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USING GREEN ROOF CONCEPT AS A PASSIVE DESIGN TECHNOLOGY TO MINIMISE THE IMPACT OF GLOBAL WARMING

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ABSTRACT: Global warming phenomenon or climate change has grabbed people attention worldwide. This phenomenon leads to many environmental issues including, higher atmospheric temperatures, intensive precipitation and increase greenhouse gaseous emission. Sea level rising, melting of ice sheets, drought, hurricane are also the effect of global warming. This climate change will also affect the indoor temperatures of buildings. When the outdoor air temperature increases, building will experience indoor discomfort conditions. The demand for mechanical ventilation will be critical and lead to higher energy consumption in building. In conjunction with, researchers worldwide collectively agreed that one way of reducing the impact of global warming is by implementing green roof technology. Green roof technology is a technology of integrating plants with built environment. Green roof or also known as ecoroof, living roof or vegetated roof is a roof which is partially or completely covered with vegetation and soil or growing medium. Green roofs give many benefits to the environment such as by improving thermal performance and reducing energy consumption in building. Plant layers on the rooftop provide shading and insulation and could significantly reduce the energy consumption especially in air conditioning spaces. Apart from that, they also can be implemented as heat island mitigation technique in urban areas and used as stormwater runoff. This paper investigates the benefits of green roof to the indoor and outdoor environment. It focuses on the review of current knowledge regarding the environmental benefits of planted roof/green roofs in other countries and the potentials of this technology to be implemented in Malaysian context.

Keywords: global warming, green roof, thermal performance, energy consumption.

1. INTRODUCTION

Climate change which manifested in global warming has become critical worldwide. High temperature, abundant precipitation and rise of sea level are the indicators of global warming. Since the late 19th century, the mean global temperature has increased by about 0.3 to 0.6 ^{0}C (Maslin, 2004). Global warming results from the increase of greenhouse gas emissions. Carbon dioxide (CO_2) which is the leading greenhouse gas is said to be the reason for this global warming. According to Smith (2005) climatologist worldwide agreed that carbon dioxide increase in atmospheric concentration was because of human activities. As the CO_2 in atmosphere increases, the ability of earth surface to reradiate heat to the atmosphere is lessen. CO_2 acts like a blanket over the surface and keep the earth warmer than it would otherwise be (Houghton, 2004).

The warmer climate outside will also affect the indoor temperature of building. When the outdoor air temperature increases, building will experience indoor discomfort. The demand for mechanical ventilation will be critical and lead to higher energy consumption in building. Recent research discovered that the ability of ocean to absorb CO_2 in atmosphere decrease because of global warming. So, the CO_2 concentration in atmosphere is predicted to be continuously increased. Naturally plants play a very important role in absorbing CO_2 from the atmosphere in order to counter the detriment of the greenhouse effect.

2.0 GREEN ROOFS AS A STRATEGY TO MITIGATE THE IMPACT OF GLOBAL WARMING

Planted roof or green roof can be defined as roof that consists of vegetation and growing medium and sometime refers to roof garden in some places (Anon, 2007, Dunnett and Kingsbury, 2004). It also defined as roof that supports vegetation. Green roof can be divided into two distinguished types which are either considered as extensive or intensive. According to Osmundson (1999), intensive green roof or generally known as roof garden can only be built on the roofs of building that are strong enough to support the load. They are ideally suited to reinforced–concrete structures and steel frame. However, with the technological advances, they can be built on the various types of structures. The differences between extensive and intensive green roofs is summarised in the table below.

Table 1: Summarised of the differences between extensive and intensive green roofs

Intensive Green Roof	Extensive Green Roof
1. Require intensive maintenance	1. Require extensive maintenance
2. Accessible	2. Inaccessible
3. Require deeper substrate (min 15 cm)	3. Require shallow substrate (only 2 to 15 cm)
4. Heavy weight (saturated weight between 200 to 500 kg/m^2)	4. Low weight (saturated weight between 60-150 kg/m^2)
5. High cost	5. Low cost

Source: Werthmann, 2007& German National Standard DIN 1055 – Design Load for Buildings.

2.1 BENEFITS OF GREEN ROOF

2.1.1 As a thermal reduction and thus energy saving.

By providing large surfaces with vegetation, they contribute to the improvement of thermal performance of building (Eumorfopoulou and Aravantinos, 1998). This finding was supported by Niachou A, et al (2001) which discovered the indoor temperature values in the building with green roof are lower during the day. They measured the roof temperatures in non-insulated building with and without green roof. The result shows that the surface temperature of non-insulated building without green roof are vary from 42 to 48^{0}C while the surface temperatures of the green roof upon non-insulated building are lower and ranging from 28 to 40^{0}C. They also concluded that the existence of large temperature differences due to the installation of green roof could contribute to energy saving potential.

A well designed and managed green roof could behave as a high quality insulation device and reducing the heat flux through the roof in summer (Barrio, 1998). A group of researchers form Japan has conducted the field measurements of roof lawn garden planted on non-woven fabric on an actual three-storey pre-cast reinforced concrete building. From the measurements, it confirmed that the amount of heat coming into room during summer was reduced by a roof lawn garden. The reduction of roof slab surface temperature from 60 to 30^{0}C was observed during the measurement and estimation of 50 percent in heat flux was calculated by simple calculation (Onmura et al., 2001). Another study on the thermal performance of extensive rooftop greenery systems has been conducted in Singapore by Wong et al. (2007). That study concluded that the green roof tends to experience lower surface temperature than the original exposed roof surface. In areas well covered by vegetation, over 60 percent of heat gain was prevented by the implementation of green roof system. According to that study, the heat flux through the roof structure was greatly reduced after the installation of the green roof system. Those findings strongly supported the above statement.

The Pen State Center for Green Roof Research has developed a green roof field experiment in Central Pennsylvania which consists of 6 separate experimental buildings. Three buildings were developed with green roofs and the other three were constructed with dark roofs. The temperature, meteorological conditions and water retention and runoff were monitored on those roofs. The hourly averages of temperature data was taken every five minutes. These data demonstrate the cooling potential of green roof surfaces compared to dark impervious roof surface. The peak temperature of 30^0C or lower can be measured on the green rooftops (Gaffin et al., 2005). Other researchers from India discovered that the combination of green roof and solar thermal shading lead to the reduction of average indoor air temperature by 5.1^0C, from the average indoor air temperature for the bare roof (Kumar and Kaushik, 2005).

Researchers from Columbia University Center for Climate Systems Research and NASA Goddard Institute for space studies had discovered that green roof could potentially reduce energy usage, fossil fuel consumption and greenhouse gas emissions. On average 2^0C reduction in indoor air temperatures were measured in building with green roofs during daytime hours and 0.3^0C higher at night. That study also confirmed that vegetated surface, green roofs may reduce outdoor air temperature and urban heat island effect through evapotranspiration, shading and increased albedo. Thus it also supported the above mention findings. That study also discovered that a 50% extensive green roof scenario reduced New York City's average surface temperature by < 0.1 to 0.8^0C and the green roofs could help the region prepare to adapt the global warming by reducing energy usage, fossil fuel consumption and greenhouse gas emissions by moderating temperature inside the building. The need for space heating and cooling is reduced by cooling the surface because green roof reduces the flow of energy into and out of a building (Rosenzweig et al., 2006)

Spala et al (2008) found that the installation of green roof on the office building in Athens presents a significant contribution to the energy saving during summer period. The remarkable reduction of building cooling load was estimated during the simulation study. However, during winter, the effect of green roof installation is not significant because of the variation of heating load was quite small.

Green roof also can effectively reduce the need of air conditioning in summertime thus contribute to energy saving in building (Liu and Baskaran, 2003). Liu, in another study, made a conclusion that green roofs are giving better performance in the summer than in the winter because the ability of reducing heat gain than heat loss (Liu, 2006). Researchers also proved that plants and substrates are the major contributor to the thermal performance and energy reduction aspect. Several study related to those variables are explain below.

a. Effect of Plants on Thermal Reduction of Green Roof

Many studies had proved that different kinds of vegetation could give different thermal reduction measurements. Large foliage development with mainly horizontal leaf distribution could give excellent thermal reduction (Barrio, 1998). Niachou A et al (2001) discovered that surface temperature of green roof varies with different types of vegetation. Lowest temp was measured in the space with thick dark green vegetations. That finding was supported by Wong et al (2007) which indicated that the temperatures measured underneath the relatively extensive greenery coverage were relatively lower than that measured underneath the groundcover with tiny leaves. Lower temperatures were measured under thick foliage while higher temperatures were obtained under sparse vegetations or only soil, and green plants irradiated and reflected less solar heat (Wong et al., 2003).

The Millennium Park in the city of Chicago has established a green roof on top of a huge subterranean parking garage and commuter train terminal. One of the reasons why the city Mayor, Richard M. Daley initiates the green roofs in Chicago is that the capacity of green roof to mitigate heat island effect. In 1995, more than 700 people died during a July 1995 heat wave in the city. The plants on green roofs cool the air and reduce ozone formation and also insulate the roofs, keeping buildings cooler in summer and cutting electricity use (Shufro, 2005).

The selection of plants to be planted on the roofs depends on to the final plant height required, their flowering period and the type of soil these particular plants needed (Spala et al., 2008). This finding was strongly supported by Theodosiou (2003). Theodosiou had discovered that foliage height was strongly influenced by the transpiration levels and related to the shading of the soil surface. The shorter the foliage height, the stronger the thermal connection between them. However, on the days of continuously high temperatures, the high foliage still contributed to the removal of thermal loads from the building interiors. Foliage density also plays an important role in energy phenomenon. Large parameter values could practically complete shading the lower foliage area and the soil layer surface, thus protecting it from solar radiation (Theodosiou, 2003).

Green roof plants should also be tougher and need fewer nutrients than plants found in most gardens. Low growing, shallow-rooted perennial plants that are heat, cold, sun, wind, drought, salt, insect and disease tolerant are the most successful green roof plants (Snodgrass, 2006).

b. ***Effect of Substrates on Thermal Performance of Green Roof***

Substrates or growing media can influence plants establishment and performance under various conditions. Different factors of substrate such as type, depth, slope and irrigation can give different performance of green roof. According to Snodgrass (2006), the green roof medium must be substantially lighter, less rich and more porous than soil used for ground-level garden. The medium or substrates chosen for green roof should be evaluated by its organic content, pH and nutrient levels, weight, porosity and water retention capacity.

For the tropical climate condition such as Singapore, the used of thin layers of substrates, which low thermal capacity, result in high surface temperature caused by the reradiated heat. However, substrates with low thermal capacity can be easily cooled down at night, thus trapped and reradiated less heat. The dark colour of substrates has a tendency to absorb more heat during the day time. The moisture of substrates also gives impact to the thermal performance of green roof. When the substrates is dry especially during drought period, the substrate temperature measured can exceed the surface temperature of the original exposed roof (Wong et al., 2003).

Both (a) and (b) improve the environment in cities by reducing solar radiation, daily thermal variation and annual thermal fluctuations. Heat island effect is a major environmental problem in most urban area which leads to higher energy demand in building. By greening the rooftops in urban area the problem of heat island effect will be reduce. To mitigate heat island effect in urban areas, it requires the implementation of greening rooftops in large scale. In Tokyo, the implementing roof vegetation which contributed to vegetation-covered area by 3.4% and 16.4% from the present, the maximum surface temperatures are reduced by 0.1^{o}C and 0.6^{o}C respectively (T. Kinouchi and Yoshitani, 2001). According to David Beattie, the Director of Penn State University's Center for Green Roof Research, some estimates has been made regarding an effect on the heat island when implementing green roof in cities. If a substantial part of the roofs in the city like Atlanta and Toronto were to green, the temperature could be reduced by 12 degrees. Rosenzweig et al (2006) discovered that when 50% extensive green roof covered the New York City, the average temperature is reduced by 0.1^{o}F to 1.4^{o}F (<0.1^{o}C to 0.8^{o}C). From above findings, it is proven that green roof could reduce heat island effect in urban areas.

2.1.2 Green Roofs as Storm Water Mitigation Technique

Green roof reduces stormwater overflow by retaining, evaporating and detaining runoff (Rosenzweig et al., 2006). Daniel Hillel wrote in the research report of Green Roofs in the New York Metropolitan Region, the amount of runoff from bare roofs is about 85 million cubic meters for a total roof area of 85 million square meters. That amount can probably be reduced by half if the roofs are covered with vegetation. This study was supported the previous study done by VanWoert et al (2005) which says that vegetated platforms retained greater quantities of stormwater than the conventional roofs with a gravel ballast. They concluded that vegetated green roof systems not only reduced the amount of stormwater runoff but they also extended its duration over a period of time beyond the actual rain event .

2.1.3 Other Benefits of Green Roof

Leaves of plants absorb the gaseous pollutants, while particulate matter is breakdown by soil microbes and removing it from the atmosphere. Green roof can significantly extend the life of a roof by protecting its roof membrane with a series of layers and protects it from the extreme temperature fluctuations and ultraviolet rays. This has a positive impact on the people living or working around them. A 2003 report shows that worker productivity in green building is higher than in buildings that are less environmental friendly (Snodgrass 2006 cited Kats 2004). Scientists at the Lawrence Berkeley National Laboratory in Berkeley, California shows that those painted white or planted roofs reduce annual air conditioning costs by tens of millions of dollars in jurisdictions that have implemented heat island mitigation measures (Snodgrass 2006 cited Pomerantz et al 1999)(See Snodgrass 2006). The ‘eco-roofs’ in England are designed to provide habitat in highly populated areas for bird species such as black redstarts (Snodgrass 2006 cited Gedge 2003)(see Snodgrass 2006).

3. THE MALAYSIAN SCENARIO

In Malaysia, those notable buildings with roof top garden such as:

(i) the famous Mewah Oil Headquarters at Pulau Indah Industrial Park, Port Klang, Selangor designed by Ken Yeang. This building has a sky garden at the roof top and a continuous internal vegetated ramp adjoining a cascading watercourse and a large straight staircase, with terraces.

(ii) the Rice Museum (Laman Padi) in Langkawi, and

(iii) the Malaysian Design Technology Center at Limkokwing Institute of Creative Technology has an extensive rooftop landscaped terraces which insulate the building from the hot tropical sun. Commercial and education blocks are naturally cooled by lush green foliage.

Figure 1: Mewah Oil Headquarters, Port Klang, Selangor

Source: www.ldavies.com

Figure 2: Planting of rice on the roof top at Laman Padi Langkawi.

Figure 3: The Malaysian Design Technology Center at Limkokwing Institute of Creative Technology

Source: www.ldavies.com

However, the benefits of this technology have not been thoroughly studied by the Malaysian researchers particularly on the thermal and energy aspect. The documented technical information and cost involved in this construction is also unavailable. Therefore something has to be done to encourage this technology to be spread out in this country. An extensive research on green roof construction must be taken into consideration by the Malaysian research institutes of higher learning to educate and provide awareness to the public. Installing potted plants on the rooftop seems to be the easiest way of constructing green roof. If potted plants on could also give the positive impact in reducing the global warming impacts particularly on the thermal performance and energy consumption in building as intensive and extensive green roof could do, the Malaysian public should be encourage to used this technology in order to lessen their burden on paying for the electricity cost. Apart from that, flat roof construction can now be considered as a tropical design element, which previously it was not.

4. CONCLUSION

Literature reviews have revealed how green roof can act as one of passive techniques in mitigating the environmental issues. However, most of researches investigate the effect of green roofs on the thermal performance, energy consumption and rain water and heat island mitigation aspects. None of them have investigated on how much this technology could reduce the amount of carbon dioxide in atmosphere since there is no research paper focusing on that part. The ability of green roof as sound insulator is also one of the environmental aspect which has not been studied yet.

Another issue is that researchers only emphasized on planting the vegetation on multilayer component of green roofs such as substrate, drainage layer, root barrier and as such. None of them have ever studied on how much the potted plants on the roof top could contribute to lessen the environmental problems. Therefore, further research on the role of potted plants in reducing the impact of global warming should be carried out in order to reduce the cost of green roof construction. It was observed from those reviews, that the researches were conducted outside Malaysia and none in the Malaysian context. Therefore, it is time that such research to be carried out to find out the effective variables in green roof technology in the Malaysian context for its thermal performance, energy savings, effective carbon dioxide uptake, cooling of the external environment, the prevention of flooding and many other Tropical Malaysian criteria.

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