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Green Skyscraper: A Smart Solution for Sustainable Infrastructure

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***Abstract*— Green Skyscraper concept has been emerged to mitigate the effects of the increasing impact on the environment and it can work as a smart solution, to improve the building construction process. This research has been emphasized on integration of plants in skyscraper design, which play a vital role for the energy conservation by the building as well as improving the living quality into these vertical cities. Throughout the thesis work, it has been studied to establish the necessity of planting to incorporate into skyscrapers, for the well-being of our economy, society and the environment. The rules and regulations in various countries have been studied. The provision of integrating plants into skyscraper includes the four possible options like Green Roof, Green Wall, Bio-filter and indoor potting plants which can be incorporated into the design. The benefits and impacts have been studied in terms of energy savings and indoor environmental qualities. Green roof can reduce 50% of cooling load; Green wall can reduce 100 C indoor temperature; whereas Bio-filter and internal plants purify indoor air by 50-60%.**

Keywords: - Green skyscraper, Integration of plants, Green Roof, Green Wall, Bio-filter, Environmentally optimized solution and aesthetics.

I. INTRODUCTION

The Skyscraper is a Dutch term which literally translated refers to a building that gently touches the sky. The concept of Skyscraper was introduced in Europe for first time in for of European Skyscraper. The construction of John Hancock Center in Chicago in 1969 marked a new phase in the evaluation of the skyscraper in United States. Skyscrapers, by definition are not primarily ecological. The construction and running of these tall buildings can only be achieved at the cost of an extraordinary input of primary energies and raw materials (Powell and Robert, 1999). They will ensure highly efficient use of spatial resources if provided with high density of quality workstations and good connections to public transport system. Thus, skyscrapers today deserve more emphasis for its impact on environment. The reestablishment of "green" that was eliminated by its construction can be a possibility to refurbishment the nature as well as improve the quality of living into it. The theory of 'Green' Skyscraper has been notably shaped by the writing of Ken Yeang. He proposes, in his theories, the interconnecting measures regarding the use of energy, water and light. He further relates these to green plants, local climate, and ecology to the spatial conditions and the functions of the building (Lepik, Andres, 2004). Thus, the planning and design of skyscraper influenced by a complex series of demands, where green plants can play a vital role for the energy conservation by the building as well as improving the living quality into these vertical cities. The Minara Mesiniaga in Malaysia (1992) is such practical example of an ecological tall building. Green Skyscraper refers to both the practice and product of creating tall buildings which are better for our health, environment and economy. It will be environmentally responsible and resource efficient throughout its life-cycle, as well as a sustainable and high-performance building for economy, utility, durability, and comfort (EPA). Definitions of green skyscraper vary but the green movement has five main goals.

a) Ensure a healthy, productive indoor environment for occupants to work and live.
b) Prevent negative impacts to our environment and improve its health.
c) Reducing operating cost and increase profitability for building owners through energy and resource conservation.
d) To find out the provisions of integrate plants

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into the skyscraper design.

e) Analyze their impacts on energy consumption and living environment.

f) Suggest some alternative solutions to eliminate the drawbacks and propose some guidelines for good practice to make it viable economically, socially and environmentally.

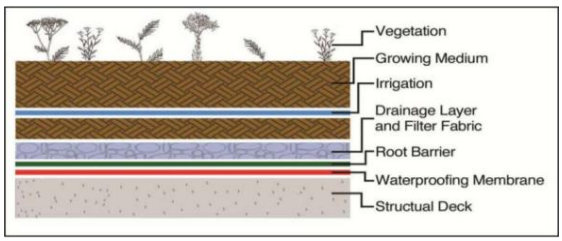
II. COMPONENTS OF THE GREEN SKYSCRAPER

1. Green roof
2. Green wall
3. Bio-filter
4. Indoor potting plants

1.Green Roofs: Green outer

Green roof has been in existence for over 3000 years, the earliest green roofs were seen to be as form of a turf roof. The turf roof contains growth of grasses and plants roots and this kind of roof is still in existence in Norway and Iceland. In warm climatic region green roof was first identified as roof garden which was seen in the ruins of Pompeii after the volcanic eruption of Vesuvius Mountain in AD 79. Green roof was also seen in the famous Hanging Garden of Babylon which was constructed around 500 B.C. During Middle Ages green roof was also found in Guinigi Tower, Lucca, Italy.

Green roof can the defined as a roof that contains plant or vegetation and it may be fully or partially covered on the roof and it's an addition on a normal concrete decked roof. Green roof has several layers the top layer is the vegetation stratum, followed by growing medium or soil layer, irrigation layer, filter fabric layer, drainage layer, waterproofing membrane layer, and then the roof deck. Green roofs cost more than the normal traditional roof but it has its own advantages and benefits on the long run which will counter the initial cost of installation.



A) Fig.no.1

As shown in above figure types of Green Roof According to Mentenser et al. (2006) depth of green roof substrate layer defines green roof into two types which are the intensive and extensive green roof. Intensive Green Roof Intensive green roof is the type of green roof that contains different types of vegetation starting from grasses, shrubs to small trees. It's often roof garden and it may also include walkways, benches, tables, and fountain on the roof. The intensive green roof has a depth greater than 150mm. This type of green roof has a heavy weight and required high maintenance. The slope of an extensive green roof is less than 100. Intensive green roof can weigh from 171 – 391kg/m2 (Breuning, 2015) Extensive Green Roof The extensive green roof is simpler compare to intensive green roof because it's lightweight and requires low-maintenance and drought resistant plants usually sedum species are used. It also has thickness of less150 mm. According to Breuning (2015) extensive green roof can weigh from 73kg/m2 to 122 kg/m2. Looking at extensive green roof from sustainable point of view it's considered to be more important because it has low weight and can be used in more rooftops compare to the intensive type. When elements of both extensive and intensive green roof are found in green roof it's considered to be semi intensive green roof.

Benefits of Green roof:

a) The roof act as an important parameter during monsoon since it absorbs the storm water and prevents the wastage of storm water and also reduce the probability of floods.

b) It acts as the insulating barrier in summer as well as in winters since it prevents the heat flux transfer.

c) Green roofs cover the waterproofing membrane, protecting it from UV rays and extreme daily temperature fluctuations. This protection extends the lifespan of the waterproofing twice as long as conventional roofing, meaning that membranes under green roofs last twice as long as those on traditional roofs.

d) Green roofs make the most of unused space within the increasing density of our cities. Rooftops can be developed into social and recreational spaces and used for urban agriculture.

2. Green Wall:

Green-wall technologies, are also known as Vertical Greening Systems (VGS) or bio walls. They consist of vertical structures that spread vegetation that may or may not be attached to a building facade or to an

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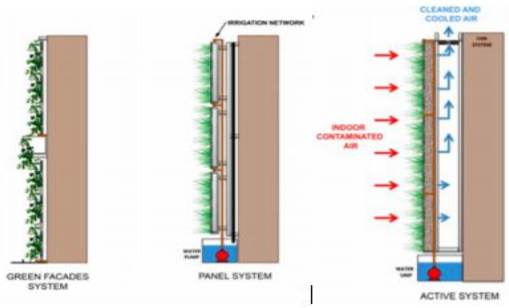
interior wall. Attending to the level of complexity, there are several green-wall typologies that range from the simplest configuration to the most complex and high-tech design. Based on the type of vegetation and support structures used, these systems can be divided into two major groups: green facades and living walls.

In green facade systems, or green screens, the vegetation cover is formed by climbing plants or cascading groundcover as shown in Fig.no.2. Specially designed structures can be used to force the plant development through the building's wall, which can serve as support for the climbing vegetation. Normally, green facades are rooted at the base in the ground or in plant boxes, but intermediate planters, fixed to the wall at a certain height or even on rooftops as a falling green cascade, can also be used. Due to the lower diversity and density of plants, green facades normally require less intensive maintenance and protection than living walls. Living walls are generally more complex infrastructures that involve a supporting structure with different attachment methods. A waterproof backing is required to isolate the living wall from the building in order to avoid problems. The irrigation network is also necessary while fertigation, monitoring, and lighting systems are optional. There are many ornamental species and there are many successful experiences of planting edible herbs and vegetables to create vertical gardens of lettuce, mints, thyme, strawberries, etc.

On the other hand, species used in outdoor living walls vary greatly depending on location, as well as site specific microclimate (sun and wind exposure, height, etc.). Traditionally, the green wall has acted as a "passive" bio filter, but new approaches and technologies are moving towards the integration of living walls (both indoors and outdoors) within the building's air conditioning and ventilation systems. The result is called "active living wall," in which an air current is forced to pass through the green wall and collected afterwards so that the recycled fresh air can be supplied to the building's interior as the air has been cooled, filtered, and humidified by the plants and growing media.



B) Fig.no.2

• Lists of plants in Green wall
Spider plant
Dracaena
Ficus
Peace lily
Boston fern
Snake plant
Bamboo palm

Benefits of Green Wall:

a) Reduces urban heat island effect and smog.
b) Cleans outside air pollutants and dusts and offsets the carbon footprint of people and fuel emissions.
c) Acts as a sound insulator.
d) Cleans the water that flows through the wall.
e) Acts as the heat insulation and helps in reducing the cooling and air condition load.
f) Acts as an oxygen supplier at high level.
g) Prevents the waste of wall area.
h) Increases real estate value.
i) Prevents the wastage of rain water sliding over the wall.

3.Bio-Filter:

Bio-filter is one of the organic methods which includes Bio-reactor containing living material which captures and diminishes the pollutants biologically. A bio filter is a bed of media on which micro-organisms attach and grow to form a biological layer called bio film. Bio filtration is thus usually referred to as a fixed film process in which bio film is formed by a community of different micro-organisms. Nature has the built-in capacity to adjust to environmental changes. It can repair itself after damage or adapt to exposure from a wide range of compounds. Although the time scale may vary from minutes to centuries, in time a natural ecosystem can repair almost any damage it may sustain.

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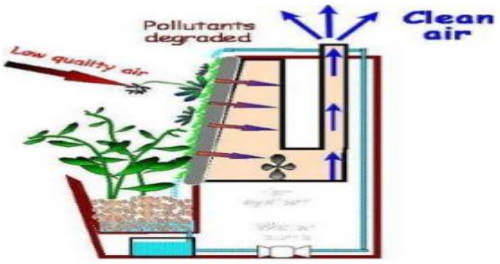
For example, given enough time nature can restore a site contaminated with organic compounds such as VOCs (Volatile Organic Compounds). One reason for this is that, frequently, materials such as VOCs that are toxic to some life are food for others. Most of the biological breakdown of VOCs is done by microbes (bacteria), although higher plants may also be involved. Some pollutant-degrading species are usually present and active in most environments, and the act of introducing the pollutant only increases their relative numbers and/or activity levels (Yeang, 2006).

Biofilter act as a vegetated return air register. It is a vertical hydroponic green wall containing a range of specifically selected plants. The plants include ferns, mosses and a range of other flowering and foliage plants. Air is actively drawn through the green wall of plants and highly specialized beneficial microbes actively degrade pollutants in the air into their benign constituents of water and carbon dioxide. The clean air is then distributed throughout the space by a mechanical ventilation system. Through the natural processes of biofiltration and phytoremediation, the system removes and breaks down common indoor air pollutants. The System is an ecological approach to maintain the indoor environment with the whole life cycle of the system taken into account. Although the systems are typically designed up to over 20 years of operation, the biological aspects have the ability to continue with their functions forever. The biology component is a self-repairing, self-rejuvenating air cleanser.

Benefits of Bio-filter:

a) Bio filters are less subject to variable or intermittent loading and to hydraulic shock.

b) Because micro-organisms are retained within the bio film bio filtration allows the development of micro-organisms with relatively low specific growth rate.



C)Fig.no.3

IV. INDOOR POTTING PLANTS:

Urban Indoor Air Quality (IAQ)is an international health issue, since city dwellers spend 90% of their time indoors. So, it has become necessity to improve the indoor air quality. Interior landscaping has become increasingly popular during the last 30 years. Most architects now include plants in their design specification for new shopping centres, office complexes and other public areas, and people expect to see when they walk through the door. Thus, plants became such important building accessory. The main reason is, indoor plants look attractive – people get charmed by the graceful arch of palm leaves or the exotic beauty of orchids. However, recent research has shown that the value of plants goes far beyond the purely aesthetic. Plants are actually good for the building and its occupants in a number of subtle ways and are an important element in providing a pleasant, tranquil environment where people can work or relax.

Types of Indoor Plants:

There are Different varieties of indoor plants which can be used to serve different purposes. Some plants are good for day time whether some are useful for night time workers. Based on the functionality or occupancy time these plants are helpful to decorate and enhance the indoor environmental quality. According to the study of Dr. B. C. Wolverton about indoor plants are as follows:

a) Night time workers Bromeliads, orchids and succulents exchange Oxygen and Carbon Dioxide at night rather than as most other plants do during the daytime. This makes them perfect bedroom plants to refresh the air for breath during sleep.

b) Plants which raise humidity levels as plants return 97% of the water human give them back into the air, water loving plants help to raise humidity levels. Particularly useful in centrally heated or airconditioned buildings. Examples of some water loving plants are Schefflera, Bamboos and Hemp.

c) Peace Lily: Spathiphyllum. Winner of Dutch office plant of the year 2007. A good all-rounder and best at removing all toxins.

d) Boston Fern: Nephrolepis exaltata and obliterate. Good air cleaner; also good for raising humidity levels and keeping the environment comfortable, particularly useful in centrally heated or

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air-conditioned rooms/spaces. Dracaena deremensis, marginata and fragrances. One of the best plants at removing Trichloroethylene emitted by photocopiers and printers, perfect for the home office. Umbrella plant: Schefflera actinophylla. Good air purifier and also a water lover which means Schefflera is good for humidifying the air, like Boston ferns. Ivy: Hedera helix. Good at cleaning the air, the plants can also help to reduce the physical signs of stress.

Benefits of Indoor plants:

a) Reduces the air pollution.
b) Reduces work place illness.
c) Reduce stress and negativity.
d) Contributes to meet at-least 75% of indoor environmental quality(IEQ) criteria.
e) Enhances aesthetic view.
f) Absorb and buffer noise.

III. CONCLUSION

The aim of the thesis was to find out the possible ways to integrate plants into skyscrapers and asses how the integration of plants into the skyscraper design can help reducing the energy use, and enhance the living quality. The impacts of these options on energy consumption and living environment, such as the benefits of Green roof, Green wall, Biofilter and Indoor potting plants on living condition, environment, economy and society is elucidate with some of their drawbacks, and the available technologies to integrate these options into the buildings. Discussion and recommendations were made to overcome some of the drawbacks and some guidelines were proposed for good practice to make the 'Green Movement' viable economically, socially and environmentally. Thus, this research has fulfilled its aim and objectives to its full extents for designing a Green Skyscraper with incorporating the plants into it.

IV. FUTURE SCOPE:

The Green roof can be a good replacement for the land which is been used as the recreational area on the plot.
The Green walls can be more improved by combining green wall as the part of vaccum as the outer panel so this will lead to development of the natural and permanent sound insulator and air purifier resulting in reduction in the air conditions load and artificial sound barrier. This is the smart solution in the city area as well as industrial areas as these are the area which are mainly facing the sound and air pollution. The Green walls and Green roof will increase the planting of different plants thus converting the concrete world into the green world and hence there is much more area available for the development of water storage lakes, for developing different types of infrastructure requirement as there is scarcity of land. Green Infrastructure is the need for the design of sustainable structure and can satisfy the demands of the future generation. This research is an attempt to highlights various methodology to save energy as a when feasible. The paper recommends the need of designing and implementing all possible energy saving integrated technique for sustainable development in our country. It also highlights that rules and regulations are supposed to be modified and policy decision should be incorporated by the authorities at the national level.

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