EVALUATION OF VERTICAL GREENERY SYSTEMS FOR BUILDING WALLS

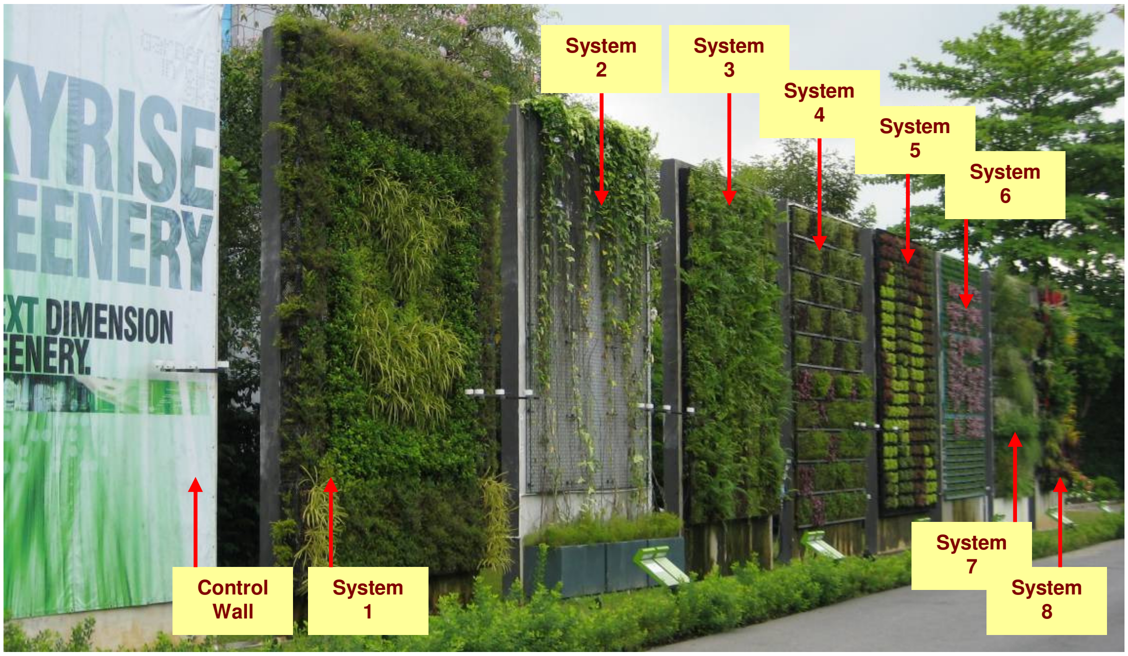

Fig 1: Control wall and the 8 vertical greenery systems in HortPark

With the idea of introducing nature back into the urban landscape, a partnership is strengthening between nature and the city. Since the outer surfaces of building offer a great amount of space for vegetation, planting on roofs and walls has became one of the most innovative and rapidly developing fields. This research involves the study of different vertical greenery systems installed in National University of Singapore (NUS) and HortPark with the 6 following objectives.

Vertical greenery systems can be broadly classified into 2 major categories: green façade and living wall. The 2 frequent green façade systems are the modular trellis panel as well as the cable and wire-rope net systems while the use of planter-cassettes or the modular system with substrate are commonly found in living wall systems.

THERMAL IMPACTS

Vertical greenery systems 3 and 4 appear to have the best cooling efficiency throughout an entire day for the average temperature reduction of the wall surface as well as the best capacity for substrate surface temperature reduction. These results point to the potential thermal benefits of vertical greenery systems in reducing the surface temperature of buildings facades in the tropical climate. A significant reduction in wall temperature will lead to a corresponding reduction in the energy cooling load and consequent saving in energy cost.

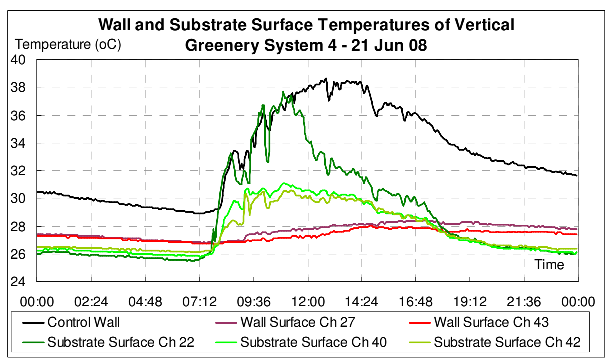

Fig 2: Temperatures of wall and substrate surfaces for vertical greenery system 4 on 21 Jun 08

In terms of the least fluctuation in average wall temperature, vertical greenery system 4 and 1 show the highest capacities. For the least fluctuation in average substrate temperature, no vertical greenery system performs relatively well, having a mix range of values. The capacity of the vertical greenery systems to limit the fluctuation of wall surface temperatures of building facades is valuable in prolonging the lifespan of building facades and cost savings in maintenance and replacement of façade parts.

Table 1: Ambient temperatures

VGS	Temperature (°C)					
	0.15 m		0.30 m		0.60 m	
	Min	Max	Min	Max	Min	Max
0	26.3	34.9	25.2	33.6	25.2	33.6
1	24.8	31.9	26.3	34.0	25.2	32.3
2	25.6	32.8	25.6	32.8	25.6	32.8
4	25.3	31.5	25.2	31.9	26.0	32.8

The effects of vertical greenery systems on ambient temperature are found to depend on specific vertical greenery systems. Vertical greenery system 2 has hardly any effect on the ambient temperature while reductions in the ambient temperature of up to 3.3°C are observed from vertical greenery system 4 at a distance 0.15 m away. Given the preponderance of wall facades in the built environment, air intakes of air-conditioning at a cooler ambient temperature translate into saving in energy cooling load.

ACOUSTICS IMPACTS

The insertion loss experiment shows stronger attenuation at low to middle frequencies due to the absorbing effect of substrate while a smaller attenuation is observed at high frequency spectrum due to scattering from greenery. Vertical greenery systems 2, 7, 5, and 1 have a reduction of 5 dB to 10 dB for low to middle frequency range (125 to 1250 Hz). In the high frequencies (4 to 10 kHz), vertical greenery system 8 outperforms the rest with a highest insertion loss of 8.8 dB.

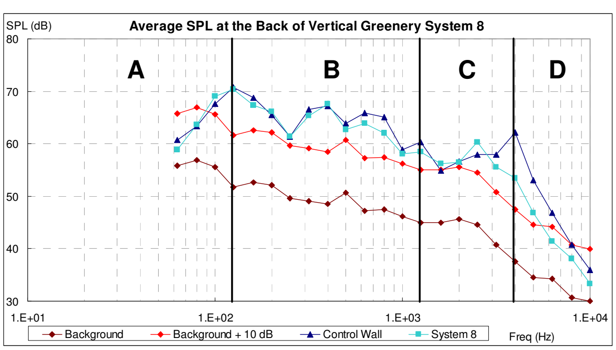

Fig 3: Average SPL at the back of vertical greenery system 8

The sound absorption coefficient of the vertical greenery system in the reverberation chamber is found to have one of the highest values compared with other buildings materials and furnishings. As frequencies increases, the sound absorption coefficient increases. In addition, with greater greenery coverage density, there is an increase in the sound absorption coefficient. Therefore, vertical greenery systems may be useful if they are installed internally to enhance speech privacy.

Fig 4: Acoustics experiment setup of vertical greenery system inside reverberation chamber

ADOPTABILITY AND PLANT SUITABILITY

Based on observation, plants species must be able to tolerate the high temperature and periodic temperature fluctuation of Singapore's weather. Secondly, the substrate moisture requirements of plants, their tolerance to drought and periods of water stress as well as their ability to tolerate moisture on their surface must be taken into account. Lastly, the climbing habit and their degree of aggressiveness of growth should be reviewed to ensure its aesthetic performance.

The correlation equation shows that the shading coefficient has a relationship with the leaf area index (LAI). Furthermore, a lower shading coefficient means a denser greenery coverage density, leading to a greater thermal insulation and a lower LAI. Therefore, the key behind shading is thicker and denser greenery coverage.

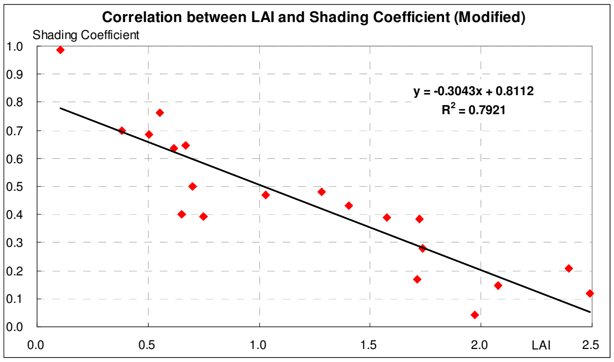

Fig 5: Correlation equation between shading coefficient and LAI

In addition, it is clearly determined that the effect of wind has little or no impact of the plant species, substrate and structure of vertical greenery systems. The concern is to ensure that the substrate is not loose such that it can be blown off under strong wind.

Lastly, results reveal that the volumetric substrate moisture level does have an impact on the substrate back surface temperature. During the interval where watering occurs, the presence of substrate moisture within the vertical greenery system causes the substrate back surface temperature to drop by about 1ºC. Generally, the higher the level of volumetric substrate moisture content, the higher its temperature reduction capability and a water supply of 2 minutes is sufficient to cause an adequate reduction in the substrate back surface temperature.

Table 2: Substrate back surface temperatures

Water Supplied	Temperature (°C)	
	Min	Max
Maximum Supply	23.75	27.80
Medium Supply	23.55	27.80
No Supply	24.48	32.05

PERCEPTION STUDIES

The perception studies are grouped into 3 sections, survey questionnaires directed to building professionals and households, interview questionnaires with landscape architects and suppliers as well as case studies questionnaires to end-users in Singapore Management University (SMU) and Republic Polytechnic (RP).

Research findings from the survey questionnaires suggest that building professionals and end-users generally agree with most of the benefits of vertical greenery systems. However, all 5 respondent groups disagree that vertical greenery systems can enhance the lifespan of building façade, improve rainwater retention and reduce the load on our drainage system. Furthermore, concerns regarding vertical greenery systems that are true are the notions that installing vertical greenery systems require high initial and maintenance cost. There is also a lack of technical information, maintenance instructions and information on plants suitability locally. Lastly, there is lack of awareness of the benefits and performance as well as grants and subsidies for vertical greenery systems.

Fig 6: Vertical greenery systems of SMU

From the interview questionnaires, both the landscape architects and suppliers feel that as vertical greenery systems are still in an infancy stage, there is a huge challenge in building confidence in developers and architects. They believe that vertical greenery systems have a good prospect of being successful. However, there should be continuous technical and professional advice from the experts to the facilities management throughout the entire initial set-up and maintenance period.

From the case studies carried out in SMU, most respondents believe that vertical greenery systems are able to reduce air pollution and provide fresh air. In addition, the lack of building science knowledge may be the reason why respondents are unable to find the link between vertical greenery systems and energy saving. The result of acoustic benefit is also not prominent. Many respondents are willing to install vertical greenery system despite the higher maintenance cost. Lastly, the physiological health of respondents will improve with vertical greenery systems.

Fig 7: Vertical greenery systems of RP

From the RP results, the majority of the respondents believe that vertical greenery system has helped to reduce heat, filter airborne particles and reduce greenhouse gases. However, a number of respondents are unable to see the relationship between heat and pollution reduction with vertical greenery systems. Respondents believe that vertical greenery systems will increase the relative humidity in the air, helps to bring nature closer. Respondents are unable to understand that vertical greenery system will cause a reduction in the energy cooling load, increase the property value and helps to reduce noise pollution.

SIMULATIONS

Simulations are performed to determine the effects of vertical greenery systems on thermal comfort and energy consumption of a building. This is followed by a calculation to obtain their effects on the thermal performance of building envelope through the envelope thermal transfer value (ETTV). Lastly, the role of vertical greenery systems in reducing the UHI effect within an estate is simulated.

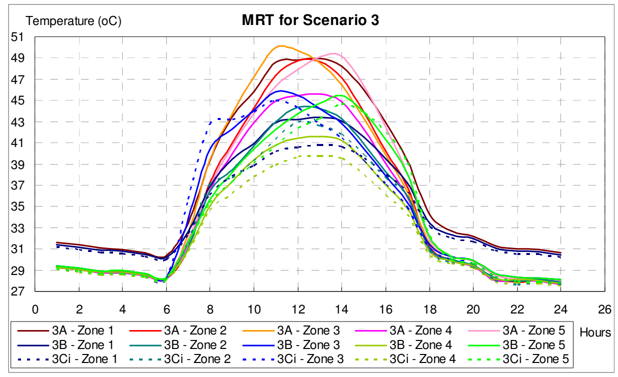

Figure 8: MRT for scenarios 3A, 3B and 3C(i) corresponding to without, with half and with full vertical greenery systems

Energy simulation results using TAS show that vertical greenery systems are effective in lowering the mean radiant temperature (MRT) of a building if the entire glass façade is covered. Similarly, the presence of vertical greenery systems is able to lower the cost of the energy cooling load significantly if the shading coefficients of the plants species are low and the vertical greenery systems cover the entire façade.

With the presence of vertical greenery systems, an ETTV of a building with full glass façade is effectively reduced by 13.38% with a lower shading coefficient.

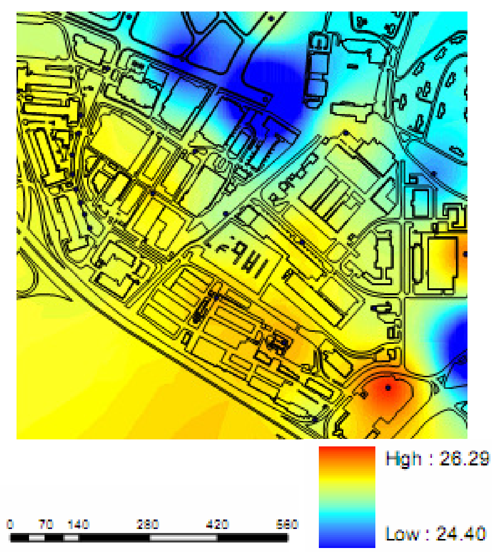

Fig 9: Minimum estate air temperature without vertical greenery systems

From the Screening Tool for Estate Environment Evaluation (STEVE) air temperature prediction model, it is generally true that the presence of greenery is able to reduce the estate air temperature. The increase of greenery coverage from the presence of vertical greenery systems is most significantly felt in the reduction of the minimum estate air temperature, where there is a drop in the minimum estate air temperature throughout a large region of the estate.

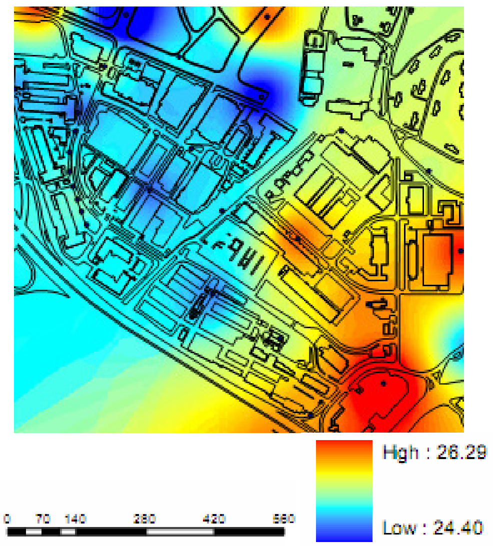

Fig 10: Minimum estate air temperature with 100% vertical greenery systems coverage

CONCLUSION

In summary, many factors such as the physical structure, dimensions of the panels holding the substrate and plants species, substrate type, composition and moisture content have an impact on the performance of vertical greenery systems. The findings from these studies will be helpful in elucidating the complex interactions between various parameters and the role that each factor plays individually and together in the built urban environment.

Perception studies show that only with the appropriate level of government support and industry-government partnerships, can vertical greenery systems achieve sustainable development in Singapore. With all the encouraging perceptions, it is with anticipation that vertical greenery systems will gradually become one of the driving forces realizing Singapore's dream of attaining the status of "City in the Garden".

Contact Details

Name : Dr Wong Nyuk Hien
Organization : National University of Singapore
Department : Department of Building
Tel : 65163423
Fax : 67755502
Address : 4 Architecture Drive, Singapore 117566
Email : bdgwnh@nus.edu.sg