IMPLEMENT THE VERTICAL GREENERY WALL (FACADE) TO MULTI-STORED BUILDING IN SRI LANKAN CONTEXT

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Abstract

The use of vertical greening has an important impact on the thermal performance of buildings and on the effect of the urban environment, in both summer and winter. Plants are functioning as a solar filter and help to prevent the absorption of heat radiation of building materials extensively. Applying green façades wall (GFW) is not a new concept, where most of the developed countries have been implemented the vertical greenery to their buildings while realising its sustainable benefits. However, vertical greening can provide a cooling potential on the building surface, which is to be very important during summer periods in warmer climates. In this study, an analysis of the effect on temperature (air and surface) of vertical greening systems on the building level is presented. An experimental approach was set up to measure the temperature on direct and indirect GFW, using infrared thermometer and psychrometer. And the energy saving effect of the thermal resistance was identified by using heat transfer calculation. A comparison between measurements on a bare façade wall (BFW) and a GFW were done in the summer season to understand the contribution of vegetation to the thermal behaviour of the building envelope.

Since the research was focused on quantifying the vertical greening systems and in the possible effect on the thermal resistance, the main conclusions that could be drawn from the selected buildings are presented. The evaluation was done in different locations, namely, in front of bare facade wall (BFW) and greened facade wall (GFW), and identified small differences of air temperature between façade walls. Further, it was investigated that inside and outside surface temperature of walls and finally concluded that the vertical greening systems are effective natural sunscreens, due to a reduction of the surface temperatures behind the green layer compared to the BFW. It was found that the energy recovering value between the BFW and GFW. The final result of energy requirement was less to the GFW than the BFW.

Keywords: Vertical green wall (façade), temperature reduction, vertical greenery impacts, heat transfer, energy saving and sustainable benefits, experiment method

1. Introduction

A study by Bellomo (2003 cited Perini *et al*., 2011) mentioned that the integration of vegetation on buildings, through vertical greening, allows to a relevant improvement of the building's efficiency, ecological and environmental benefits where as Campiotti *et al*. (2011) stated that plant techniques, commonly known as Green Façades was regarded as an important solution for providing insulation to building and thus contributing to save energy consumption by reducing energy demand on space conditioning. Moreover, a study of Minke *et al*. (1982 cited Ottele, 2011) found that main benefits of green façades applications are of economical, social and environmental origins such as greenhouse gas reduction, adaptation to climate change, air quality improvements, energy saving by insulation, habitat provision and improved aesthetics whereas Pal *et al*. (2000) emphasised that sound reduction is also possible by the use of vegetation. Sri Lanka has been changed to the eco concept, therefore, vegetation plays an important role in Sri Lankan context. Although, green walls have been actively promoted in many countries, rather less attention has given within Sri Lankan context.

As described by Perini *et al*. (2011) the sun radiation can warm up the building envelope. In that manner, a huge amount of energy is consumed by Air Conditioning in the multi-stored buildings due to the warmed up building envelopes. Since the use of vertical greenery concept is beneficial in reducing such issues to a great extent, this research was carried out to study on different vertical greenery systems and possibility of implementing concept of vertical greenery to multi-stored building in Sri Lankan context. Therefore, the research was to improve energy saving in terms of reducing temperature, protect building environment from sun radiation and improve other sustainable benefits by implementing vertical greenery façade.

2. Methodology

The detailed comprehensive preliminary literature survey was carried out by referring books, journals, conference papers, e-papers and dissertations in order to identify the vertical greenery concept, its environmental impacts and other sustainable benefits. Further, an experiment was adopted with instrument (e.g. infrared thermometer and psychrometer) and observations to gather data for the research.

This empirical study focused on two greened building in Colombo district of Sri Lanka, which is contributing to inside temperature reduction of building and enhancement of aesthetical appearance. Only the direct and indirect greening was selected to examine in the selected area to the research. The experiment was done in a way that allocating two days per building as well as getting measurements five times per day by using infrared thermometer and psychrometer. Then a heat transfer equation (as below mentioned) was used to measure the temperature difference between the bare wall (BW) and greened wall (GW) to analyse the experimented data. The results were discussed by using graphs and diagrams.

$$\mathbf{Q = (K*A*\Delta T)/L}$$

Equation 1: Heat transfer equation

3. Literature Review

Ottele (2011) described the vertical greenery types and its growing methods, the ground rooted traditional green façades and modern techniques to create green walls which ensure that fundamental differences arise in vegetation types. Basically one can understand systems rooted into the ground and based on hydroponic systems (not rooted into the ground), green wall technologies may be divided into two major categories namely: rooted into the ground and rooted in artificial substrates or potting soil.

Besides, in the case of an indirect greening system, where vegetation is supported by cables or meshes, many materials can be used as support for climbing plants as, for example, steel (coated steel, stainless steel, and galvanized steel), types of wood, plastic or aluminium. Each of the materials enumerated changes in the aesthetical and functional properties due to the differences in weight, profile thickness, durability and cost (Perini *et al*., 2011). The indirect greening systems can be combined with planter boxes at different heights of the façade (see Figure 1) in this case the system requires, the rooting space, nutrients and a watering system should be sufficient (Perini *et al*., 2011).

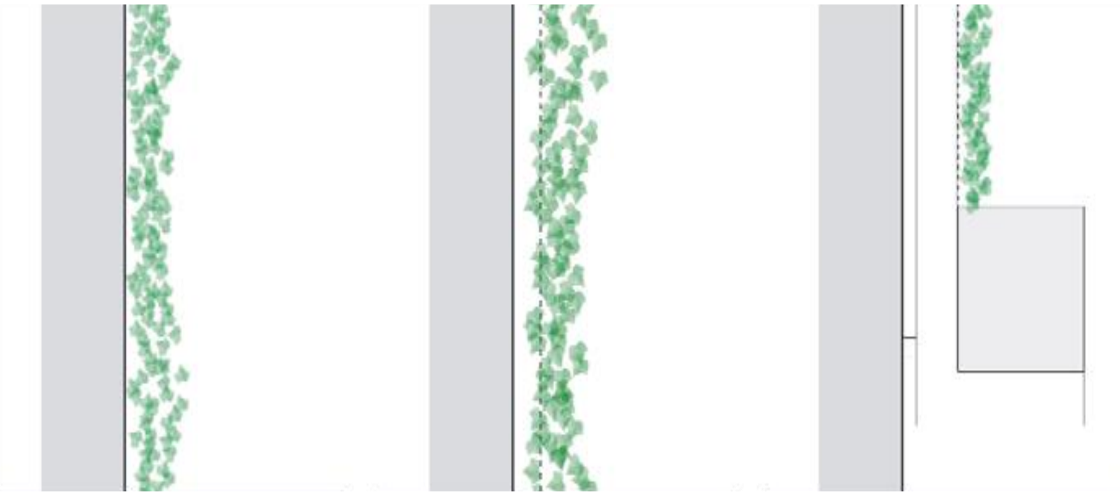


Figure 1: Direct greening system (a), Indirect greening system (b), Indirect greening system combined with planter boxes (c)

Source: (Adopted from Perini et al., 2011, p.2)

In literature, a general overview is given on the advantages and disadvantages of green walls in general (Peck *et al*., 1999 cited Ottele, 2011). The Table 1 describes on different greening systems and its advantages and disadvantages according to literature.

Table 1: Vertical greening type, advantages and disadvantages

Source: (Adopted from Peck et al., 1999 cited Ottele, p.24)

Vertical greening type	Advantages	Disadvantages
Direct façade greening	Low planting costs	Chance on moisture problems (constructions without a cavity wall)
	Suitable for retrofit projects	Maintenance costs
	Relatively little technical expertise needed	Not suitable for each construction
	Increased biodiversity development	Long growing period to get result
	Breeding and nesting possibilities	Maximum greening height of +/- 25 m
	No need for irrigation systems	
	Reduction of indoor and outdoor temperature due to evapotranspiration and shadowing	
	Conversion of air polluting substances (CO_2, NO_x and SO_2)	
	Absorption of particulate matter (PM_x) on leaves	
Indirect façade greening	No direct contact of vegetation with façade	Maintenance costs
	Suitable for retrofitting projects	Long growing period to get result
	Possibility to green older constructions (a nine-inch wall) without change on moisture problems	Maximum greening height of +/- 25 m
	Increased biodiversity development	
	No need for irrigation systems	
	Reduction of indoor and outdoor temperature due to evapotranspiration and shadowing	
	Conversion of air polluting substances (CO_2, NO_x and SO_2)	
	Absorption of particulate matter (PM_x) on leaves	
	Improved aesthetic value	
Wall vegetation	Development of vegetation spontaneously	Can be unattractive due to backlog idea
	Natural effect	Not suitable for each construction material (growing possibility or damaging effects)
	Inexpensive	
	Increased biodiversity development	
	No need for irrigation systems	
	Conversion of air polluting substances (CO_2, NO_x and SO_2)	
	Absorption of particulate matter (PM_x) on leaves	

In this backdrop, preliminary literature survey has identified the general benefits of vertical greening 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 effectiveness and energy saving capability. In contrast, some risks of vertical greening have also identified, namely, moisture problems, damage and deterioration and maintenance. Further, some positive as well as negative results of vertical greenery in other contexts were identified through the preliminary literature survey.

4. Research findings and analysis

4.1 Experiment 1: Rotary International School

The Rotary international school building which is situated in Nugegoda in Colombo district of Sri Lanka was started around 30 years ago and researchers found this building as a direct vertical greening building. Sri Lanka is more apposite to tropical climate changes, thereby, the building architectures decided beforehand, approximately 25 years ago to set up the vertical greenery to reduce the temperature inside, as a result, they do not use any air cooling systems yet (see Figure 2)

Figure 2: Rotary international school

The Figure 3 explains in terms of the total average, maximum and minimum amount of temperature levels while passing heat through the direct vertical greenery.

Table 2: Greenery effect (Rotary Building)

Distance	Maximum (T)	Average (T)	Minimum (T)
0	30.9	30	28.4
0.225	31.7	30.86	30.2
0.425m	33.65	31.84	30.15
0.525m			
0.725m			
0.925m			
1.125m			
1.325m	35.2	33.38	31.4

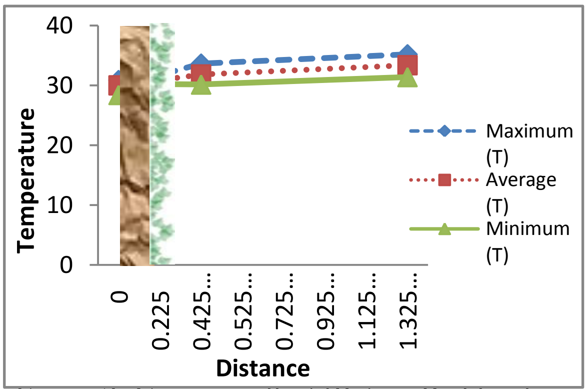
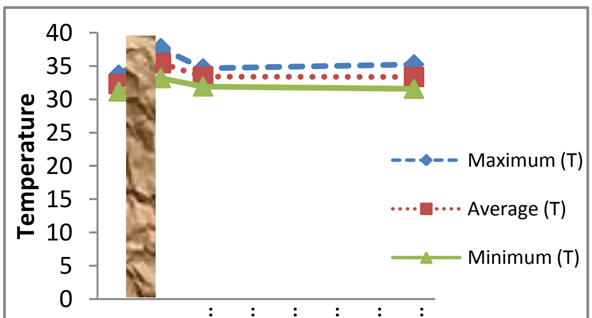


Figure 3: Greenery effect (Rotary Building)

Table 3: Bare wall effect (Rotary Building)



Distance	Maximum (T)	Average (T)	Minimum (T)
0	33.7	32.32	31.2
0.225	37.7	35.46	33.2
0.325m	34.65	33.42	31.95
0.425m			
0.625m			
0.825m			
1.025m			
1.225m	35.25	33.38	31.6

Figure 4: Bare wall effect (Rotary Building)

With related to Figure 4, readers can easily understand that how much temperature is differencing via vertical greenery as well as the trends of maximum, minimum and average temperature.

However, when the radiation comes near to the vertical greenery, the temperature is being slightly reducing and passed through the greenery, where the temperature level goes down from the 1m air temperature level to GW inside surface temperature by 3.38^{0}C. Therefore, buildings must be recovered only a little amount of temperature by using energy consumption. Besides, above BW line chart explained the temperature difference without using any greenery.

When comparing with greenery wall, the temperature is increasing while radiation is nearing to the BW outside surface. Ultimately from 1m in front of BW to BW inside surface, temperature is varying by 1.06^{0}C, on the other hand in the vertical greenery wall, high level of temperature is reduced while facing the inside surface. Therefore, if the BW restricts the temperature, temperature was very little amount of the BW inside surface. However, the vertical greenery wall is also providing a little amount of barrier, however the inside surface of vertical greenery is less than BW inside surface wall. Therefore, finally it can be concluded that the vertical greenery is better than the BW. Ultimately the direct greening is reducing temperature by 0.98^{0}C (GW 0.1m air temperature 31.84^{0}C - GW surface outside temperature 30.86^{0}C).

Further, the heat transfer equation is only considered at the wall outside and wall inside surfaces which is more sufficient to get the answers as well as need to identify how much heat is being transferring inside the room and how much energy is needed to recover those heat transfers.

As per the heat transfer calculation, if the Rotary building used only the brick wall without using vertical greenery then they have to recover the 22.33W energy per second. On the other hand, in Vertical GW (façade) rooms, they have to recover only the 6.12W energy per second. Therefore, while comparing the BW and GW, they do not need to spend more energy to the vertical GW.

4.2 Experiment 2: Dehiwala House

One of the houses located in Dehiwala was selected as an indirect greening system which is situated at station road, Dehiwala in Colombo district of Sri Lanka. The building was started around 3 years ago as a house. This vertically greened building consists of two floors. Here, vertical greenery was done as an indirect vertical greenery type. (see Figure 5).

Figure 5: Dehiwala House

Measurement was done in a particular area and the thickness of the wall is 0.225m. According to the meter reading, the building could have achieved energy saving by reduction of the temperature. Following line chart (see Figure 6) explains the vertical greenery temperature trends inside the building. Here, additionally GW inner leaf air temperature is also included. This is because of the indirect greening system consists of the 0.5m air cavity between the vertical greenery and the wall surface. According to this summary line chart, the temperature gradually is decreased from in front of 1m of vertical greenery to wall inside surface as 3.28^{0}C. Table 4 and Figure 6 explain this trend clearly.

Table 4: Greenery effect (House)

Distance	Maximum (T)	Average (T)	Minimum (T)
0	30.9	29.54	27.1
0.225m	31.6	30.62	28.6
0.625m	32.2	31.22	28.9
0.725m			
1.025m	33.85	32.1	29.55
1.225m			
1.425m			
1.925m	35.45	32.82	29.8

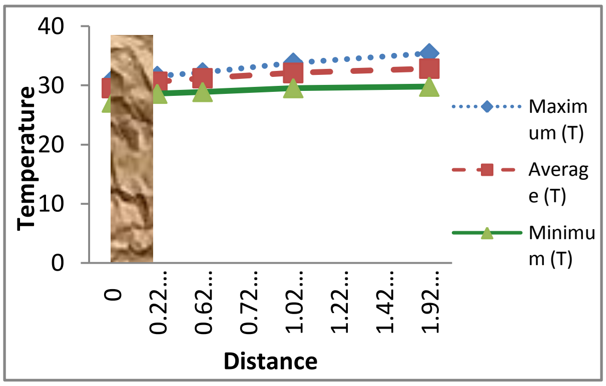


Figure 6: Greenery effect (House)

In this chart (see Figure 6) the temperature difference can be easily identified. While sun radiation coming near to the vertical greenery, gradually it is reducing and passing to the 0.2m thickness vertical greenery and further reduces.

Moreover, the line chart (see Figure 7) explains the temperature difference of the BW, from 1m in front of the BW to inside surface of BW.

Table 5: Bare wall effect (House)

Distance	Maximum (T)	Average (T)	Minimum (T)
0	32.5	31.36	29
0.225	37.8	34.5	29.2
0.325m	34.75	32.72	29.55
0.425m			
0.625m			
0.825m			
1.025m			
1.225m	35.4	32.94	29.75

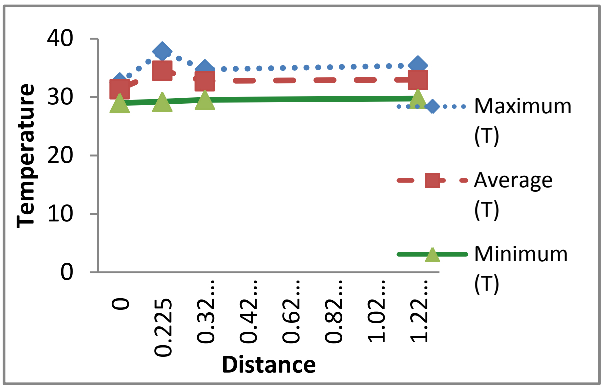


Figure 7: Bare wall effect (House)

In this chart (see Figure 7), average temperature is gradually decreased from 1m in front of BW air temperature to BW inside surface temperature by 1.58^{0}C (32.94-31.36). Ultimately, indirect greening has reduced temperature by 1.48^{0}C (32.1-30.62) from 0.1m before indirect greening to outside surface of BW and temperature reduced by 3.14^{0}C from BW outside surface to BW inside surface temperature.

As per the heat transfer calculation, if Dehiwala house used only the brick wall without using vertical greenery then they have to recover the 22.32W energy per second. On the other hand, in Vertical GW (façade) rooms they have to recover only the 7.68W energy per second. Therefore, while comparing the BW and GW, they do not need to spend more energy to the vertical GW.

4.3 Maintenance cost and appearance of the vertical greenery of the building

The maintenance cost is not a barrier to the vertical greenery cultivation to the direct and indirect vertical greenery. Sometimes, it may cause a small amount of maintenance cost for the purpose to cut or shape the greenery for a good appearance. Although, it is not that much affect to the cost estimation, however, aesthetic view is also much higher than the normal BW.

4.4 Comparison of vertical greenery wall temperature differences between the Foreign and Sri Lanka

According to the air temperature measurements taken at 0.1m inside and outside the GW surface, in some countries, direct greenery has reduced temperature by 4.71^{0}C while indirect greenery has reduced temperature by 5^{0}C. However, in Sri Lanka, the direct greenery temperature difference stands at 0.98^{0}C while indirect greenery temperature is 1.48^{0}C, once the measurements are taken at 0.1m inside and outside the GW surface. The fairly low temperature differences in Sri Lanka are because of being a tropical country where the maximum temperature goes up to 35.4^{0}C, which in turns could not reduce much temperature, even if the greenery has absorbed sun radiation for its photosynthesis. However, a considerable temperature differences have appeared in foreign countries since those are cool or non-tropical countries where the maximum temperature goes only up to 20.6^{0}C.

In that manner, with compared to some other countries, the temperature reduction is rather lower as well as rather less amount of temperature is being transferred inside the room in Sri Lanka.

5. Conclusions

With the idea of introducing vertical greenery in Sri Lanka to strengthen the link between city and nature, energy saving and other benefits of vertical greenery wall were studied. Key findings of the study revealed that average difference between the BW outside and inside surface temperature was 3.14^0C, while the average difference between the greened façade wall outside and inside surface temperature was 0.86^0C by direct vertical greenery. Since, the GW difference was less than BW difference, the potential of energy saving in the GW area is increased than the BW area.

In contrast, by the indirect vertical greening, average difference between the BW outside and inside surface temperature was 3.14^0C, while average difference between the greened façade wall outside and inside surface temperature was 1.08^0C. Then, the greened façade wall difference is less than BW difference.

Further, this research identified energy saving capability of buildings by using two different types of vertical greenery. According to the heat transfer calculation of the building at experiment 2 (Rotary building) will have to recover 22.33W per second, if vertical greenery is not applied.

On the other hand, in vertical GW (façade) rooms, only 6.12W per second is recovered. Therefore, while comparing the BW and GW, it can be concluded that the building would have a higher energy transfer with BW when compared with GW. Similar result was observed for the house with GW created indirectly. Therefore, both direct and indirect vertical greenery buildings can save more energy and can contribute towards environment sustainability by using less amount of electricity.

6. Recommendations

All types of vertical greening systems could enhance the thermal resistance. Thereby, the building gets comfort ventilation (air quality) with minimum energy usage. Hence, it is recommended that any vertical greenery façade wall type will be appropriate and can be used as an energy saving enhancement method in Sri Lankan context. With all the encouraging results of vertical greening systems, it is anticipated that vertical greening systems will gradually become one of the driving forces for realising green building envelopes in dense urban areas worldwide.

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