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EFFECT OF GREEN FAÇADE ON THERMAL COMFORT IN OFFICE BUILDING

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Abstract: **Recent concerns of sustainability in architecture have brought about the need for buildings to conserve energy and have less impact on the environment. green façade systems can be used as a passive tool for energy savings in buildings. Those studies proved that installing a vertical greening system on the building facade has many advantages not only for the building but also for the city. Acting as a shading as well as thermal insulation in the building, reducing greenhouse gas emission, and improving the microclimate are some of the advantages of vertical greening system that already being proved. This study aims to review some studies related to the thermal performance of vertical greening system on the building façade. This paper explores the literature on green façade systems and goes on to focus on the effects of this facade on the thermal comfortability in office buildings. By means of literature review we are able to understand the energy saving potential the green façade has on buildings.**

Keywords: **Green façade, vertical greening, Thermal comfort, Façade, plants.**

1. INTRODUCTION

Thegreen façade is an exterior wall planted with plants used mainly for decorative and ecological purposes. In order to create the vertical greening façade, the plant must have certain characteristics and the soil and water system must occupy the wall or support structure. The plant used for the vertical greening façade is usually the plant of aerial roots, vines and climbing plants as well. For the plant to be able to climb or cascade down the structure, the support structure is used.

Vertical garden or green façade are also becoming popular landscape design for home and building, according to (Sunakorn and Yimprayoon, 2011). It is widely known that the plant absorbs heat and light from the sun for the process of photosynthesis and is the best solution to boost air quality in some areas as it absorbs carbon dioxide during the day. Based on these parameters, we can conclude that in a house, the vertical greening system can minimize heat and temperature as well as improve the air quality.

Greening the building façade in cities using climbing plants can change the building-environment interaction. This interaction lowers the building's outside temperature and cools the respective internal space s. For their growth, plants absorb significant amounts of solar radiation and biological functions. It serves as a natural barrier to prevent excessive sunlight from the sun. Vertical greenery system (VGS) becomes a strategy for greening the city by taking advantage of larger wall spaces available in urban canyons, reducing heat and energy consumption and increasing the cooling effect on all areas around the building.

Today, rising temperatures are due to the replacement of natural vegetation with pavement, buildings and other structures in urban areas. Tree supply can cool the building and its surroundings by shading and reducing the heat emitted and evapotranspiration (Wong et al., 2010; Chiang and Tan, 2009; Cheng et al., 2010; Wong et al., 2010b). The natural process of evapotranspiration is the process through which water is transferred through transpiration from plants from the ground to the atmosphere. It shows that plants provide a cool environment where the soil and plants are perfectly insulated (Papadakis et al., 2001; Wong et al., 2003). Vertical greenery system is a great way to save energy in air conditioning, and its benefits do not end there. It occurred because the plants found in the VGS were present. Living walls and green façades improve thermal comfort in both indoor and outdoor building environments by reducing heat transfer from and to the building envelope (Stec et al., 2005). They shade solar radiation buildings, absorb solar radiation for photosynthesis and evapotranspiration, decrease solar reflection and atmospheric re-radiation (Wong et al., 2010).

Ecology and environment are beneficial for green roofs, such as improving air quality and reducing air pollution, increasing biodiversity, reducing the effect of heat island in urban areas. This is due to the lower amount of heat emitted by greening and humidity that is affected by plant-based evapotranspiration and indirect benefits as energy savings for buildings (Ottelé et al., 2010). Indeed, both the growing medium and the plants themselves provide isolation and shade that can reduce energy for cooling and enhance indoor and outdoor comfort, especially in the Mediterranean region (Wong et al., 2010b).

In addition to these benefits, social and economic values are involved in improving the durability and the psychological feelings of citizens with regard to the real estate market.

Cooling serves the basic function of providing health and comfort. In warm climates, especially where the humidity is high, comfort does not only depend on the rate of fresh air supply is obtained, but more to the speed at which the air moves around the space to promote evaporation cooling. Prianto and Depecker (2002) stated that one of the main challenges in the humid tropics is to induce the movement of air inside the building in a crowded urban life with low wind speeds. In this study, a measurement of low air velocity was recorded in this building's fourth floor, which is 0.023 m / s. This situation occurs because of the building's on-site position and orientation. It confirms a study conducted by Chiang et al. (2000) on the impact of design parameters on the internal air flow to enhance thermal comfort such as the building's position and orientation, window size, interior partitions, and balcony and roof shape effects.

2. METHODS AND MATERIALS

This is a desktop study done by reviewing the literature relating to the green façade and thermal comfort. The reviews will be collected from different articles on this specific topic The basic review questions to be answered where: what are the benefits and threats of the green façade? what is thermal comfort? What are the factors affecting thermal comfort? what are the thermal effects on vertical greenery system.

3. LITRRATURE REVIEW

3.1 Benefits and threats

Aesthetic enhancement and sound reduction are the common benefits of green facades. They can also serve as an “extra insulation” of the building envelope [M. Ottelé, TU Delft, 2011.]. In winter, evergreen vegetation layer decreases the wind flow around the building façade. In addition heat radiation of the external walls is insulated by the dense plant foliage and thus help prevent building to be cooled down [K. Perini and P. Rosasco, vol. 70, pp. 110–121, Dec. 2013.]. Of all sun light that falls on the leaves, merely 5–30% of energy is passed through the leaf. The others may be reflected, transformed into heat, used for photosynthesis or evapotranspiration. This blocking of the direct sunlight disposal ensures a cooling effect in warmer climates and help the reduction of heat island effect especially in urban areas. [R. Sharp, J. Sable, F. Bertram, E. Mohan, and S. Peck 2008], [N. H. Wong, A. Y. Kwang Tan, Y. Chen, K. Sekar, P. Y. Tan, D. Chan, K. Chiang, and N. C. Wong, 2010]. Due to the evapotranspiration, green façades cool the heated air through evaporation of water [M. M. Hasan, A. Karim, R. J. Brown, M. Perkins, and D. Joyce 2012]. A research in Australia quantified energy saving and indicated that the green façade can save 9.5-18% of the cooling energy consumption in commercial buildings [K. Sathien, K. Techato, and J. Taweekun 2013], [H. D. van Bohemen, M. Ottelé, and A. L. A. Fraaij, 2009]. Relevantly improves the buildings’ energy efficiency and produces ecological benefits for a more sustainable urban environment, [M. Köhler, 2008], [A. K. Pal, V. Kumar, and N. C. Saxena,2000]. The green envelope also reduces the quantity of UV light and cause a positive effect on building durability [M. M. Hasan, A. Karim, R. J. Brown, M. Perkins, and D. Joyce 2012].

Some of the benefits of installing vertical greening systems in the building facades have been proved by the previous research. Those benefits are including the provision of indoor sound insulation [C.A. Pope, M. Ezzati, D.W. Dockery,2009], filtering the air from the outside thus providing better indoor air quality [R. Kumar and S.C. Kaushik,2005], and acting as an external shading that moderating indoor temperature [R. Kumar and S.C. Kaushik,2005]. These studies show the added value of vertical greening systems application in building envelope. Installing vertical greenery on the building façade will provides benefits not only for the environments, but also for the building itself and the user of the building.

On the other hand the installation costs of direct green façade as well for indirect greening are climbing plants, and a dig at the base of the façade and the supporting system and steel mesh cost should be added to indirect green façade. For the indirect green façades combined with planter boxes the costs are higher because besides these systems they require an irrigation system. Maintenance cost depends on the type of the green façade. For the direct and indirect green façades, which is planted at the base of the façade, maintenance covers only pruning every year. These costs are different for the first four years and for the other remaining years of service life. For the indirect greening system combined with planter boxes, maintenance needs include also the plant species substitution and water pipes substitution [K. Perini, M. Ottelé, E. M. Haas, and R. Raiteri,2012].

3.2 Thermal comfort

Accommodating the occupant of the building with a satisfactory thermal condition is the essential principle for achieving an adequate environmental condition. Thermal comfort is the state in which the mind of the person is satisfied with the current thermal situation in their surroundings, according to the British Standard BS EN ISO 7730 (2005). Briefly, it is when the brain of a human induces the sensation of either too warm or too cold.

3.2.1 Factors affecting thermal comfort in working area

It is difficult to define the term thermal comfort as it depends on certain criteria and varies depending on the human body. The factors affecting workplace thermal comfort, however, can be divided into two main categories, environmental factor s and personal factors (McMullan, 1998).

3.2.1.1 Environmental factors

- Air temperatures
- Radiant temperatures
- Air velocity
- Humidity

3.2.1.2 Personal factors

- Clothing insulation
- Metabolic rate

The environmental factor is where the thermal state is considered during the assessment of thermal comfort. Using certain instruments and measuring, this element can be obtained. However, as the human psychology is different, the personal factors are difficult to measure. McMullan (1998) may support this claim, whereby the occupants hardly come to terms with the fact that their offices ' current internal atmosphere is good enough.

3.3. Thermal effects on vertical greenery system

Francis and Lorimer (2011) state that the potential of living walls is called reconciliation ecology to represent ecological engineering technique. It is a more realistic and practical solution to change the diversity of anthropogenic habitats without affecting land use. It is confirmed by Pérez, et al. (2011) that between the building wall and green facade created, and it has the characteristics of low temperature and high humidity in accordance with the surrounding ecology. Kontoleon and Eumorfopoulou (2010) found that for east or west oriented surfaces, the influence of a green layer on the wall surface was more pronounced. Wong et al. (2009) performed a simulation research and found that green facade is able to lower the mean radiant temperature values and that 50% greenery coverage and a shading coefficient of 0.041 can reduce the envelope thermal transfer value of a glass facade building by 40.68%. In terms of influencing air temperature and wind speed, Sunakorn and Yimprayoon (2011) studied climbing plants as vertical shading devices for naturally ventilated buildings. The bio facade room's indoor air temperature remains below the control room during the daytime. In a naturally ventilated room, the bio facade also improves ventilation. The difference between the green façade directly attached to the wall and the green façade indirectly attached to the wall (with an air gap) was studied by Perini et al. (2011).

On the surface of the wall behind the direct green façade, a small temperature reduction of 1.2oC was found compared to t he surface of the bare wall, and an indirect greenery system reduction of 2.7oC was found. In principle, a living wall's cooling effect is beneficial in reducing the energy consumption needed to cool a single building, and reduces the city's heat-insulating effect. Wong et al. (2010b) stated that it has the potential thermal benefits of vertical greenery systems to reduce the surface temperature of building facades in tropical climates to a maximum temperature of 11.5o C. This is a significant reduction in wall temperature that will result in a corresponding reduction in the energy of the cooling load and consequent energy cost savings.

4. CONCLUSION

Green façade provides environmental benefits including energy conservation, air pollutant reduction and also improves thermal comfort. It also act as insulation in the building in the research. Green façade is also acts as shading that blocks direct solar heat, thus the thickness of the greening façade system and its distance to the building envelope are also things that affect interior temperature reduction. The thicker the greening façade, the solar thermal propagation time to the interior space will be longer. This resulted in the stability of interior temperature for a longer time. Considering this reason, the system of double skin green façade and living wall has more advantages compared to traditional green façade.

Another advantage of green façade that proved by the previous research is its ability to improve the wind velocity in the cavity between the wall and the greening system. This makes green façade suitable to use in the area with low wind speed characteristic. Further studies still need to be done to find out the optimum distance of the green façade's cavity to achieve the optimum wind velocity.

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