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A Review on Cooling Performance of Vertical Green System for Green Facade and Living Wall

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Abstract: The increases of global temperature and Urban Heat Island (UHI) in tropical region has become a main issue that associates with the warm environment in urban area compared to rural area. Numerous of studies stated that the rapid of development and population growth resulting the changes the natural environment which become the main factor for the urban heat island. Vertical Green System (VGS) is one of alternative to curb the current issue and it is benefits to society and environment for a practical practice in a long term. The objective of this review is to study the cooling performance of vertical green system (VGS) for the living wall and green façade and discuss the suitable type VGS in tropical region. Selected previous research study will be the material to reviewing the cooling performance by determine the temperature reduction that perform by the VGS and discuss on the suitable type of VGS in tropical region were analyze. The comparison between Shafiee's and Reséndiz's research found that the percentage of living wall cover area are 26% and 76% respectively, for temperature cooling efficiency for both are 19.6% and 9% respectively, and 19.5%RH is needed for 8.7˚C temperature reduction. The green façade analysis from Othman's and Jaafar's research found that the cooling efficiency are 36% and 8% respectively and the relative humidity show 5%RH to achieve 2˚C of temperature reduction. Both living wall and green façade is relevant to applied for tropical region depends on its usage which the living wall system suitable for high rise building and green façade suitable for residential after considering the complexity system design, maintenance, and cost for the VGS.

Keywords: Vertical Green System, Living Wall, Green Façade, Cooling Performance

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1. Introduction

The Vertical Green System (VGS) is a sustainable practice by using plants as living shading brings benefits to ecological value, indoor and outdoor comfort, insulating properties, and improving surrounding air quality [1]. In urban area, the lack of plants or the vegetated surrounding area is one of the factors that cause the Urban Heat Island (UHI) due to the remaining carbon dioxide at surrounding that cannot absorb by the plant due to limited plants absorption capability and lacks the number of plants to absorb the appropriate volume of carbon dioxide. To curb thermal stress, the usage of vertical green system is a good practice that has great potential to improve cooling effect [2]. The practice of growing VGS around the perimeters of buildings to screen the shading from direct sunlight and cool the air.

The aim for this review is to study the cooling performance of the VGS for living wall and green façade and discuss on suitability of living wall and green façade for tropical region. This review is focusing on cooling performance of VGS for living wall and green façade by analyze the temperature readings.

2. Literature Review

Urban Heat Island is due to the urbanization process, the forest is being turned into a concrete jungle with a high density of structures. By modifying the surface energy balance of the metropolitan region, urbanization causes a significant change in the land surface characteristics, resulting in the replacement of greenery with the urban concrete and a significant shift in the land surface characteristics [3]. To put it another way, urbanization fosters changes to the Earth's geographical profile. Furthermore, as shown in Figure 1, the thermal properties of urban structures are higher, resulting in higher temperatures in the city compared to the surrounding rural environment [4].

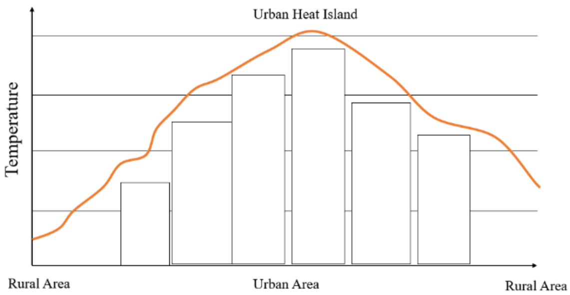


Figure 1: Illustration of the urban heat island [4]

The tropical environment is one of the most challenging climates to include into a design. Summertime comfort is exceeded due to the high temperature and humidity throughout the year. According to ASHRAE (2013), the ideal interior temperature for achieving thermal comfort in the summer is 26°C. However, in tropical climatic nations, this temperature restriction is no longer applicable [5]. Building design for tropical climates should place a greater emphasis on managing the amount of heat transfer and ventilation. Thus, it is a building's heat is rejected while light and cold air are in.

Green wall system provides an option for reducing the thermal load on buildings, the climbing plants planted in a supported vertical system, either directly against or on supported structures incorporated into exterior building walls, are defined as a green wall system or vertical green system. The green wall system can be classified into two types which are a green façade and a living wall as described in Figure 2.

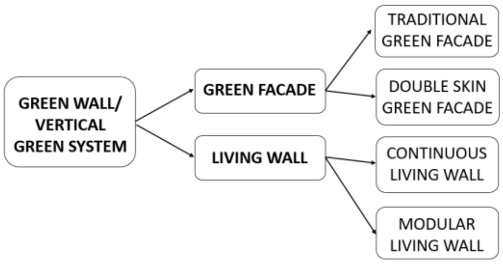


Figure 2: Classification of Green Wall [13]

A green facade can be classified into two classifications which are classic green facade and double skin green facade. Traditional green facades have deciduous climbing plants that are rooted in the ground and cover the building's wall, as shown in Figure 3 (a). For double skin layer require modular trellis, stainless steel cables, or stainless-steel mesh as supporting system see in Figure 3 (b). The building envelope serves as the structure for the climbing plants, so there is a risk of damage to the building's walls. As for living wall it has more complicated structure than a green facade, with specific supporting components, a growth medium, and an irrigation system to service a wide variety of plants [6]. The living wall is shown in Figure 3 (c) below as part of a new breakthrough in wall covering. Pre-vegetated panels are attached to a structural wall of a freestanding frame to enable quick covering of vast areas and more uniform growth along the building's wall, allowing it to reach the top of tall structures. The living wall enables for the creation of a green wall aesthetic idea based on plant colour and density change [7]. As a result of its complexity in providing a range of plant alternatives with quick and excellent coverage on a very tall structure, a living wall system has a high construction cost.

(a) (b) (c)

Figure 3:(a) Traditional Green Façade, (b) Double Skin Green Façade, (c) Living Wall. [6,7]

3. Methodology

3.1 Data Collection

This data collection is using online platform to search on previous research related to VGS for living wall and green façade for cooling performance through ProQuest, Science Direct, MyTO, and UTHM PTTA Digital Archive.

3.2 Data analysis

The data analyzed using previous articles in terms of the cooling capacity study on temperature reduction and discuss on the suitability of the living wall and green façade in tropical region.

4. Results and Discussion

4.1 Living Wall

The analysis of previous research on cooling effect is tabulated and the summary of detail and findings is shown in Table 1.

Table 1: Summary findings of cooling performance by living wall.

Author	Findings
Yang He et al, (2016) (Shanghai) [8]	The living wall is set on wall of test room (3m x 3m x 2.7m). Summer data comparison for temperature is 34˚C for bare wall and 32˚C for living wall. Temperature difference is 2˚C between living wall and structure wall.
Elham Shafiee et al, (2020) (Shiraz) [9]	The living wall size is set up on test cell 3m, 2.40m, and 2m. The green wall cooling effect at least 0.2 ˚C, at most 8.7 ˚C and average of 2.59 ˚C at range of 43˚C to 36.1˚C. For living wall RH recorded range of 63.6% to 11.4%.
Katia Perini & Marc Ottele, (2014) (Mediterranean region) [10]	Summaries data for temperature reduction of living wall system is range between 2-6˚C in European regions. VGS benefits on reduction of air and surface temperature.
J.A. Sánchez-Reséndiz et al, (2018) (Mexico) [11]	The living wall size is 2.1m x 2.6m is set on a hut is 2.5m x 3.2m x 2.3m . The meteorological data show warmest weather is on April to May with 21˚C in average. The recorded data show the peak of readings for living wall and bare wall is 13.2˚C and 16.5˚C. The differences temperature between living wall and bare wall is 2˚C at peak hot weather at 28˚C.
Matthew Fox et al, (2021) (England) [12]	The study of existing living wall on a building and no data of size living wall. The findings, the indoor temperature difference not more than 2.5˚C at peak of 18˚C ambient temperature.

According to Yang He et al. [8], which conduct a study for thermal and energy performance by using Vinca Major Varegata type plant for living wall system using living wall in Shanghai with the humid subtropical climate condition. The living wall was set on wall of test room (3m x 3m x 2.7). The meteorological data taken was measured 33˚C of average weather temperature and 52.6%RH throughout the year. The temperature readings for summer, the maximum outer surface temperature of structure layer recorded up to 34˚C for bare wall and 32˚C for living wall in the daytime. The air temperature in living wall area is about 2.5˚C lower than bare wall. For winter, the maximum difference of outer surface temperature between living wall and bare wall is approximately 10˚C in the daytime. The maximum local air temperature differences between living wall and bare wall are about 2˚C in the daytime.

According to Elham Shafiee et al. [9], conducted study on the ambient air temperature and reducing temperature in day and night in Shiraz by using living wall panel of Gazania, Petunia Sprawling, Liriope and scrollable Cactus as the plants. This research was carried in the semi-arid climate. The living wall size was set up on test cell 3m, 2.40m, and 2m. Data readings was taken for 5 days, living wall reading resulted a maximum temperature of 36.1˚C, minimum of 14.8˚C and the average temperature is 23.25˚C in 24 hours with the highest relative humidity is 63.6%RH and the lowest is 11.4%RH. The readings for panel wall are with a maximum temperature of 43˚C, a minimum of 14.4˚C and average temperature is 25˚C in 24 hours with the highest relative humidity is 51% and the minimum is 7.5%. The comparison between the present of living wall and without living wall, the present of green wall temperature reduction of at least 0.2˚C, at most 8.7˚C and with the average of 2.59

˚C reduction ambient temperature with 6.8% relative humidity differences. The living wall temperature reduction is not more than 1.5˚C.

According to Katia Perini and Marc Ottelé [10] which reviewing on the performance, practicability and sustainable of vertical green system in Mediterranean region. The data analysis consists of 4 main topic which is the characteristic of VGS, the improvement for building using VGS, the sustainability of the VGS, and the advantages and the disadvantages of VGS. In first topic state the placement for VGS is crucial to maximise the performance of the VGS not only for aesthetic as shown in Figure 4 and the material for VGS medium and irrigation system design must be consider the climate factor to ensure the plant growth healthy. Second topic state that the plant of VGS is the main cause of heat loss and reduction of temperature in range of 2˚C to 6˚C basically and for Mediterranean climate the VGS can reduce as much as 10.8˚C based on previous data. For third topic state the VGS life span can up to 50 year and using recycle material for the supporting system and choosing vegetable as vertical plant which leave less environmental footprint. As for fourth point, VGS can act as insulation or shading that benefits on reduction of air and surface temperature. Green façade is relatively cheap but the plant height usually 5 to 6 meter height and if using specific plant, it can be grown up to 10 meter to 30 meter.

Figure 4: Aesthetic of Living Wall. [10]

According to J.A. Sánchez-Reséndiz et al. [11] studies the thermal behaviour in living wall system using 6 types of plant, Sedum reflexum, Sedum obtusifolium, Sedum mexicanum, Sedum crassulaceae, Sedum moranense, and Tall fescue (grass) in Mexico, semi arid climate. The living wall was set on a hut is 2.5m x 3.2m x 2.3m . The meteorological data show warmest weather is on April to May with 21˚C in average. The data recorded for January, the maximum and minimum data reading by sensor for living wall and bare wall is 13.2˚C – 10.8˚C and 16.5˚C – 9.8˚C respectively which shows that the differences 2.4˚C of temperature. For April, the data shows the temperature difference up to 2.5˚C between living wall and bare wall for approximately maximum external temperature 29˚C. In July, the temperature is recorded 28˚C to 16˚C and the living wall temperature is 2˚C lower compared to bare wall temperature. The data for October recorded outside temperature is plus minus 27˚C maximum and plus minus 16˚C minimum and the average temperature difference for living wall and bare wall is 0.5˚C which living wall is having the low temperature.

According to Matthew Fox et al. [12], studies the thermal performance of existing living wall system on a building in England, temperate climate. The plant for the living wall is Carex spp, e.g. Dryoteris spp, e.g. Luzula spp, and e.g. Sarcocca confuse. The study of existing living wall on a building and no data of size living wall. The data is recorded for 5 weeks with interval 15 minutes and the result shows during the experiment conduct the external temperature is between 15˚C to 1.5˚C and internal temperature is 17.2˚C. The comparison data show slightly temperature difference between 0.3˚C to 2.5˚C maximum in range of plus minus 22˚C to 13˚C of 5 weeks reading.

Based on Table 4.1, Yang He et al. and J.A. Sánchez-Reséndiz et al. conduct the study on building which mention in table above and the detail size sample of living wall is only provided by J.A. Sánchez-Reséndiz et al. Both study data recorded is meteorological data and the temperature changes of bare wall and living wall. Study comparison between Elham Shafiee et al. and Matthew Fox et al., the experiment is conducted different method which Elham Shafiee et al. study the living wall on test cell and provide the size sample data for living wall is 3m x 2.4m x 2m while Matthew Fox et al. conduct the study on existing living wall on structure and no detail of size sample living wall and building structure is provided. The study data recorded is the temperature indoor and outdoor for both and additional for Elham Shafiee et al. that provide the RH data. For Katia Perini & Marc Ottele conduct a review study which proven that the living wall can give cooling effect up to 6˚C compared to Yang He et al. only 2˚C temperature reduction in a humid subtropical climate. Between all author, Elham Shafiee et al has the highest temperature reduction as much of 8.7˚C which contribute to cooling effect.

4.2 Green Façade

The analysis for green façade based on previous study that have tabulated and the summary of the findings detail is shown in Table 2 and explained below.

Table 2: The summary finding of cooling performance by green façade.

Author	Findings
Ahmad Ridzwan Othman & Norshamira Sahidin, (2018) (Indonesia) [13]	The experiment is conduct on 2 existing building with and without green facade. The temperature compared is 2.55˚C at maximum of differences between 2 building indoor and outdoor during sunny daytime which is at peak of 35.3˚C.
Badrulzaman Jaafar et al, (2014) (Malaysia) [14]	The living wall is set up on 3rd of 5 story residential building. No detail data on green façade. At peak reading of 45.81˚C green façade able reduce 13˚C of temperature between green façade and without VGS.
Jeffrey W. Price, (2010) (Washington DC) [15]	The green façade was set up on hut of 2.5m x 2.5m x 3.5m. Interior wall cooled as much 1.75˚C in average and exterior wall cooled as much 6.17˚C by present of green façade at peak of 43˚C.
Jamil bin Abid, (2017) (Jeddah) [16]	The green façade detail is not provided. The experiment is conduct at 4 Site (A,B,C,D). Temperature reduction of Site A, B, C, and D is 6.74 ˚C, 4.79 ˚C, 4.93 ˚C, and 3.8 ˚C respectively with different type of plant.
Ileana Blanco, (2021) (Italy) [17]	The green façade is set on hut (4.2m x 1.5m x 2m). The surface temperature cooling effect from 1.4 ˚C (hot cloudy day at peak 41.4˚C) – 3.3 ˚C (cool sunny day).

According to Ahmad Ridzwan Othman et al. [13], studies the cooling performance of green façade on existing building in Indonesia which having tropical climate. The experiment is conduct on two existing building with and without green facade. The data is measured from 8a.m. till 5p.m.The findings show that building without green facade recorded temperature range of 35.3˚C to 28.7˚C for outside of the building and 33.45˚C to 28.5˚C for inside of the building which clearly show there is slightest changes in temperature differences. While data for green facade building is recorded temperature range of 32.75˚C to 28.3˚C for outside of the building and 31.1˚C to 28.2˚C for inside of the building.

According to Badrulzaman Jaafar et al. [13], studies the effectiveness of vertical green system curb the warm condition is a residential building in Malaysia which has equatorial climate. For the plant usage for green façade is not mentioned which this study is solely to measure the temperature reduction to determine the cooling performance of façade. The living wall is set up on 3rd floor of 5 story residential building. No detail data on green façade size. The findings of the experiment are the temperature recorded is in range of 45.81˚C to 24.17˚C for control type, 37.45˚C to 25.96˚C for living wall, and 33.96˚C to 26.32˚C for green façade. The comparison of three types shows that green façade reduces more than living wall due to the plant properties and both VGS temperature result is much lower than control type experiment which at peak of 45.8˚C. For the relative humidity comparison, green façade produces more humidity than green wall with differences of 1.4% of 71.7% RH for green façade. Based on the result the green façade is having good cooling performance compared to living wall.

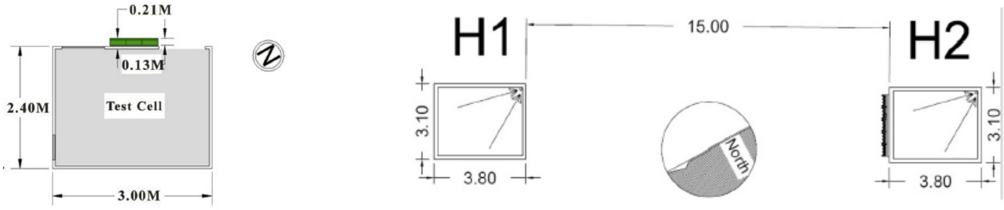
According to Jeffrey W. Price [14] which studies the cooling effect of green façade in Washington DC which has humid and subtropical climate. The plant of green façade used is Vitis berlandieri. rupestris, Vitis berlandieri. rupestris, Vitis champini, Bignonia capreolata, Lonicera sempervirens, Gelsemium sempervirens, Celastrus scandens, Wisteria frutescens, and Passiflora incarnata. The size of green façade was set up on hut of 2.5m x 2.5m x 3.5m. The data reading for non vegetated hut temperature of south and west outdoor are 43˚C and 56˚C respectively in hot sunny day. Compared to vegetated hut, the temperature reading for south and west are 35˚C and 38˚C respectively at peak hot sunny day. For interior readings, the average of temperature reduction for south is 1.04˚C and 1.75 ˚C west on hot sunny day.

According to Jamil bin Abid [15] which studies the cooling performance of existing green façade in Jeddah. The plant of study is Bougainvillea Glabra, Quiqualis Indica, Jacquemontia Pentantha, and Pentalinon Luteum. The green façade detail is not provided. The experiment is conduct at four Site (A,B,C,D). Site A is at peak of 43.65˚C on bare wall and 36.91˚C which resulting reduction of 6.74˚C and for the relative humidity recorded 65.17% on façade compare to bare wall 47.08%, for site B the temperature recorded at peak 40.43˚C for bare wall and 35.64˚C for façade which reduce 4.79˚C and for RH is 55.31% on bare wall and 66.41% on façade resulting 11% increases, at Site C the temperature readings at peak with 45.19˚C on bare wall and 40.26˚C for façade the temperature reduce to 4.93˚C and RH reading are 56.19% for façade and 46.36% for bare wall, and for Site D temperature readings are at peak 37.56˚C at green façade and 41.36˚C for bare wall and the RH 57.55% for façade and 49.21% for bare wall.

Based on Table 2, Ahmad Ridzwan Othman & Norshamira Sahidin and Jamil bin Abid conducted study on existing green façade on building which both weather is tropical type. Between both studies, the detail of size sample living wall and building dimension is not provided. But, Jamil bin Abid provide full detail of plant characteristic for four set of the experiment while Ahmad Ridzwan Othman & Norshamira Sahidin only do the measurement of temperature differences between indoor and outdoor. Next, the comparison of Jeffrey W. Price and Ileana Blanco both façade is set up on the hut that dimension have mention in table above and Jeffrey W. Price only state the size of the façade sample. For the data reading, the Ileana Blanco analyse the maximum and the minimum the temperature for wall surface and Jeffrey W. Price analyse the maximum and minimum of interior and exterior the hut. For Badrulzaman Jaafar et al. the study is conduct on 3rd floor of the building and no specific detail on façade size sample or plant detail that same as Ahmad Ridzwan Othman & Norshamira Sahidin. Between all author, Badrulzaman Jaafar et al. having the highest temperature difference with 13˚C.

4.3 Review Overview

The analyses for comparison of related parameter that involve with cooling performance of vertical green system for living wall and green façade. For living wall will be comparing with Elham Shafiee et al. and J.A. Sánchez-Reséndiz et al. research which their research having same semi-arid climate and same orientation of living wall. The living wall setup by Elham Shafiee et al was mounted on a room labelled as test cell with 3 meter length, 2.4 meter width, 2 meter height and J.A. Sánchez-Reséndiz et al. living wall was mounted on a hut of 3.8 meter length, 3.1 meter width, and 2.3 meter height. Both living wall is oriented facing west see Figure 5, and the percentage of living wall area cover the bare wall for Elham Shafiee et al and J.A. Sánchez-Reséndiz et al are 26% and 76% of the surface area. The cavity between living wall and bare wall is not mentioned, it is one of the factors for cooling effect which the cavity allow heat to dissipate by cold air and increase the cooling performance.



(a) (b)

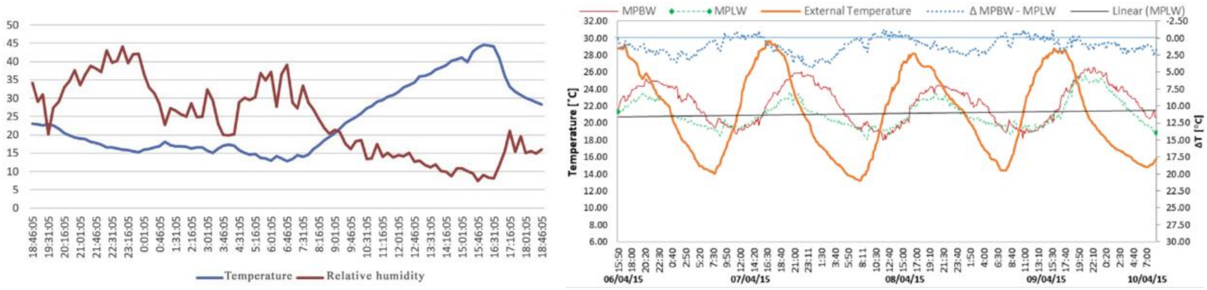
Figure 5: (a) Shafiee's living wall orientation, (b) Reséndiz's living wall orientation.

For the living wall plant, both living wall using flowering type of plant that grow in range of 25mm to 400mm width to hold the heat radiation penetration. The meteorological data, both recorded different warmest months as for Shafiee's is July while for Reséndiz's is May which the temperature recorded is exceed 25˚C and both conduct the experiment on warmest month refer Figure 6.

(a) (b)

Figure 6: (a) Shafiee's meteorological data,(b) Reséndiz's meteorological data.

Based on previous data, the temperature recorded is the temperature of ambient and the sensor measurement is place outdoor and indoor mounted with and without living wall panel while for relative humidity sensor is place on living wall area or without living wall which the sensor placement is outdoor. Elham Shafiee's living wall cooling performance is up to 8.7˚C by comparing the temperature of bare wall with living wall and without living wall at highest temperature recorded is 44.5˚C and 35.8˚C recorded for living wall which as much of 19.6% cooling efficiency improvement that lower the outdoor temperature and prevent direct heat penetration to indoor. For J.A. Sánchez-Reséndiz's living wall cooling performance is up to 2.5˚C by comparing the temperature of the bare wall and bare wall with living wall, at highest temperature recorded for bare wall is 28˚C and 25.5˚C for living wall with 9% of cooling efficiency improvement. The result comparison is presented in Figure 7. Both cooling efficiencies can be enhanced significantly by having cavity between living wall panel and bare wall which allow the heat is dissipate by air naturally. The method of living wall mounted side by side with bare wall that allow the heat is transfer via convection and both researcher state that a lag of heat transfer to achieve equilibrium for indoor and outdoor but the equilibrium cannot be achieve as the time goes by the ambient temperature is drop while in the night time the indoor heat is slowly dissipate through convection which mean there is heat trap and that's prove the living wall mounted to bare wall is act as insulation that suitable applied on four season country. Thus, the living wall system role is to reduce heat in semi arid climate which it is a passive alternative to improve temperature condition that improve the thermal comfort as well.



(a) (b)

Figure 7: (a) Shafiee's Temperature versus Relative Humidity data for without living wall, (b) Reséndiz's Temperature versus Hours data.

As for relative humidity, it is one of the parameters that to prove the cooling performance for the living wall. Elham Shafiee's data show that the highest relative humidity is 63.6% for living wall refer Figure 8 and 44.1% for bare wall at 36˚C for living wall which 19.5%RH more produce by plant that able to reduce 8.7˚C of ambient temperature. While relative humidity for J.A. Sánchez-Reséndiz's is recorded for highest is 78% at 29˚C and the lowest is 28% at 12˚C which obviously when the temperature is high the high humidity is needed to reduce the temperature. Thus, the temperature reduction by humidity is the effects of the plant that release water vapor to the ambient air.

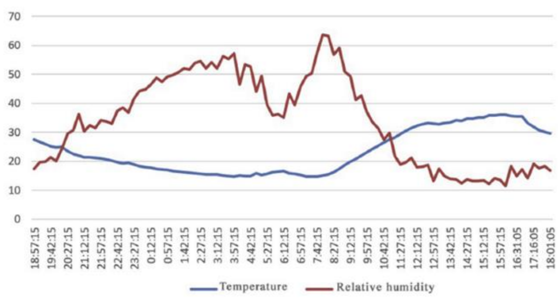


Figure 8: Shafiee's Temperature versus Relative Humidity data for with living wall.

For green façade the comparison analysis will be Ahmad Ridzwan Othman et al. and Badrulzaman Jaafar et al. research which their research having same tropical climate, the placement of façade and method of research. Both research conducting on façade mounted on high rise building, for Othman's the façade is mounted on building all around and for Jaafar's façade is mounted on 3rd of 5th floor building corridor that facing north. The method for both research is same which to measure the air temperature and humidity for the present and absent of façade. Based on previous data, Jaafar's data recorded 45.8˚C for absent of façade and 33.9˚C with present of façade that show the cooling efficiency is 36% with the façade absent on high rise building. For Othman's temperature data recorded 35.3˚C for absent of façade and 32.75˚C for the present of facade and this show the cooling efficiency is as much of 8% by the present of green façade. From both comparison that obviously the façade area cover is crucial to increase the cooling efficiency which Jaafar's façade prove that by having façade all around building will increase the cooling performance significantly.

As for humidity, Othman's recorded 70% relative humidity for the present of façade comparing to the absent of façade is 65% see Figure 9 which show as much of 5% relative humidity to achieve 2˚C of temperature reduction. The Jaafar's relative humidity recorded 96.7% for the absent of façade and with the present of façade is 86%. For both relative humidity data can be more valid if consider wind speed as parameter because the façade is in high rise building which there is movement of air that influence to temperature and relative humidity data readings. From both comparison shows the differences of relative humidity is very small by considering the research took place at tropical climate which hot and humid throughout the year.

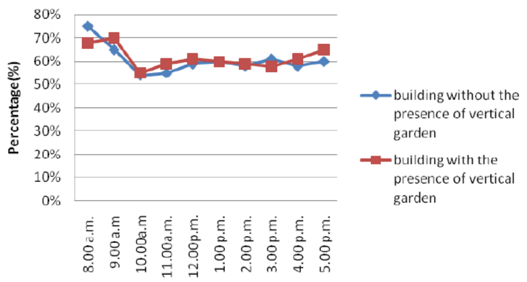


Figure 9: Jaafar's Relative Humidity data.

Thus, the temperature comparison shows that façade that mount on high rise building still give cooling effect which this research can be further by considering other variable that relates to cooling performance in high rise building and there not much different for relative humidity since the research is conduct in city area of tropical climate.

4.4 Vertical Green System for Tropical Region

In this subtopic will explain the criteria to consider for choosing type of vertical green system for housing or building in urban area. The criteria to be discuss is the characteristic of vertical green system, durability, maintenance, and cost. In a dense urban area, which the usage of vertical green system are viable option to create a better environment in urban heat island. To having the vertical green system, first identify the purpose usage of vertical green system either for shading, insulation, or aesthetic purposes. The different purposes of usage will determine the type of vertical green system that various on the method of installation and the cost involvement, the shading purposes solely to shade the structure or wall to reduce the penetration of sunlight, the living wall also can be shading or act as insulation that depends on the method of living wall installation which usually the living wall is install on the bare wall of the structure. Besides, the living wall also bring aesthetic value to building structure that consist of different type of plant use for the living wall. After identifying the types of vertical green system, the green system must be adequate to place in a densely populated urban places which considering the size of the green system that able to fit to the wall structure. For tropical region, the selection of plant for vertical green system must be appropriate according to climate which usually living wall use Bougainvillea for building and green façade use climbing type of plant for shorter height. The irrigation design for living wall system is crucial to feed the plant which the moisture will be higher which a proper water proofing is needed to avoid erosion and building damage.

The supporting system is use for shading type of vertical green system which it is a structure that support the plant for grow. Supporting system for living wall is a panel which install on the wall to place the planter box for seeding the plant while for green façade the supporting system is to support the climbing type of plant to climb on. Selection material is crucial to determine the life span of the system for the next replacement and determine the impact on environmental footprint which if the supporting system is using stainless steel will burden the environmental footprint significantly. For supporting system design must be take count the weight that sustain by the plant and plant with soil for living wall to ensure the system able sustain for years while for the living wall that install direct to bare wall should consider proper plant species so that the plant will not grow aggressively that cause to damage on building structure as shown in Figure 10. The cost for vertical green system obviously shows the living wall will cost more by considering the complexity of the design and the maintenance for the living wall, compared to green façade that having simple setup which the planter box is located on ground then the plant climbs through supporting system and there is no continuous irrigation system needed. Cost of the vertical green system various depends on material used and the complexity of the design which living wall system demand more than green façade.

Figure 10: Damaged structure by living wall.

Hence, based on criteria considered it is safe to say both living wall and green façade is relevant to applied. Depends on the type of vertical green system, the living wall is suitable for high building structure which the irrigation system can be setup in the building since the building have spacious place while green façade is suitable for residential house due to its low maintenance and cost effective. By having the vertical green system means more green plant to absorb the carbon dioxide and block sunray penetrate inside building structure which improve surrounding environment quality and provide a comfort environment toward occupant.

5. Conclusion

In conclusion, it can be summarized as follow,

1. The temperature reduction by living wall is range of 2˚C to 8.7˚C and for green façade is range of 1.4˚C to 13˚C. The vertical green system can give cooling performance up to 13˚C depend on size of the vertical green system size, the weather during experimental, and the orientation of the vertical green system.
2. The suitability of vertical green system for tropical region is both the living wall and green façade depend on its usage which living wall is suitable for high rise building due to its complexity design and green façade suitable for residential house which the plant cannot grow high height and it has relative low cost for maintenance.

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