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A review on typologies and the role of vertical greening in reducing the heat gain through building façades.

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ABSTRACT— The significant components of heat load in buildings are due to external wall that receives direct solar radiation and transfers the heat through conduction. The absorbed radiation elevates the outside surface temperature to a higher value than the outside air temperature which gradually shifts to lower indoor wall surfaces, increasing energy consumption. The physical characteristics of the wall, color, the material of the exterior surface, and the intensity of the sun radiation perpendicular to it, all affect the external surface temperature. Vertical greening is an emerging concept that comes in between the wall and direct solar radiation to block the direct solar radiation and reduce conductive heat transfer through the facade using vegetation. This paper elaborates on different vertical greening systems and their efficiency to keep away the direct solar radiation striking the building fabric.

KEYWORDS: solar radiation, heat gain, outside surface temperature, vertical greening system.

1. INTRODUCTION

The annual energy demand reduction depends on the wall's thermal characteristics that make up the building facade. The heat exchange between the outdoor and indoor environments based on the construction elements depends on physical parameters, air-passage permeability, Construction quality, and The number of thermal bridges created by the interruption of the thermal insulation materials. The exchange of heat and air penetration impacts the hygrothermal factor of the internal environment and its energy consumption. The plant's evaporation enhances the thermal performance of façades by lowering cooling loads on buildings and energy costs for space cooling [3]. There are different types by which the vegetation can be applied to the wall to block solar radiation.

2. TYPES OF VERTICAL GREENING

Following the most recent advancements in green wall technology, it's essential to consider and group all currently installed green wall systems based on their methods of construction and major characters. There are two systems under which the green wall is grouped, which include Green facades and living walls. In Green facades, a single species of climbing plants grow from the soil placed at the base to cover the entire wall while the Living walls use technology and materials to support a wider range of vegetation and growing medium which is placed on the surface of the wall. (Figure 1)

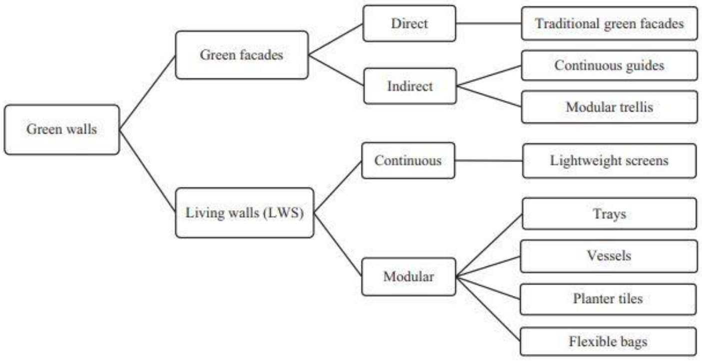


Fig 1: Classification of green walls based on construction characteristics (2)

2.1 Green Facades

It has two systems, a Direct greening system, and an Indirect greening system. Traditional green facades are also known as direct greening systems as it uses self-clinging climbers that are planted directly in the ground. (Figure 2).

Modern green façade also known as indirect greening systems incorporates a support structure vertically for the climbing plants to grow (figure 3). In this type, plants can be rooted in the ground or planters, and be trained to grow along a support structure. Continuous and modular technologies are included in indirect greening systems.

Fig 2: Traditional Green Façade, Lleida Spain

Fig 3: Indirect greening, Babylon Hotel, Vietnam

- Continuous guides: A single support structure serves as the basis for continuous guides, which control plant growth throughout the whole surface. (figure 4)
- Modular trellises—are constructed by placing many of these components along the surface. The

modular trellises include unique support structures for directing plant development and vessels for plants to root in. (figure 5) [7], [8]

Fig 4: Continuous guide, Helios residences, Singapore

Fig 5: Modular trellises, Pasona headquarters, Japan

2.2 Living Wall

Based on application, living wall systems (LWS) are divided into continuous or modular. Continuous LWS uses thin, porous screens into which individual plants are placed. Continous LWS is also known as “Mur Vegetal”, (Figure 6) discovered by French botanist Patrick Blanc. While in modular LWS, specific dimensions are included, including the growing medium. The components are either fastened directly to the vertical surface or supported by an additional structure. (Figure7) The installation, structure, and weight of modular LWS varies, which includes flexible bags, planter tiles, trays, or vessels.

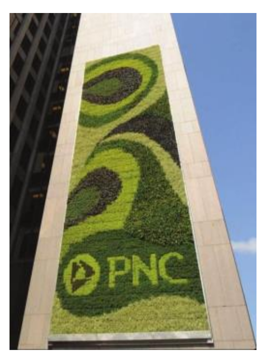
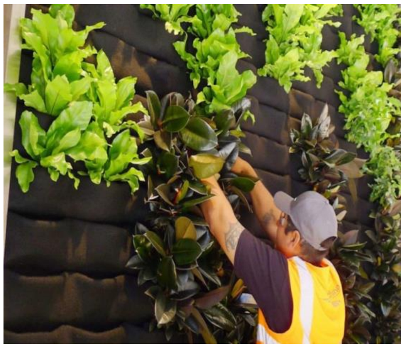


Fig 6: Mur Vegetal, Quai Branly museum, Paris **Fig 7:** Modular LWS, One PNC Plaza, USA.

- Flexible bag: it comes in lightweight material with a growing medium that makes the installation of vegetation easy on surfaces with various shapes, like sloping and curved surfaces. (Figure 8)
- Planter tiles: it has a unique shape as a design feature for the outside or interior cladding of buildings. They serve as an innovative approach to cladding by inserting the plants rather than just forming a layer of vegetation. (Figure 9)

- Vessels: it is typical plant support, with the difference being that it can be attached to vertical structures.(Figure 10)
- Trays: consist of several interlocking pieces made of lightweight materials like plastic or, metal (Figure 11) [7], [8]



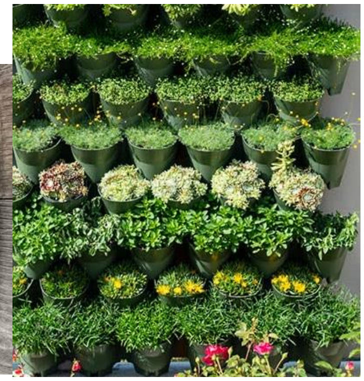


Fig 8: Flexible Bag **Fig 9:** Planter Tile **Fig 10:** Vessels

3. SYSTEM REQUIREMENTS

Fig 11: Modular LWS (Trays) Hotel intercontinental, chile

3.1 Supporting Element

- Direct green facades or Traditional or unsupported. It is dependent on the climbing plant's ability to fix itself on the wall. The risk of plants falling after reaching their maximum coverage is high as it does not require any additional support.
- Indirect green façades or "double-skin facades," separate the building's surface from the plants with an air gap. These structures, whether continuous or modular, anchor and support the weight of the plant, increasing the system's tolerance to environmental factors. It is made of stainless or galvanized steel cables, wires, or trellises. The steel structures and tensile cables support the climbing plants with denser foliage while the slow-growing plants are supported by using grids and wire nets since they have less spacing between them. (Fig 12).

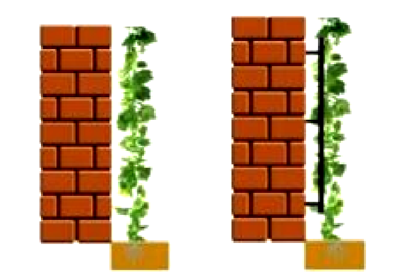


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Fig 12: Direct and Indirect green façade

- Living wall: It has a frame for holding the materials and supporting the plants (Figure 13)
- Continuous LWS: the frame is fastened to the wall by creating an air gap between the surface of the wall and the system. This frame holds the bottom panel and the additional layers which are porous, flexible, and root-resistant screens that are fixed to the base panel and shield the wall from moisture. The outside layer of the screen is then cut to create pockets for the insertion of each plant separately (Figure 14)
- Modular LWS: consists of vessels, planter tiles, trays, and flexible bags made of lightweight interlocked parts, such as polypropylene, polyethylene, aluminum, stainless steel, and galvanized steel.

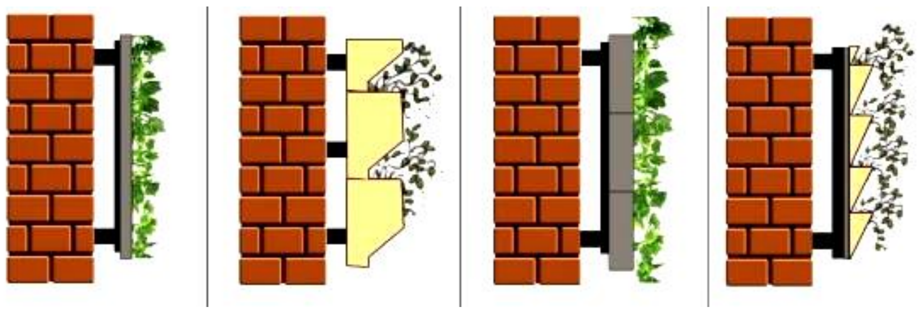

Fig 13: Living wall (left to right), continuous LWS,Vessels,Tray,Flexible bags

3.2 Growing Medium

- Green façade plants grow from the growing medium placed at the base level.
- Continuous LWS does not require substrate. These systems make use of thin, absorbent screens with pockets where plants are placed. Due to the lack of substrate, continuous LWS are frequently hydroponically based and need a constant supply of fertilizers and water.
- Modular LWS can be grown in the organic or inorganic growing medium. Peat moss, coconut coir, bark, wood fiber, rice hulls, and wood fiber, are a few examples of organic materials. Perlite, pumice, vermiculite, sand, and hydrogel, are a few inorganic components. Compared to soil these growing medium are light in weight and helps in water retention.

3.3 Vegetation

- The green façade has a limited choice of plant selection. Climbing plants are thought of as an inexpensive method of vertical greening. Evergreen or deciduous foliage are the two basic forms of plant species used. There is a noticeable visual difference for the entire year as deciduous plants shed their leaves in the fall while evergreen plants keep their foliage all year. It's crucial to keep in mind that climbing plants have some growth restrictions. Some species reach 5 or 6 m, 10 m, and even 25 m, and it takes them around 3–5 years to cover their whole area. The use of vegetables and aromatic herbs in green facades is one of the latest ideas for green walls. (Fig 14)

Fig 15: Edible and aromatic herbs (Left to right) indirect green façade and modular LWG

Living wall has a wide variety of plant choices. it explores the application of plant species to create patterns, contrasts in color, texture, leaves shapes and density, vibrancy, and growth to create pleasing designs

3.4 Drainage

For removal of excess moisture and improved aeration from the substrate, the modular system has grooves or holes on the sides and rear face of modules to encourage plant growth.

3.5 Irrigation

Irrigation is completely dependent on the type of system, plant species used and the climatic condition of the region. An irrigation system is needed to supply the necessary water for plant growth in modular green facades and LWS. To promote the growth and development of the plant water is treated with nutrients, fertilizers, phosphates, minerals, amino acids, or hydroponic materials. Modular LWS and modular green façades use drip irrigation systems while the irrigation system for plants in Continuous LWS is located at the top of the structure and connected to the main irrigation system. The permeable screen enables the uniform distribution of water and nutrients along the surface.

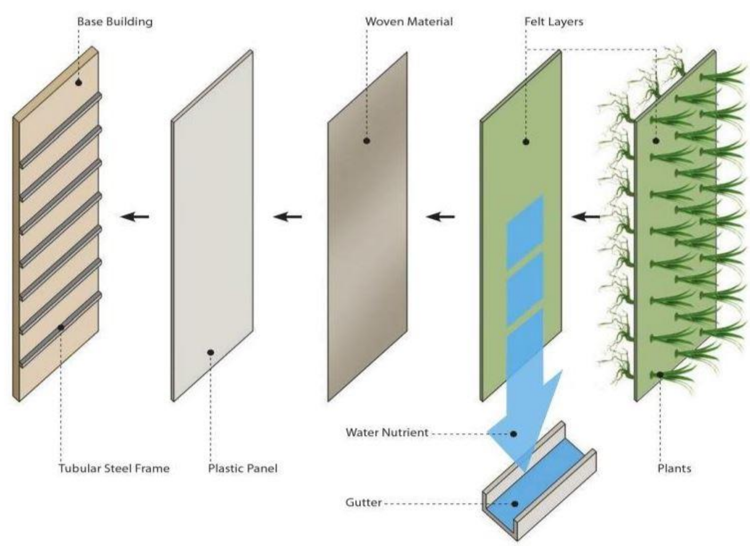

Fig 14: Exploded view of continuous LWS showing its irrigation

3.6 Installation and Maintenance

- Green façades with climbing plants are very economical, but their plant diversity is constrained. These systems exhibit issues in preserving vegetative continuity when plants need to be replaced. Some climbing plants need support as they develop to make sure they cover the entire surface. It's also necessary to remember that some climbing plants have the potential to ruin building surfaces by penetrating cavities or fractures with their roots.
- Continuous LWS are frequently hydroponic systems, which have a disadvantage in terms of sustainable development as it increases the maintenance costs due to the need for a constant supply of water and nutrients.
- Modular LWS: To reduce installation, maintenance, and replacement issues, a growing number of modular LWS are being introduced to the market [4], [9], [6], [5]

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3.7 Cost

Living wall installation is expensive and requires additional maintenance than the green facades. the cost of a good system varies between Rs 1650 -1800 per sq foot. a basic system cost between 800 -1200 per sq ft.

4. COMPARISON OF GREEN FAÇADE AND LIVING WALL [2]

System	Divisions	Subdivisions	Merits	Demerits
Green facade	Traditional greening	Traditional green façade	Requires no support, growing media, and irrigation Low cost and environmental burden Climbing plants	Limited plant choice based on climate Slow surface coverage with a scattered growth Surface deterioration and maintenance problem Plant detachment
	Modular greening	Continuous guides	Development guidance for plants Low water consumption Climbing plants	Limited plant choice Slow surface coverage Scattered plant growth
		Modular trellis	Lightweight support Development guidance for plants Controlled irrigation For maintenance, it is easy to assemble and disassemble Climbing plants	Limited plant choice High installation cost Scattered plant growth
Living wall	Continuous systems	Felt pockets	Uniform growth Wide variety of plants High aesthetic value Uniform nutrients and water required Shrubs, grasses, and perennials	Complex to install High water and nutrient required Heavy maintenance
		Trays	Easy to assemble and disassemble Wide plant variety Controlled irrigation	Complex to install Limited surface form based on tray dimensions

	Modular system		Shrubs, grasses, perennials, and succulent plants	High environment burden of materials used.
		Planter tiles	Increased variety of plants Great aesthetic value Attractive designs can be created	Complex implementation Limited space for root development Surface form limited based on tile sizes High installation cost
		Flexible bags	Adaptable for clopped surface Wide variety of plants with aesthetic value	Complex to install Limited to maximum load building High installation cost

5. ENERGY SAVING MECHANISM

A plant-covered façade's energy balance is influenced by heat flows, including Solar radiation, Heat radiation exchange between the sky and the façade, vegetative layer and the facade, Convection to and from the façade, Evapotranspiration of plant layer, Storage of heat in façade material, Conduction of heat through the façade.

5.1 Evaporative cooling

During the process of transpiration in plants, Oxygen is released and carbon dioxide is taken in more easily by plants with leaves. At the same time, water from the plant evaporates from the surface of the leaf and enters the atmosphere. The term for this procedure is evapotranspiration. Evapotranspiration is carried out through stomata, on leaf structure through which the gas exchange between the leaf and atmosphere is controlled. The rate of evapotranspiration depends on the stomates aperture, which is dependent on the air temperature, relative humidity, and light levels.

Temperature: The rate of evapotranspiration increases with the increasing temperature due to a higher amount of energy available to convert the liquid water to vapors.

Humidity: The transpiration and evaporation rate drops when the humidity level is high.

Light level: As a response to the light levels, the stomates open during the day and close at night, indicating that evapotranspiration does not occur at night.

5.2 Thermal insulation

The vegetated wall improves the insulation properties of a structure, which reduces the annual consumption of energy. The green vegetation minimizes the heat loss from the structure in winter and heat gain into the fabric in summer; it additionally adds thermal mass to balance the internal temperature in the entire year.

5.3 Wind Barrier

In winter, obstructing the wind's impact on the structure façade will increase the structural energy efficiency, as the cold wind is significant in reducing the indoor temperature of the structures. The green vegetation system of buildings plays a major role in blocking the impact of wind on the structure's exteriors.

5.4 Shading Effect

The shading effect depends on foliage density. Leaf area index (LAI), leaf dimension, plant layer thickness, and density are used to express it. The projected total leaf area per unit surface area—which varies with pla+nt size, frequency, and age—is referred to as the leaf area index. The range is between less than 1 for young plants and loose foliage that does not cover the wall to 3-5 for older plants with thick foliage. The facade orientation with the most sun exposure reduces heat conduction and lowers surface temperature the most. For the northern hemisphere, vegetation on the east and west sides significantly improves façade thermal efficiency. The shading effect by vegetation has a great impact in a hot climate throughout the year rather than in temperate and cold climates during summertime [6], [5].

6. CONCLUSION

The primary issues in the area of the green wall are to develop alternative methods to improve the performance and durability through simple installation and maintenance methods. The success of the vertical greening system is dependent on the right selection of the type of vertical greening which is influenced by climate, budget, maintenance, and purpose of implementation. Therefore it is mandatory to understand the different systems for choosing the right type of vertical greening. Making it successful does not end immediately after its installation as it requires careful maintenance and regular irrigation. Even though it requires additional time, effort, and money the benefits obtained by it are numerous. It is the only positive approach to bring back the lost greenery to mitigate the rising temperature which has resulted due to rapid urbanization.

7. REFERENCES

[1] (12 November 2013). The 2013 Joint Symposium on Innovation and Technology for Built Environment, Hong Kong, p. 1-12

[2] Antony Wood, Payam Bahrami& Daniel Safarik. (2014). Green Walls in High-Rise Buildings: An Output Of The CTBUH sustainability working Group. council on tall buildings and urban habitat:Chicago,

[3] Aznar, F., Echarri, V., Rizo, C., Rizo, R. (2018). Modelling the thermal behaviour of a building facade using deep learning. PLoS ONE, 13 (12), e0207616, https://doi.org/10.1371/journal.pone.0207616 Building and Environment, 46 (11), 2287-2294, ISSN 0360-1323,

[4] Bustami, Rosmina, A., Martin Belusko, James Ward and Simon Beecham. (2018). Vertical greenery systems: A systematic review of research trends. Building and Environment, n. pag. https://doi.org/10.1016/j.buildenv.2011.05.009.(https://www.sciencedirect.com/science/article/pii/S036013231100148X)

[5] Katia Perini, Marc Ottelé, Fraaij, A.L.A., Haas, E.M., Rossana Raiteri. (2011). Vertical greening systems and the effect on air flow and temperature on the building envelope.

[6] Koumoudis, S. Green wall planting module, support structure and irrigation control system. US 2011/0088319 A1; 2011.4

[7] Manso, Maria & Castro-Gomes, João. (2015). Green wall systems: A review of their characteristics.

Renewable and Sustainable Energy Reviews, 41, 863–871, 10.1016/j.rser.2014.07.203.

[8] Perini, K., Ottelé, M., Haas, E and Raiteri, R. (2011). Greening the building envelope, facade greening and living wall systems. Open Journal of Ecology, 1, 1-8. doi: 10.4236/oje.2011.11001.

[9] Tamási, A., Dobszay, G. (2015). Requirements for Designing Living Wall Systems – Analysing System Studies on Hungarian Projects. Periodica Polytechnica Architecture, 46 (2), 78–87. https://doi.org/10.3311/PPar.8337