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1. Analysis of Crack Propagation in an Adhesive Joint — 1
   M.D. Mohan Gift
   J. Selvakumar
   S. John Alexis

2. Analysis of the Thermal Behavior of the Double Skin Envelope in the Full Scale Testing Modules of the Postgraduate Unit for a Cloudy and a Clear Day — 13
   Ricardo Sánchez Benítez
   Leonardo B. Zeevaert Alcántara

3. Energy Conversion from Biodegradation of Non-thermal Pre-treated Algae Biomass for Microbial Fuel Cell — 25
   Muhammad Haikal Zainal
   Oskar Hasdinor Hassan
   Liana Shakira Ab Samad
   Ab Malik Marwan Ali
   Muhd Zu Azhan Yahya

4. Mode III Stress Intensity Factors of Sickle-Shaped Surface Cracks in Round Bars — 33
   A.E Ismail

5. Perpendicular Dowel-bearing Strength Properties without Glue Line for Mengkulang Species 45
Nor Jihan Abd Malek
Rohana Hassan
Tengku Anita Raja Hussin
Ng Dick Tern
Constantine Adam

6. The Use of Edible Vertical Greenery System to Improve Thermal Performance in Tropical Climate 57
Hazril Sherney Basher
Sabarinah Sh Ahmad
Abdul Malek Abdul Rahman
Nurulhusna Qamaruz Zaman

The Use of Edible Vertical Greenery System to Improve Thermal Performance in Tropical Climate

Hazril Sherney Basher
**Sabarinah Sh Ahmad*
Faculty of Architecture, Planning and Surveying
Universiti Teknologi MARA
Shah Alam, 40450, Malaysia

Abdul Malek Abdul Rahman
School of Housing, Building and Planning
Universiti Sains Malaysia
Penang, 11800, Malaysia.

Nurulhusna Qamaruz Zaman
School of Geography, Earth and Environmental Sciences
University of Birmingham
Edgbaston, Birmingham, B15 2TT
West Midlands, United Kingdom

**Corresponding author: sabar643@salam.uitm.edu.my / sabrin63@gmail.com*

ABSTRACT

The vertical greenery system (VGS) is a passive shading and urban greening solution for multi-storey buildings. Buildings installed with VGS could benefit from lower indoor air temperature, which in turn will save energy. As cities are experiencing urban heat island due to excessive development and overpopulation, building occupants turn to mechanical cooling to cool the interior space. Normally, the VGS is installed with living aesthetic plants that function to absorb solar radiation. However, in this paper, Psophocarpus Tetrogonobulus (Winged Bean Plant) is selected as the plant medium based on its ability to provide vegetable pod, have longer lifespan and withstand heat gain from long sun exposure. This edible VGS could lower the building energy cooling load and at the same time provide food production at a household level. This paper presents a series of recently measured data from the use of Test Cell (ground level) at University Sains Malaysia, Penang. The VGS managed to reduce the surface temperature by an average of 2.4°C, while the maximum surface temperature drop achieved was 6.4°C. These promising results *indicated that the VGS installed with edible plants such as wing beans could save energy through the benefits of shading in urban multi-storey buildings.*

Keywords: *vertical greenery system; multi-storey building; temperature reduction; energy saving*

Introduction

The rising trend for migration from rural to urban areas has been observed globally as well as in Malaysia. According to the Department of Statistic Malaysia [1], at least 70 percent of 40.6 million Malaysians would populate Malaysia's major cities by 2020. As a result of this urban migration trend, landed property has become scarce and housing developers have focused in constructing multi-storey buildings for urban dwellers. Hence, when many high-density buildings are constructed, the basic requirements for vegetation have often been overlooked.

There are many manmade structures that replaced trees such as concrete pavement, buildings and street fixtures. Urban areas built with hard surfaces often experience urban heat island (UHI) effects that in turn contribute to the rising of global ambient temperature and climate change [2]. Apart from this, human activities also contributed to climate change. From the burning of fossil fuel to feed the demand of industries, transportation, businesses and comfortable living, urban dwellers are responsible towards the increase in carbon dioxide emissions [3].

The use of mechanical cooling is one of the contributor's to rising enegy consumption in cities. Urban dwellers are keen to use air conditioning system as part of cooling mechanism to cool the indoor environment. When this system operates, it increases heat gain built up towards outside ambient temperature through gas release. As stated by Zain-Ahmed [4], this system consumed at least 50 percent of overall building electricity and increased energy consumption if it is not properly controlled.

Aim

The aim of this paper is to investigate the optimum temperature reduction using vertical greenery system (VGS) installed with *Psophocarpus Tetrogonobulus* (winged bean plant) on a test cell. The application of this system is tested on ground level before application on high rise building can take place.

Literature Review

Definition

Vertical greenery system (VGS) is akin to green building envelope. There are many similar keywords or phrases that are in line with the vertical greenery system such as bio-facade [5], green facade [6], green wall [7], bio-shader [8] and so on. The vertical greenery system is commonly divided into two groups which are called "support system" and "carrier system" [9,10]. The support system is normally associated with green façade while the carrier system is similar to living wall system. In this paper, the vertical greenery system is more focused towards the support system. The support system functions by guiding plants up on a vertical surface depending on types of structures, climate condition and budget. When compared with carrier system the support system is more economical and can be implemented on household level. It is considered cheap in terms of production and maintenance. However, the support system is limited to climbers and creepers.

Thermal Effects on Vertical Greenergy System (Support System)

Previous studies related with the use of vertical greenery system are more focused on the improvement of building thermal performance using ornamental plants. There are few researchers who opted to explore the use of edible plants rather than ornamental plants in tropical climate condition. This transition could produce multiple benefits that would lead to the reduction of energy consumption and some food supply for the household. In terms of thermal effect, Sunakorn and Yimprayoon [11] have conducted a research in Thailand and were able to reduce the air temperature by a maximum of 4.71°C. Moreover, they found that the VGS also improved the ventilation in a naturally ventilated room.

In Netherland, Perini [12,13] studied the differences between the thermal performance of support system that are attached directly on the wall and the indirect system (with an air gap). The results showed that the wall behind a direct VGS was able to reduce an average surface temperature of 1.2°C when compared with the surface of a bare wall. For the indirect approach, the VGS was able to reduce the surface temperature at least 2.7°C.

A similar study using indirect VGS was conducted in Penang Malaysia [14,15]. In this study, the VGS installed with edible legume plant was able to reduce the surface temperature by a maximum of 11.0°C. However, the comparison between the surface wall behind the VGS and the bare wall was not conducted side by side, which may trigger different results. Majority of the findings from thermal performance studies that uses VGS support system were conducted at the ground level. In this paper, the investigation of ground level VGS is essential before it can be compared with higher level.

Experimental Description

The research was carried out using a ground level test cell located at the University Sains Malaysia, Penang (5°21'17.1"N, 100°18'28.3"E). This test cell was chosen as a pilot study to gather preliminary results before the implementation of VGS in high rise condition. The test cell is situated on a ground level that can be compared later with multi-storey level results (Figure 1). The size of the test cell is 4.8 m (l) × 4.2 m (w) × 3.3 m (h). It is made out of brick wall and metal deck roofing. Only a portion of surface wall that expose to west orientation will be used to measure thermal evaluation. This research investigated possible surface temperature drop between a bare wall (without VGS) and wall behind the VGS (with VGS). The measurements were compared side by side simultaneously to achieve better results [16].

This research uses a rack system that is made out of plywood that housed the VGS plant. The rack system functions to guide the plant upwards to reach its desired foliage density. The size of the rack system matches the size of a single door leaf that is 900 mm (w) × 2100 mm (l). The rack system is divided into two different intervals, which are upper interval and low interval. Two different points were measured to identify different surface temperature values (Figure 2).

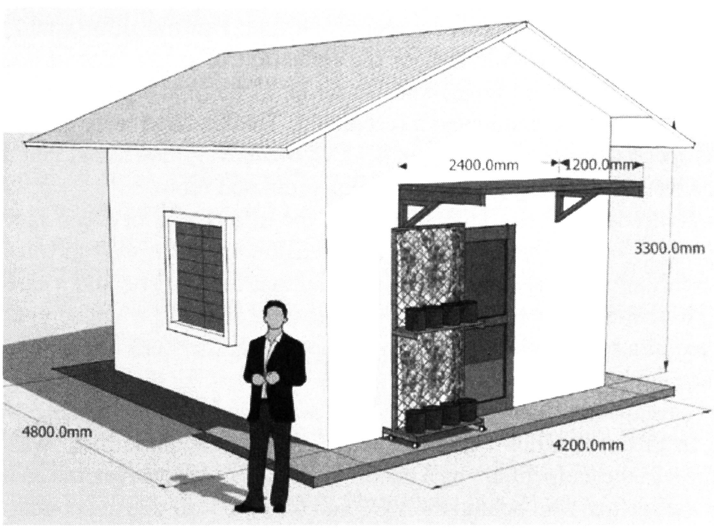

Figure 1: Test Cell on Ground Level

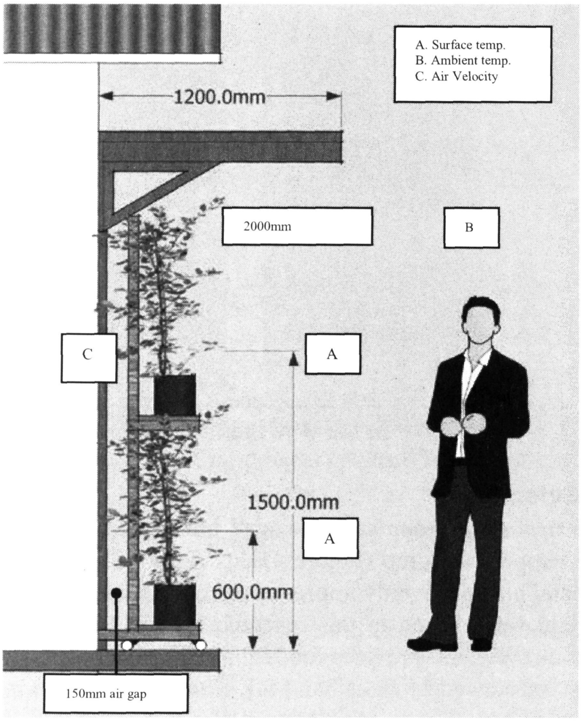

Figure 2: Section of Vertical Greenery System

Experimental Equipment

The main parameters recorded in this research are surface temperature, ambient temperature and air velocity. The surface temperature was recorded using an IRtek laser point thermometer (Figure 3a). While the ambient temperature and air velocity was recorded using a hot wire thermo anemometer. The IRtek laser point thermometer measured at two different points (600 mm, 1500 mm from the bottom of the ground level) for each bare wall (without VGS) and VGS wall (with VGS) [17]. The readings were taken at 2 hours interval from 9 a.m to 5 p.m. The Data collection was conducted for a one week period on dry season between (13 March – 19 March 2015) [18].

Figure 3: a) IRtek laser point thermometer and b) hot wire thermo anemometer

Plant Selection

Psophocarpus tetrogonobulus (winged bean plant) was used to investigate the surface temperature drop (Figure 4). Previous research is focused on the use of ornamental plants that only improves thermal and aesthetic purposes. The winged bean plant was chosen in this research for the benefits of improving thermal performance and also provides food for building occupants. The winged bean plant was first introduced by Fukaihah [14], who indicated that it is the most effective legume plant to be used as part of vertical greenery system. The author added that the plant could absorb heat from solar radiation more effective due to its darker leaf features when compared with other edible legume plant such as *Pisum sativum* (Sweet Pea), *Vigna unguiculata sesquipedalis* (Long Bean) and *Phaseolus vulgaris* (Kidney Bean). Apart from that, the winged bean plant has a longer lifespan due to its tuberous root that can store sufficient nutrients over a two-year period.

Figure 4: *Psophocarpus tetrogonobulus* (winged bean plant)

Results and Discussion

Temperature Evaluation

During the investigation, the winged bean plant was used as the shading component of the vertical greenery system. The temperature evaluations were conducted for a week. Data of 3 clear days were selected in order to identify and differentiate dry and wet readings. Measurements were taken from two interval points. From the experiment, the lower interval (600 mm from floor level) of wall behind VGS managed to reduce surface temperature at least an average drop of 2.4°C (Figure 5). The bare surfaced wall indicated an average reading of 31.5°C, whereas the wall behind the VGS recorded 29.1°C. The maximum surface temperature drop achieved at this lower interval was 6.4°C, which occurred on day 2 (14 March 2015) at 3 p.m. The minimum surface temperature drop was at least 0.7°C recorded on day 2 at 1 p.m. When compared with the upper interval as shown in Figure 6, the lower interval readings performed efficiently. The foliage cover at this interval was denser compared with the upper interval.

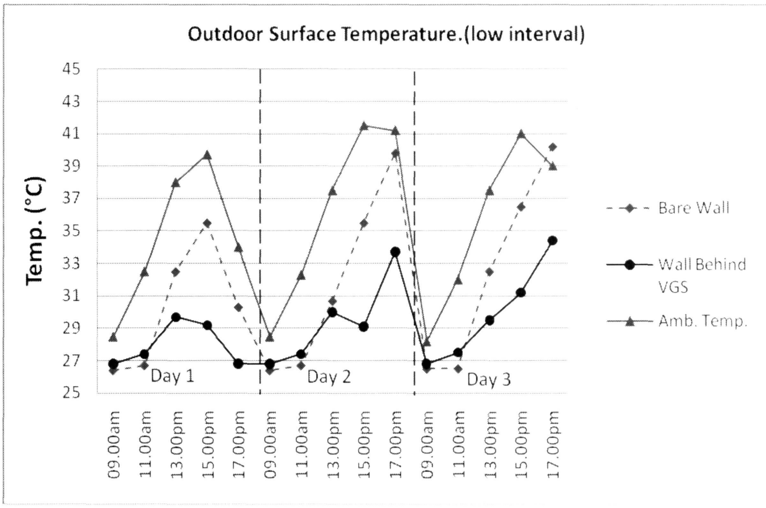

Figure 5: Surface Temperature Trend (low interval)

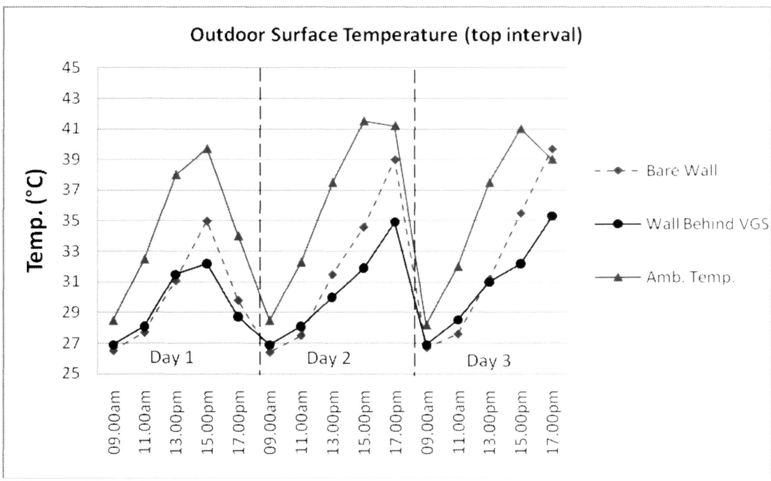

Figure 6: Surface Temperature Trend (upper interval)

The upper interval (1500 mm from ground level) readings showed different results (Figure 6). At this level, the VGS managed to reduce the surface temperature by an average of 1.1°C. The maximum surface temperature drop recorded was 4.4°C that occurred on day 3 (15 March 2015) at 5 p.m. The minimum surface temperature drop was only 0.2°C. During this investigation, the highest ambient temperature reading was 41.5°C. At this point, the bare wall surface showed a temperature reading of 35.5°C, whereas the wall behind the VGS achieved 29.1°C. The ambient temperature for both data sets peaked at 1pm onwards and began to decline after 2 p.m. During this hour, the ambient temperature readings were ranged from 38°C to 40°C. From this experiment, it indicated that the most effective time for the VGS to achieve better thermal performance was at 3 p.m. The high ambient temperature led to higher surface temperature reduction. The lower interval of the VGS showed lower readings compared with the upper interval due to higher foliage coverage, which is estimated at 70 percent.

Conclusion

From this paper, it can be concluded that the application of vertical greenery system (VGS), where the shading element comprised of winged bean plants, managed to reduce the surface temperature through the benefits of shading. Overall, the average surface temperature drop recorded was 2.4°C (lower interval) and 1.1°C (upper interval). The maximum surface temperature drop achieved was at least 6.4°C and it occurred in day 2 of investigation at 3 p.m (lower interval). The vertical greenery system (VGS) of using winged bean plant also proved to operate efficiently when it is exposed to high ambient temperature. The vertical greenery system of using winged bean plant will be tested on multi-storey residential balcony (transitional space) and the results can later be compared with the test cell data.

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