Analysis of Thermal Effectiveness in Sri Lankan Context a Research based on Vertical Greeneries of Multi-storied Buildings

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Abstract *— Thermal energy, which comes from the heat, makes the great influence state-of-the-art of global climate simulations. This effect feels especially for multi stored buildings and concept of greenery has been introduced as a tool for mitigating the thermal effect directly by shading heat-absorbing surfaces and indirectly through evapotranspiration cooling. These greeneries can be placed either horizontal or vertical or both surfaces, which are having the direct exposure to the heating sources. Vertical greens, the key concern of this research, especially gives more benefits by make use of natural processes such as lighting and temperature control. It has been observed that vertical greenery reduces thermal effect up to some extent and reduce energy consumption of the building for air conditioning. Studies have shown that vertical greenery systems are able to reduce thermal heat transfer into the building which in turn reduces energy consumption for air conditioning.*

This research is carried out as a case study based work. Three case study areas are selected, which are having the great exposure to the sun light. Two main categories of vertical greens layers can be observed basically in Sri Lanka and the selected sites as case study areas covers both categories of vertical green layers. First category is wall vegetation that is the green layer on the wall and the rest category is the green facades, which is the green layer not having any contact with the wall and vegetated by using a separate support. The spot temperatures on both sides of different walls with and without green layer using Infrared thermometer is observed, compared and analysed.

A significant temperature reduction is observed between inside and outside of a room of a building is able to obtain the effect of vertical green vegetated wall when compared to the bare wall. This reduction tends to decrement the cost of energy for air conditioning of a building. Literature expresses, to reduce the room temperature from a single degree of Celsius using a split air conditioner requires the almost 5% of its total energy consumption per day. Thus it has been observed the significant amount of energy can be saved due to the vertical greenery, when validating the above criteria for the research findings. Concluding the research, the choice of design parameters for vertical greenery is an essential to make sure its contribution for energy saving, since the direct relationship exist the energy reduction and vertical greenery.

Keywords — Vertical greenery, vertical green vegetated wall, green façades, thermal comfort, energy saving

I. INTRODUCTION

Due to artificial urbanization, urban heating has become a serious problem. People replace the green patches with buildings and there are no places to replace those removed green patches on the land. Greenery is expected to be one of the effective countermeasures, and much research is available regarding vertical greenery in multi-stored buildings. The main objective of this research is to find out the thermal effectiveness of vertical green in multi-stored buildings in Sri Lankan context while reducing energy consumption for air conditioning and introducing this concept to the country which will help in gaining more benefits.

The term “green” refers to environmentally friendly practices from building design to the landscaping choices. The tangible benefits of high performance or “green” buildings have long been apparent in business. Energy saving, lower operating cost and reduced taxes is advantages which are relatively easy to measure. In a local research it has been found that, “Through the preliminary survey, it has been identified the general benefits of vertical greening such as Air quality improvement and its velocity changes, Ecological aspects and its attractive appearance, Protection against driving rain and sun radiation, Sound absorption and noise reduction, Social impact, Cost effective and Energy saving. And there are risks of vertical greening such as Moisture problems, Damage and deterioration, Maintenance."(Jefas N.M, 2012)

Studies have shown that vertical greenery systems are able to reduce thermal heat transfer into the building which in turn reduces energy consumption for air conditioning. In Sri Lankan context, this green concept is in the process of familiarizing. But a country like Sri Lanka which is near to the equator and having a tropical climate should consider about the countermeasures to reduce the energy consumption for air conditioning in multi-stored buildings due to the increasing demand of energy.

It is clearly classified that vertical vegetation will be more popular in urban greening, with the expansion of new methods adopting to construct a very efficient building (with less energy consumption, and by replacing removed green patches in the land etc.) with the use of the landscaping industry. "It is hoped that the complex requirements of the vertical vegetation to be functional could be unveiled, and performance and maintainability of the plant cover and the total vertical greening system could be benchmarked to allow design and operational improvement in the future".(C.Y. Cheng, 2010)

II. SIGNIFICANT OF THE RESEARCH

Studies have shown that vertical greenery systems are able to reduce thermal heat transfer into the building which in turn reduces energy consumption for air conditioning. This report contains a general description of vertical greening systems (plants or vegetation against a façade) and their behaviour in relation to thermal comfort (temperature variation) and its support to energy saving which used for air conditioning.

Greening of the building envelope with vertical green layers considering the temperature aspect can have high influence on the thermal comfort in the building and also on the environmental profile as shown in the report. From the literature survey, general description of vertical greening systems (plants or vegetation against a façade) and their behaviour in relation to thermal comfort, aesthetics, energy saving and some of other benefits were discussed.

III. LITRATURE SURVEY

In the literature survey, initial intension is to discuss about the term green and the definitions about vertical green. The benefits can be gained due to the effect of the vertical greenery, thermal effectiveness and reduction of energy consumption for air conditioning. Vertical green gives thermal comfort to the building. "Vertical vegetation, in addition to green roofs, can cool buildings in tropical and subtropical climates through their impact on shading the building, adding to exterior wall insulation, evaporating moisture from the growing substrate and transpiring moisture from leaf surfaces"(Wong, 2010).

The presented literature survey contains a general description of vertical greening systems (plants or vegetation against a façade) and their behaviour in relation to thermal comfort to mitigation of the energy consumption for air conditioning in the building. "Increased air temperature can be expected to be particularly problematic in urban areas, where temperatures already tend to be a few degrees warmer than the surrounding countryside. This difference in temperature between urban and rural areas has been called the 'urban heat island effect'(Badrulzaman Jaafar, 2011). Besides the aesthetical value, a green envelope improves the urban environment conditions and the living conditions of the inhabitants. As mentioned above unstable and increasing energy prices, concern over environmental impact and occupant health and comfort are the drivers of green buildings today(Honeywell). A green envelope can intercept the radiation and thus reduce the warming up of hard surfaces; great quantities of solar radiation are adsorbed for the growth of plants and their biological functions(Krusche, 1982).

Vertical vegetation can cool buildings in tropical and subtropical climates through their impact on shading the building, adding to exterior wall insulation, evaporating moisture from the growing substrate and transpiring moisture from leaf surfaces(Wong, 2010). Several parameters may affect the amount of the vertical vegetation's improvement of energy performance. Examples are choice of vegetation, growing medium, and extent of wall coverage, water availability, geometry and direction. The most important parameter in the aspect of walls covered by vegetation is the leaf area index (LAI)(Y.Stav, 2012). Vertical greening systems can be classified into ***Green facades*** and ***Living wall systems*** according to their growing method(Köhler, 2008).

According to, a metropolitan scale survey in Tokyo suggests temperature reduction by 5-8°C at facade wall surface(Shibuya K, 2007) A study conducted in Germany by(Bartfelder, 1987) shows a temperature reduction at the green façade in a range of 2-6°C compared to the bare wall. Greenery also reduces the cooling loads through better insulation and shading. According to (Dunnett, 2004) every decrease of the internal building temperature with 0.5°C may reduce the electricity use with 8% for air-conditioning. And it is estimated by (Akabari, 2001) that 5-10% of the current demand of cities is used to cool buildings and the electricity demand is increased for increment of every 1°C. Another study by (Wong N.H., 2009) in Singapore with vertical greening types shows a maximum reduction of 11.6°C. As (Eumorfopoulou, 2009) states a cover vegetation kept a daily room temperature 2°C cooler on average. And Alexander suggests that the surrounding air temperature can be decreased by a maximum of 8.4°C in an urban canyon in humid Hong Kong on a hottest day of the month(Alexandri, 2006).

IV. DATA COLLECTION

This research has been carried out as a case study based work. Three case study areas have been selected, which are having the great exposure to the sun light. Two main categories of vertical greens layers are observed fundamentally in Sri Lanka. In this case study, both the categories have been selected. First category is direct green facade that is the green layer vegetated on the wall (the green layer is vegetated on the wall/green layer having the full contact with the wall) in the residential house at Kirulapana.

Second category is the indirect green facades, which, the green layer is not having any contact with the wall (the green vegetation layer is not having direct contact with the wall/green layer is introduced some distance away from the wall).

A. Implemented Process for Data Collection

Two types of vertical green had been defined according to the literature survey as, direct green facades and indirect green facades.

Three case studies were selected and two case studies from Colombo district and one from Mathale district with good exposure to sunlight were selected in order to study the main two categories commonly found and that has been observed in Sri Lanka in previous researches. Three case studies which have been selected were multi-stored buildings. Observations were taken in two days in each place for four different times of a day. Control wall (wall without green layer) had been selected in same building.

Furthermore, as show in the Figure 4, spot temperatures at several marked places in the room area had been measured by using an Infrared Thermometer. Measurements of outdoor temperature and indoor temperature of a controlled room with no green layer and a room with vertical green layer have been taken in two days at same positions and four sets of readings. Spot temperatures from the wall to outside up to 1.5m distance in 0.25m intervals were taken by using Infrared Thermometer. From the wall to inside, spot temperatures were taken up to 1.0m in 0.5m intervals. By analysing the observations taken, the main objective is to find out whether there are any changes of the inside temperature comparing to the outside temperature where the building covered with green layer.

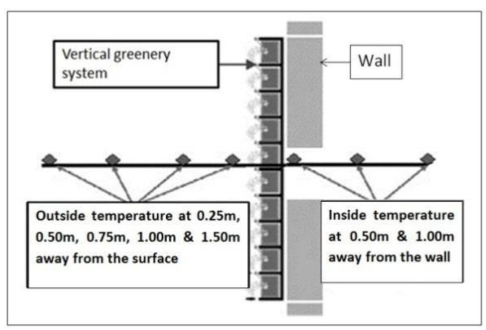


Figure 1 Method of taking point temperatures

B. Case Study 1: "Fab" Mount Lavinia

Mount Lavinia "FAB" has been selected as the 1st case study, which is situated in Colombo district of Sri Lanka. It is a two story building and front face of the 1st floor covered by an indirect green façade supported with a wood frame. The green façade is not having a direct contact with the building. After the green façade, there is a 0.4 - 0.5m distance to the wall which is glazed wall. Spot temperatures were taken in two days in different times in both green wall and control wall. Green façade was well covered with the green vegetation.

Table - 1 Green facade's effect with respect to the control wall (without greenery) on FAB Mount Lavinia

Distance from Wall	Greenery wall Temperature (T) °C	Control wall Temperature (T) °C
Inside the room(1.5m)	29.7	33.1
On the wall	32.1	33.9
0.25m from the wall	32.8	34.2
0.50m	33.4	35
0.75m	34.2	35.4
1.00m	35.2	36
1.25m	36.3	36.6
1.50m	37	37

C. Case Study 2: Heritance Hotel Kandalama

The Heritance Hotel Kandalama was selected as the case study-2, which is situated in Mathale district of Sri Lanka. It is also a multi-stored building and all the building face is well covered with an indirect green façade supported with by a concrete frame. The green façade is not having a direct contact with the building. There was a very thick green layer which the thickness about 0.1m - 0.2m in some places. After the green façade, there is a 1.0m - 0.5m distance to the wall which was a glazed wall. Spot temperatures were taken in two days in different times in both green wall and control wall.

In the building a central air conditioning system had been used for rooms. But spot temperatures which were taken between the green façade and the outside of the wall of some rooms (in air conditioned rooms) were considered as the inside temperature because it was covered with side walls up to green façade and the balcony was considered as the room, just after the balcony the green vegetation layer covered the face. Some spot temperatures which were taken inside the rooms were directly taken because they were none air-conditioned. The maximum outside temperature was 32.8^{0}C, but considering to the normal average daily temperature, this temperature was somewhat lesser.

Table – 2 Green facade's effect with respect to the control wall (without greenery) on Heritance Hotel Kandalama

Distance from Wall	Greenery wall Temperature (T) °C	Control wall Temperature (T) °C
Inside the room (1.5m)	27.2	30.5
On the wall	28.9	31
0.25m	29.3	31.1
0.50m	29.5	31.2
0.75m	30.3	31.4
1.00m	31.0	31.7
1.25m	31.5	31.9
1.50m	32.8	32.6

D. Case Study 3: Kirulapana Residential House

The residential house, which has been selected at Kirulapana, which is a two storied building with a green vegetated wall on one side covering both the ground and first floor. The green layer was having a direct contact with the building. Spot temperatures were taken in two days in different times in both the green wall and control wall.

The building was none air-conditioned and the green cover was grown on the blind wall surface of the neighbouring house. Whether this was a partition (fence) wall, the indoor temperature readings were taken from the adjoining house. The maximum outside temperature was 37 ^{0}C in outside. When considering other buildings in other case studies, this green vegetated wall did not have any opening to inside of the building. Since, considering the vertical greenery effect this wall has been selected as a living wall (green vegetated on the wall itself).

Table - 3 Green facade's effect with respect to the control wall (without greenery) on Kirulapana Residential House

Distance from Wall	Greenery wall Temp (T) °C	Control wall Temp (T) °C
Inside the room (1.5m)	28.4	31.4
On the wall	31.4	32.3
0.25m	32.8	33.4
0.50m	33.8	34.2
0.75m	34.8	35
1.00m	35.5	35.6
1.25m	36.2	36.3
1.50m	37	37

E. Limitations

Since, the spot temperatures sets were taken, some sets of temperature readings were neglected while calculating average temperatures in case study-2 Hotel Heritance Kandalama due to the variation of the weather during the days of measurement. Thus, the normal maximum temperature in Kandalama area is more than 35°C, 36°C during April that the readings were taken, but the days the spot temperatures were taken, about 34.6°C has been observed only for one reading and other readings were observed less than 33°C. This can be affected to the ultimate temperature difference because, according to the literature, the effect of vertical greenery can be very clearly observed when the outside temperature goes up.

When considering the case study-3 the house at Kirulapana, the green vegetated wall is a brick wall which has no opening such as a window. The neighbour house and the selected house as the case study-3 were separated by this green vegetated wall. To get the inside room temperatures, spot temperatures inside of the neighbouring house was considered. As the control wall, the selected house's first floor was considered.

V. DATA ANALYSIS

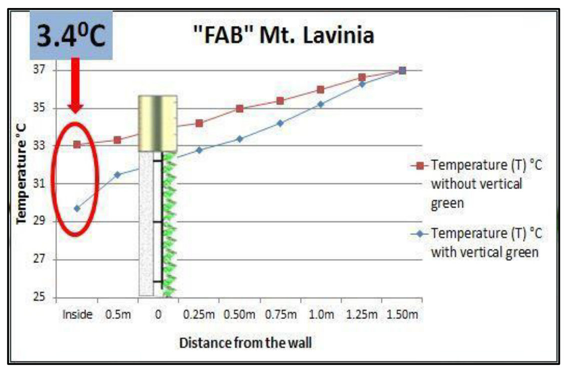
A. Case Study-1: "Fab" Mount Lavinia

There was a 3.4^{0}C temperature difference between inside and outside due to vertical green façade considering to the control wall which is not having the vertical green vegetation.

Table - 4 Green facade's effect with respect to the control wall (without greenery) on FAB Mount Lavinia

Distance from Wall	Greenery wall Temp (T) °C	Control wall Temp (T) °C	Difference of Temp (T) °C
Inside the room (1.5m)	29.7	33.1	3.4
On the wall	32.1	33.9	1.8
0.25m from the wall	32.8	34.2	1.4
0.50m	33.4	35	1.6
0.75m	34.2	35.4	1.2
1.00m	35.2	36	0.8
1.25m	36.3	36.6	0.3
1.50m	37	37	0

Figure 2 Spot temperature variation of green facade's with respect to the control wall (without greenery) inside and outside of the building



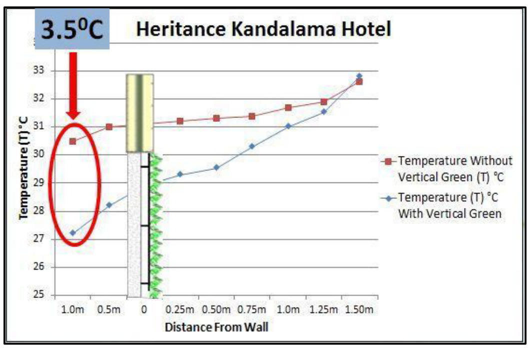
Case Study 2: The Heritance Hotel Kandalama

There was significant temperature difference of a 3.5^{0}C between inside and outside due to effect of vertical green façade considering to the control wall which is not having the vertical green vegetation.

Table - 5 Green facade's effect with respect to the control wall (without greenery) on Heritance Hotel Kandalama

Distance from Wall	Greenery wall Temp (T) °C	Control wall Temp (T) °C	Difference of Temp (T) °C
Inside the room (1.5m)	27.2	30.5	3.3
On the wall	28.9	31	2.1
0.25m	29.3	31.1	1.8
0.50m	29.5	31.2	1.7
0.75m	30.3	31.4	1.1
1.00m	31.0	31.7	0.7
1.25m	31.5	31.9	0.4
1.50m	32.8	32.6	-0.2

Figure 4 Spot temperature variation of green facade's with respect to the control wall (without greenery) inside and outside of the building



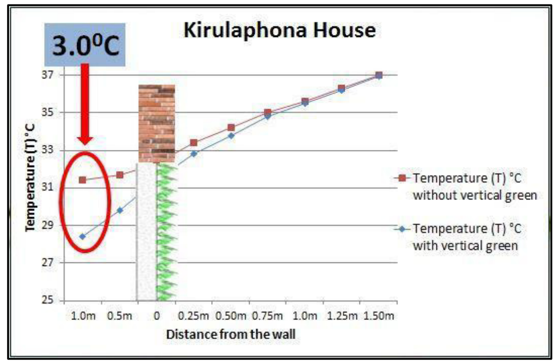
Case Study 3: Kirulapana Residential House

There was a 3^{0}C average temperature difference between inside and outside due to effect of vertical green vegetated living wall considering to the control wall which is not having the vertical green vegetation.

Table - 6 Green facade's effect with respect to the control wall (without greenery) on Kirulapana Residential House

Distance from Wall	Greenery wall Temp (T) °C	Control wall Temp (T) °C	Difference of Temp (T) °C
Inside the room (1.5m)	28.4	31.4	3
On the wall	31.4	32.3	0.9
0.25m	32.8	33.4	0.6
0.50m	33.8	34.2	0.4
0.75m	34.8	35	0.2
1.00m	35.5	35.6	0.1
1.25m	36.2	36.3	0.1
1.50m	37	37	0

Figure 5 Spot temperature variation of green facade's with respect to the control wall (without greenery) inside and outside of the building



VI. RESULTS AND OUTCOME

A. Discussion

According to the literature survey, to reduce the room temperature from a single degree of Celsius using a split air conditioner requires the almost 5% of its total energy consumption per day considering the minimum in energy reduction. The relevant data had been taken by using an Infrared Thermometer and average of measurement sets were analyse by using tables and graphs. The average of spot temperatures, were calculated and displayed in tables and graphs by using collected temperature readings. The outside temperatures are shown above as an average of all readings. Some times the average temperature calculated is lesser than the maximum ambient outside temperature.

According to the case study-1 "Fab" Mount Lavinia, a significant overall average temperature reduction of 3.4^{0}C has been identified. According to the case study-2 the Heritance hotel Kandalama, a significant overall average temperature difference about 3.5^{0}C has been identified. According to the case study-3 Kirulapana residential house, a significant overall average temperature reduction of 3^{0}C has been identified. Much higher temperature reduction can be identified due the effect of indirect green façade rather than the direct green façade and by reducing 3.5^{0}C maximum inside temperature, while a indirect green façade can reduce 17.5 % of electricity use for air conditioning (split air conditioner).

The prime objective of this research was to investigate the thermal comfort of vertical green layer in multi-stored buildings. The conclusions from the research are as follows:

- The two main vertical green façade methods discussed in the study affects the thermal comfort by reducing a significant amount of temperature from outside to inside of the building.

- Form the selected two methods, indirect green façade (the green vegetation layer is not having direct contact with the wall/green layer is introduced some distance away to the wall) was more significant in indoor temperature reduction compared to a vegetated wall.

- According to the referred literature minimum of 17.5% of electricity use for air conditioning can be reduced by obtaining a 3.5^{0}C of temperature reduction.

- An indirect green façade (distance away from the wall) can be more beneficial than vegetated on the walls (direct green façade) because it has no direct contact with the wall surface and even in the aspects of watering and insects living in green covers and specially when the protection of the wall is considered.

- Vertical green vegetation can be adopted as a counter measure of reduction of indoor temperature and reduction of energy consumption for air conditioning in Sri Lankan context.

Direct green façades and indirect green façades can improve the environment in cities which are having less green coverage. It is a good solution for cities that has no space for greenery or vegetation. Regarding the heating, less heat accumulation occurs in the case of a vertical green vegetated surface, it is therefore a wise choice to apply greened surfaces especially in warmer climates. Finally, the contribution of direct green facades and indirect green facades may be small at the building scale, they are, however energy efficiency and are recommended whenever practicable.

B. Recommendations for Implementation

From this research, it has been found that, the use of vertical green systems on multi-stored buildings can support to in improving its thermal comfort. Hence, recommendations can be implemented that any type of vertical greening system would be appropriate to gain thermal comfort of a building by reducing temperature from outside to inside while saving a significant amount of energy which is used for air conditioning the building in Sri Lankan context, although indirect green facades giving much more thermal comfort than other types. In the same time it will be a good solution to increase the reducing green areas in Sri Lanka.

C. Recommendations for Further Researches.

- Thermal effectiveness of horizontal greenery to multi-stored buildings in Sri Lankan context.
- Thermal effectiveness of the plants in horizontal and vertical greening systems in Sri Lankan context.
- Effectiveness of the different greening systems for ventilation in multi-stored buildings in Sri Lankan context.
- Thermal effectiveness of different types of vertical greening.
- Thermal effectiveness of the greening systems due to climatic changes in Sri Lanka.
- Appliances of green wall systems in different aspects for different buildings.
- Effect of relative humidity to gain thermal comfort in vertical green vegetated multi-stored buildings.
- Effect of the plant type and thickness of the green layer to increase the thermal comfort of a building.

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REFERENCES

AKABARI, H., POMERANTZ, M., TAHA, H. 2001. Cool surfaces and shade trees to reduce energy use and improve air quality in urbn areas. .

ALEXANDRI, E. A. J., P 2006. Building and environment.

BADRULZAMAN JAAFAR, I. S., MOHD HISYAM RASIDI 2011. Evaluating the Impact of Vertical Greenery System on Cooling Effect on High Rise Buildings and Surroundings.

BARTFELDER, F. K., M 1987. Experimentelleuntersuchungenzur function von fassadenbegrünungen, Berlin.

C.Y. CHENG, K. K. S. C., L.M. CHU 2010. Thermal performance of a vegetated cladding system on facade walls. Building and Environment.

DUNNETT, N. K., N. 2004. Planting green roofs and living walls,. Portland, Or. and Cambridge: Timber Press.

EUMORFOPOULOU, E. A. K. J. K. 2009. Experimental approach to the contribution of plant-covered walls to the thermal behaviour of building envelopes. Building and Environment.

HONEYWELL The Use of Advanced Insulating. Green building insullation.

KÖHLER, M. 2008. Urban Ecosyst.

KRUSCHE, P., KRUSCHE, M., ALTHAUS, D., & GABRIEL, L. 1982. Bauverlag.

N.M, J. 2012. Implement the Vertical Greenery Wall (Facade) to Multi-Stored Building in Sri Lankan Context.

SHIBUYA K, S. Y., SATOH S 2007. Survey of wall covered with plant in the city of Tokyo and evaluation of thermal environment of wall greening system.

*WONG N.H., E. A. 2009. thermal evaluation of vertical greenery systems for building walls and Building environment. The Green Building Envelop Vertical Greening***,** *270.*

*WONG, N. H., TAN, A.Y.K., CHEN, Y.,SEKAR, K., TAN, P.Y., CHAN, D.,CHIANG,K. & WONG, N.C. 2010. Thermal evaluation of vertical greenery systems for building walls. Building and Environment***,** *663-672.*

Y.STAV, G. L. 2012. Vertical vegetation design decisions and their impact on energy consumption in subtroppical cities.

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