in the 1960s. Various time intervals across the world ReinhardBornkamm, a German researcher, published his study on green roofs in 1962. BDLA pioneered the creation of roof gardens at the Deubau trade show in Essen in 1973. The market for green roofs exploded in the early 1980s, and numerous green roofs were built throughout Germany. LandschaftsentwicklungLandschaftsbauForschungsgesellschaft (FLL)Green roof construction rules have been published in German[6].

Green roofs are used by more than 10% of buildings in Germany for a variety of reasons. The bulk of green roof research and investigations were place in Germany, Scandinavia, Germany, and Switzerland. Green roof information is not easily accessible globally since it is reported in their native languages rather than English. However, as a result of the green roofs application efforts, green roofs have grown more popular all over the world. In Germany, study and use of green roofs on buildings are extremely popular nowadays, and green roof coverage is growing by around 13.5 million m2 per year.In 2005 and 2006, the Association of Standards and Testing Materials (ASTM) published guidelines for green roofs, which detailed the building of green roofs. The newest rules for the design, implementation, and maintenance of green roof sites were issued by FLL. In 2009, the USEPA published a study on the construction and advantages of green roofs. In the United States, further study on

green roof guidelines, installation, and maintenance was done, and the findings were shared with other nations interested in adopting green roofs.

Green roofs are being used in new and existing buildings in nations such as the United States, Canada, Singapore, Australia, Japan, China, Hong Kong, and South Korea to accomplish various advantages. Green roofs must be installed on 20–60 percent of the total roof surface in buildings having a floor space of less than 2000 m2 in Toronto, Canada. Green roofs should be used in every new building in Japan. Buildings bigger than 250 m2 and private buildings larger than 1000 m2 must green 20% of their rooftops or pay a yearly fee of $2,000 USD. Green roofs must cover 70% of the area of all new buildings in Portland, Oregon. In 2005, there were around 2 acres of green roofs in Portland, with additional green roofs planned to be built in the future to attain the many sustainable advantages. Governments in China and Hong Kong are urged to use green roofs as green practices. South Korea's government is promoting public-private partnerships. Green roofs will be used by the private sector and other stakeholders to make cities safer, more sustainable, and more resilient to climate change[7].

3. GREEN ROOFS FOR RETROFITTING INTO THE DEVELOPED AREAS

All natural spaces in developed metropolitan areas had been transformed to concrete surfaces (road, buildings etc.). Much of the infrastructure (telecommunications, sewage, gas, etc.) has already been constructed on the ground and underground. Applying green storm water infrastructure in the best possible location to provide numerous advantages is a major issue in these situations. Roof areas account for roughly 40–50 percent of total impermeable surfaces in modern cities. Because there are many various types of roofs in use across the world, you should first research the roof type and then choose the best green roof to reap the most benefits.Furthermore, green roofs may be retrofitted on these locations, reducing the negative consequences of urbanisation. This will also assist to enhance the local ecology. Green roof technology is not only the greatest management practise for new construction, but it is also a viable alternative for retrofitting existing structures. Green roofs and walls were retrofitted at two separate locations for the retrofitting of green roofs.

The first green roofs were built with a timber frame structure in Sydney, Australia, and another with a blockwork structure in Rio de Janeiro, Brazil. The thermal performance of these two retrofit green roofs is being investigated by the authors.They looked at the effects of these two roofs with walls and compared them to non-vegetated roofs. When compared to non-vegetated roofs, both lightweight retrofit roofs demonstrate promising cooling effects. The type of structure and the colour of its surface also have an impact on the performance of green roofs. When compared to the block work construction utilised in Rio de Janeiro, the Sydney timber frame building has better insulation and cooling qualities. This is due to the fact that timber buildings are poor heat conductors. Green walls are also beneficial to the building's thermal comfort and should be used for numerous reasons.In Catania, southern Italy, the performance of vast green roofs with and without natural ventilation. The findings show that thermal insulation is critical for improving the interior comfort of historic structures[7]–[9].

The non-insulated green roof decreases the exterior surface temperature by around 36 degrees Celsius, but the insulated green roof green roofs reduce the temperature by up to 54 degrees Celsius, according to the experiments. Building insulation is critical for reducing the heat island effect in metropolitan settings. In a dry moderate environment with hot, dry summers and winters, this study also shows that green roofs are the greatest choice for new as well as retrofitting into existing spaces.The Mediterranean region. Another research from Toronto, Canada, found that retrofitting green roofs on a structure may lower the surrounding air temperature by up to 0.4 degrees Celsius during the day and 0.8 degrees Celsius at night[10].

4. CONSTITUENTS OF GREEN ROOF STRUCTURE GREEN

Green roofs are built to help offset the negative effects of urbanization. The components of a green roof vary depending on the area and needs. Green roofs typically have the following elements:

(1) A waterproof membrane and a root barrier membrane,

(2) A drainage layer, and

(3) A vegetation layer.

(3) A membrane filter,

(4) Soil as a growth medium, and

(5) Plants.

The selection of each layer according to the location and climatic circumstances is critical for long-term environmental advantages. Each component of green roofs is critical, and they must be chosen carefully to get the best benefits.

4.1. Plants/vegetation for extending the life of the green roof:

The selection of plant layers that optimize the green roof's life is the most important and fascinating aspect of the green roof creation process. The health of the plants determines the effectiveness of green roofs. We should consider the geographic location, rainfall intensity, humidity, wind, and sun exposure while choosing a plant. The plant species we may use for green roofs is also determined by the depth of the growing medium. Several writers collaborated on the discovery of plant species depending on soil depth.

Green roof vegetation/plants enhance runoff water quality, air quality, and decrease heat waves in a region. However, it is important to note that the rooftop is not a natural environment for plant development. For the rooftop top settings, water is always a limiting issue. Furthermore, building load limitations limit the depth of the soil media. To keep plants performing well, the growth medium need nutrients as well. After taking into account all of these constraints on the rooftops, the best vegetation/plants for large green roofs may have the following characteristics:

- The ability to endure drought and severe weather.
- Cost-effective and easily accessible
- Irrigation is not required on a regular basis.
- Roots that are short and soft
- Have the capacity to live in low-nutrient environments
- Reduced upkeep
- Increased evaporation
- Has the potential to minimize heat island effects.
- Multiplications that happen quickly

4.2. Plant growth medium, number:

This layer is known as the crucial layer because it has a direct impact on plant development and is linked to the long-term viability of a green roof. As a result, the best selection of this growth medium (soil) is critical to a green roof's performance. The majority of green roof advantages, such as water quality improvement, runoff reduction, peak flow reduction, and thermal benefits, are directly linked to the substrate of green roofs. The growth medium should have distinct characteristics, such as low weight and a high ratio of organic nutrients

to aid plant development. However, it is unrealistic to expect a substrate to possess all of the required characteristics. As a result, it is common practice to mix the various components in the growing substrate. Many writers utilized commercial substrate, but only a few studies suggested using alternative low-cost, lightweight materials in the substrate for numerous advantages. Pumice, zeolite, scoria, vermiculite, perlite, peat, crushed brick, and other low-cost waste materials may also be used in the substrate. Although many writers utilized commercial substrate in green roofs instead of native soils, these substrates may function well in certain areas. It is usually suggested to utilize local waste material as a green roof substrate since it is more cost effective. On the other side, in regions where commercially produced green roofs are unavailable, indigenous substrate is used to create green roofs. It has a number of drawbacks, including

(1) Insufficient water retention;

(2) Increased weight, which may cause the building to collapse;

(3) Encourages unneeded local weed growth;

(4) Swept away the nutrients that the plant needs to grow:

(5) Has the potential to become difficult.

It is best to avoid using 100 percent local mix since it may encourage local weeds, compress the building during rain events, induce structural shrinkage, and result in structural collapse.

5. DISCUSSION

Because the plant and substrate layers have the ability to retain a significant quantity of water, green roofs are the best stormwater control techniques in metropolitan settings. As a consequence, the risks of flash flooding in metropolitan areas are reduced. Because vegetation/plants enhance evapotranspiration and the growth medium absorbs a significant quantity of rainwater, peak flow and discharge are reduced. The amount of runoff that is reduced is determined by a number of variables, including the kind of vegetation, the thickness of the growth medium, the type of drainage material used, rainfall intensity, and the slope of the green roof. The substrate of a green roof is the most essential component, and it must have a high moisture holding capacity in order to retain more rainfall. The three types of vegetation (sedum, long and short grass) were used to assess the performance of surface runoff during various rainfall events. According to the findings, the sedum generated more surface runoff volume than other vegetations.

Green roofs are the greatest techniques for controlling stormwater runoff and improving water quality. The substrate and plant layers of a green roof play a significant role in runoff reduction and pollution absorption from rainfall. The contaminants and heavy metals from the rainfall were absorbed by the substrate, which improved the water quality. The large green roof serves as a water quality monitor. The findings show that the proportion of ammonia nitrogen in green roof runoff is lower than the percentage in rainfall. The proportion of heavy metals in urban runoff from hard surfaces was considerably greater than the runoff from green roof surfaces, according to research papers on green roof water quality performance. The amount of runoff volume decrease mostly determines the reduction in heavy metal content. Row also looked at publications from various locations and concluded that green roofs had the potential to enhance water quality.

New green roof options and modifications have recently increased the use of green roofs in various parts of the world. From Korea, a green blue roof is introduced. Researchers from the Korea Institute of Civil Engineering and Building Technology (KICT) have created a new modified type of green roof to accomplish numerous advantages. The green blue roof is a mixture of two words: green and blue, where green denotes the presence of vegetation/plants on the roof and blue denotes the presence of a storage layer, similar to the blue roof. This

green roof design includes an additional layer that helps to retain water in the soil layer as well as the storage layer. The primary benefit of this roof is that it can retain more water, which helps to prevent flash floods in metropolitan areas.

Green roofs are shown to be viable strategies for reducing the negative effects of urbanization in this review article. Green roofs are the best management practices (BMPs) in urban settings because they provide numerous advantages such as stormwater management, water quality improvement, and thermal enhancement. Green roofs may readily be integrated into existing structures and offer a variety of advantages, according to many study results (environmental and social). Green roofs have the ability to preserve an area's natural hydrology as well as its ecosystem. Furthermore, it aids in the prevention of global warming by decreasing heat waves and improving climatic conditions. However, there is a knowledge gap between developing and wealthy nations, where much green roof research has already been done. Additional study has been done in cold climate regions, such as the United States, Sweden, and Germany, while more research is needed in other climatic and geographical places. Green roof components such as vegetation and substrate should be chosen locally to improve green roof performance while also lowering expenses. There is a need for further study on the life cycle costs and cost benefit analyses of green roofs in various countries. There should be some kind of incentive for building owners to use green roofs; this would encourage widespread use of green roofs. Stakeholders could promote the use of green roofs by offering financial incentives.

6. CONCLUSION

The study on green roofs has been difficult, but it has opened up a lot of possibilities for future research for the researchers. Green roof characteristics, environmental, social, and economic advantages, difficulties, possibilities, and possible applications are reviewed in this article. Although important characteristics have been revealed, numerous realities such as high building costs and management issues should be taken into account for future global applications. The goal of this review article was to show how a green roof may assist a region's natural hydrology while also reducing global warming. For the many advantages of green roofs, there is also a need to create more cost-effective green roof methods (environmental, social etc.). However, additional in-depth real-world experimental work on each component of the green roof is needed, and interdisciplinary research cooperation to address the difficulties is on the horizon. Finally, there are many difficulties and possibilities in the future for cost-effective green roof design.

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