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A Review of Thermal, Acoustical and Daylight Performance of Greenery Systems in the Realm of Green Building

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Greenery systems (for instance, green wall, green roof, etc.) for buildings remained much unexplored in the realm of green building concept, especially in the densely built-up areas of inner cities. Greenery systems concentrate on one key aspect of the greening process: the use of plants on and around buildings. It goes without saying that this can only be part of any overall greening strategy. Greenery systems help improves the local climate of the built environment by extending onto the roofs and/or facades of the building. There are many benefits of greenery systems in consideration of both indoor and outdoor built environments, for instance, in the management of thermal comfort, energy efficiency, absorbing pollutants, rainwater manager, as an aid for diversity (including genetic, species and ecosystem diversity), and reduce sound pollution. However, despite these benefits relatively little research has been made on this valuable opportunity.

This research paper concentrates greenery systems and its effect on thermal, acoustical and daylight performance in an indoor and built environment. The paper concludes that the greenery systems have significant potential as a tool to make building design a green building.

***Keywords*:** Green Building, Heating-Cooling, Acoustics and Daylight Performance, Vertical greenery systems

1. Introduction

Greenery system can be developed along various spaces of the building, that is; courtyards, terraces, balconies and so on. There are different types and typologies of greenery systems (refer Figure 1) for building; therefore, available data in this regards is scattered and spare. A systematic literature review is implemented towards understanding the greenery systems and its contribution to the sustainable designing of the building specifically for heating, cooling, acoustics and daylight performance.

Over the years, as noted by Chen Wang greenery systems has emerged from horticulture, aesthetic (or artistic expression) design, exterior, and interior landscaping, providing fashion function for the built environment (1). Advantages and disadvantages of green walls depend on many factors, for instance, installation methods, layout plans (location), types, etc.

Some studies have also shown that the greenery systems in workspaces, industry, and psychological responses that user of the building have from plants of the greenery systems may influence human behaviour and attitude at large. Alongside, it will also enhance the overall wellbeing at the workplace and productivity (2) (3). Researchers used various methods in the evaluation of the effectiveness of the green walls. These methods include qualitative (questionnaire survey of the occupants) and quantitative approaches. Greenery systems evaluations include both indoor as well as outdoor built environments.

Qualitative research on green walls in an indoor built environment revealed aesthetic as a top benefit whereas fewer benefits towards noise mitigation, as its effectiveness depends on the density

or surface coverage. On the contrary, research on green walls on the outdoor surfaces revealed significant benefits of both aesthetics and noise reduction (4). Both, indoor and outdoor air quality can be enhanced by the greenery systems as it filters toxic environmental contaminants from various pollutants.

Type	Plants for the greenery system	Growing media for the greenery system	Construction type required for the greenery system	Example of the greenery system
Wall-climbing greenery system	Climbing plants	Soil on the ground or in planted box	Minimal supporting structure is needed	
Hanging-down greenery system	Plants with long hanging-down stem	Soil in planted box on every story	Planted boxes and supporting structure should be built at according storey	
Module greenery system	Short plants	Lightweight panel of growing media (such as compressed peat moss)	Supporting structure for hanging or placing modules should be built on facades	

Figure 1: Outdoor Greenery Systems Type and Methods

2. Thermal Performance

Varieties of heating and cooling systems are explored in the green building design to ensure the requirements of the thermal comfort of the building user. The interaction between the building user, the heating systems and the fabric of the building is vital in the context of the energy (and resource) efficient performance of the system, the cost of capital investments and the achieved comfort. Evapotranspiration from the vegetation used in such a greenery system lowers the temperature around the planting environment. Assessments of the thermal performance of an indoor green wall have been observed by several researchers. Thermal performance in an indoor and built environment refers to how well a structure responds to changes in the atmospheric temperature during the daily and seasonal cycles.

Greenery systems influence several environmental parameters and thus also influence the thermal comfort of the occupants. Assessments of the greenery system's thermal performance and its influential responses on environmental factors such as air temperature, relative humidity, air speed, and radiant temperature have been observed by several researchers (5).

Rafael Fernandez-Canero estimated the untapped cooling potential of the greenery systems by using various substrates (namely, Geotextile, Epiweb, Xaxim, and coconut fiber) in a warm

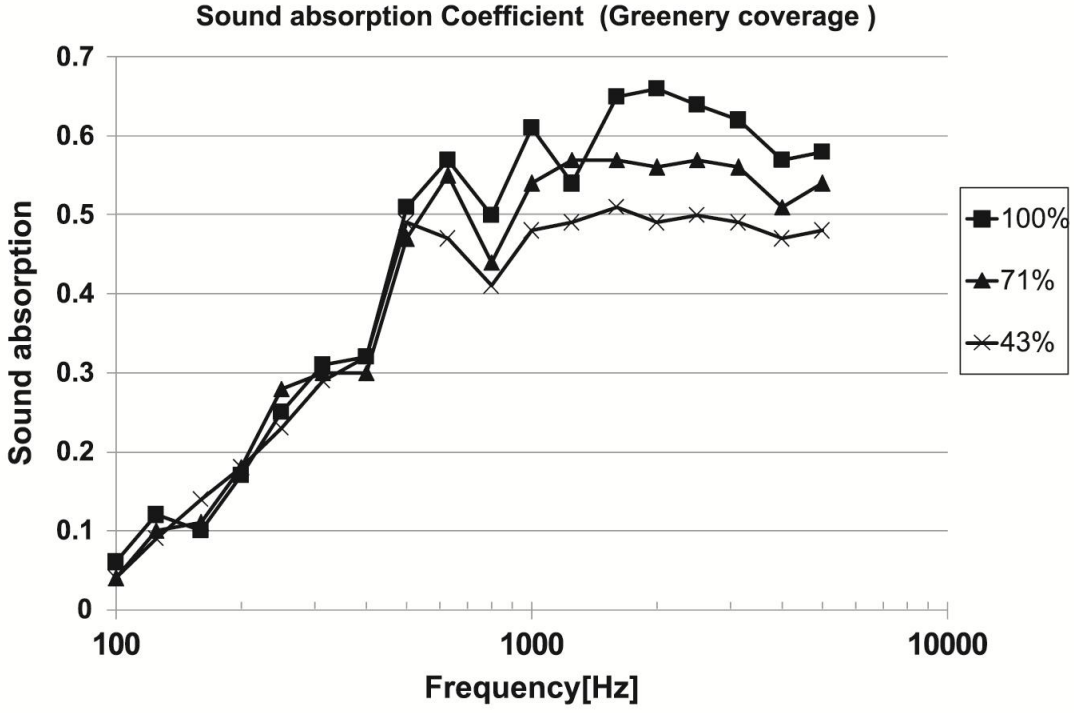
climate. In this research, in addition to plant growth and water consumption, Rafael monitored various factors, for instance, temperature and humidity (5). The research concluded with a significant cooling potential of the green wall.

An increase in the moisture levels was observed in the overall built environment and a little higher near the green wall in specific. Because of the increase in the moisture levels in the air, decrement in the room temperature was also observed. In warmer climatic condition the reduction in the room temperature was observed as around 6°C with an average reduction of 4°C in general. Thus, in this research, the greenery system was investigated and its potential in terms of cooling response, elimination of contaminants in the air and aesthetic expression of the built environment were tested. Similarly, several studies suggested that through evapotranspiration indoor and built environment can control humidity and air cooling is possible.

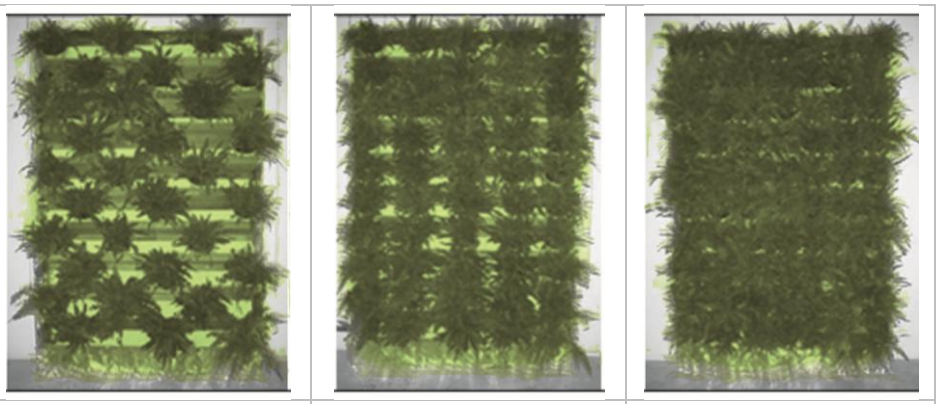
In addition to above-noted potentials, greenery systems, in many researches have been concluded highly effective for warm, arid and composite climatic regions as it provides protection from solar harmful radiation and the atmospheric greenhouse effect, contributing to combat climate change.

3. Acoustical Performance

Greenery systems are also an acoustic insulation system as it acts in passive noise reduction. Vegetation elements of the green wall, for instance, trunks, branches, flowers, twigs, needles, leaves, decayed elements and rough (and or loose) soil cause mechanism system of reflection, dispersion, and absorption of sound. When sound waves fall on vegetation surfaces of the green wall, energy conservation phenomenon with thermo-viscous acoustics occur, contributing to sound attenuation. Thus, absorption of mechanical vibration (caused by sound waves) and conversion of sound energy to heat energy with the help of vegetation elements results in sound levels reduction. Sound absorption is directly proportional to the greenery coverage on the surfaces of the environment. Figure 2 shows greenery systems modules arrangements with their sound absorption coefficient with respect to its arrangements (6) (figure composed and summarised from the various literature review with a base of research of Nyuk HienWong).



(a) Sound Absorption Coefficient of Greenery Modules



Low (43%)	Medium (71%)	High (100%)

(b) Greenery System Modules

Figure 2: Greenery Systems Modules (Low, Medium and High) Arrangements with its Sound Absorption Coefficient.

Besides vegetation type and module arrangement (density or surface coverage) as noted in figure 2, growth media is equally a crucial contributor to noise mitigation by greenery systems. In this context, destructive interference and constructive interference of sound waves are one of the unexplored research areas in the realm of sound levels reduction by greenery systems.

Accordingly, there are varieties of parameters that manipulate noise mitigation in greenery systems, for instance, the type, the depth, the pattern of module arrangement, the density (or surface coverage) of the growth media (4).

3. Daylight performance

Greenery systems in the indoor not only help improve indoor air quality but also screen or reduce the glare of the (indoor penetrating) daylight. Figure 3 shows how green wall helps reduce glare and the harshness of the daylight into the interior of a building courtyard.

Figure: 3 Green Walls Reducing Daylight Glare Effect in the Interior of a Building Courtyard.

The literature review revealed that species of indoor vegetation can be selected depending on its requirement of daylight to grow. And, use of indoor greenery systems does not have compulsion on the penetration of daylight in the indoor for the vegetation growth and functioning. There are certain low-light-requiring indoor vegetations which absorb carbon dioxide and contaminants enriching the air quality of an indoor built environment. Research on daylight pointed out the importance of greenery systems to diffuse the light and to avoid direct penetration of daylight especially in spaces for newborn babies and old age occupants.

4. Conclusion

Greenery systems have been observed to enhance occupant comfort in many ways. In this context, the paper contributes a summary of literature review pertaining to the thermal, acoustical and daylight performance of greenery systems in the realm of green building design. However, there is scare data and little research done on the greenery systems, and its potential opportunities in the thermal performance, acoustical performance and daylight performance in an indoor and built environment. Further research is required on the greenery systems and its sustainable mechanism to make building design a green building. Detail research is required on plant species, type/ typologies, layout patterns, light source, surface area coverage and its results on the energy performance of the built environment.

References

1. Chen Wang, San-San Er, Hamzah Abdul Rahman. Indoor vertical greenery system in urban tropics. Indoor and Built Environment, pp. 340-356. (2016).

2. Bluyssen, P. M., C. Roda, C. Mandin, S. Fossati, P. Carrer, Y. de Kluizenaar, V. G. Mihucz, E. de Oliveira Fernandes, and J. Bartzis. Self-reported health and comfort in 'modern'office buildings: first results from the European OFFICAIR study. 2, Indoor Air, Vol. 26, pp. 298-317. Apr (2016).

3. Tove Fjeld. The Effect of Interior Planting on Health and Discomfort among Workers and School Children. American Society for Horticultural Science, HortTechnology , Vol. 10, pp. 46-52. 10630198. (2000).

4. Z Azkorra, G. Perez, J Coma, L F Cabeza, S Bures, J E Alvaro, A Erkoreka, M Urrestarazu. March, Evaluation of green walls as a passive acoustic insulation system for buildings. Elsevier, Applied Acoustics, Vol. 89, pp. 46-56. 0003-682X. (2015).

5. Rafael Fernandez-Canero, Luis Perez Urrestarazu, Antonio Franco Salas. Assessment of the Cooling Potential of an Indoor Living Wall using Different Substrates in a Warm Climate. 5, Sage, Indoor and Built Environment, Vol. 21, pp. 642-650. 1420-326X. (2011).

6. Nyuk HienWong, Alex Yong Kwang Tan, Puay YokTan, KellyChiang, Ngian ChungWong. Acoustics evaluation of vertical greenery systems for building walls. Building and Environment, Vol. 45 Issue 2, pp. 411-420. 0360-1323.