Thermal Performance of Rooftop Greenery system in Tropical Climate of Malaysia

A case study at a 10 storied building R.C.C flat rooftop at UTM, Johor Bahru, Malaysia

Prof. Mohd. Hamdan Bin Ahmed
Department of Architecture,
Faculty of Built Environment
Universiti Teknologi Malaysia (UTM), Malaysia
E-mail: drmedan@yahoo.com

Rumana Rashid
Phd. in architecture (Candidate)
Department of Architecture,
Faculty of Built Environment
Universiti Teknologi Malaysia (UTM), Malaysia
E-mail: rashid_rumana@yahoo.com

Abstract

In tropical countries rooftop greenery is more sympathetic to the prevailing climate and provide comfortable indoor environment. This paper analysis the above hypothesis at the 10 storied residential apartment in Universiti Teknologi Malaysia (UTM). The analysis of actual performance of the rooftop greenery can provide the information on effectiveness of applying on contemporary houses for tropical climate in Malaysia. Imperial studies have been performed an internal and external roof surface temperature and air temperature were measured for a period of three days in two phase. The first phase of measurement was carried out when the rooftop was empty. After the rooftop greenery were built then the second phase of measurement was conducted. Expected findings of the research is the green rooftop will tends to experience lower surface temperature then the original exposed roof surface. So this research work will provide an introduction or preliminary guide line for thermally responsive architecture on the basis of thermal performance of the rooftop greenery system. Temperature is the main criteria of human comfort. To provide an indoor comfort environment by the rooftop greening of building is more appropriate in tropical climate of Malaysia.

1. Introduction

Green is unity, a symbolic implication, a deep significance within our present realm of reality. It has moved beyond being just another band on the color spectrum and is now an all-encompassing attitude, a common consciousness, a global movement. Green is about finding a balance between growth, waste, sustenance, resources and limits, which is what the notion of sustainability is all about. If we cannot sustain ourselves with what we have, what we produce, what we throw out; how we do it, when we do it and ultimately, why we do it, then we will no doubt perish. If we cannot sustain ourselves, and lest we forget, we have only ourselves to blame for our own problems and predicaments, then it is almost certain nature - the other side in the equation - will eventually not bother anymore. All along, nature has supported us and has created its own balances and its own methods to deal with our excesses but lately, there have been very visible signs which suggest it is simply getting tired of being, well, and good natured (Krishnan, 2005).

There are three major groups of problem for sustainability such as population growth, depletion of resource and atmospheric pollution. The common denominator of items depletion of resource and atmospheric pollution, this is energy. CO_2 emissions are largely caused by energy use, thus the best measure of CO_2 emissions, therefore sustainability, is energy demand. This is closely linked to the problem of diminishing sources of energy. According to S.V. Szokolay, 2008 the problem can attack from two directions:

1. Reduce energy demands of buildings

2. Substitute renewable sources of energy as far as possible

Furthermore, the Malaysia energy centre estimate that CO_2 emissions per capita, from the energy sector increased 45% from 1994-to 2005 (Mustapa, issue 0021). However, more than 40% of the energy consumed can be reduced if energy efficiency is practiced and sustainable technologies are applied to building. Because In 2002, 44% of the total energy used in the residential sector in Malaysia was in the form of electricity (Zain-Ahmed, 2008a). In Malaysian residential housing sector, the housing stock is made up of terrace house (61%), apartment (27%) and detached (12%). More than 70% of the detached houses are air-conditioned while 62% terrace house and 36% apartments are air-conditioned (Kubota, 2006). These air conditioners have been installed mainly in their master bedroom (94%), other bedroom 52%, living room 29% and dining room 5% (Kubota, 2008). The current trends indicate that the bigger houses tend to be air conditioned than the smaller houses and further suggest that the purchasing power of occupants is proportional to the installed air conditioner. These air conditioners have been installed mainly in their master bedroom (94%), other bedroom 52%, living room 29% and dining room 5% (Kubota, 2008). Thus it is important to find passive cooling mean that can reduce the demand of air conditioning in this hot-humid tropical climate of Malaysia. The main purpose of this study is to determine passive cooling strategies for residential building in Malaysia. The purpose of the study is to examine the cooling effect of green roof as a passive cooling method in the high rise residential apartment in Malaysia. Since most of the cities in this region hot-humid climate all the year round, it is particularly important to develop passive cooling in order to reduce energy demand caused by the growing use of air-conditioners. However, there is uncertainty on the usefulness of green roof in cooling and maintaining comfort temperature throughout day and night in hot-humid tropical climate of Malaysia. This paper presents the field measurements which compare the temperature cooling effect of green roof and original exposed roof surface. These findings lead to a discussion on the potential of indoor air temperature reduction by applying green roof and reducing the effect of Urban Heat Island (UHI) and Global warming in urban areas.

1.2 Aim and Objective

The aim is to improve the indoor environment for better living quality and to reduce the energy consumptions. The objective of this research is therefore to explore the thermal performance of rooftop garden in hot-humid tropical climate in Malaysia. Through such field measurement, it is desirable to find out the answers of the following questions:

1. How much reduction of roof surface temperature caused by rooftop garden?
2. What is the quantity of reduction of solar heat gain caused by rooftop garden?
3. Does the green roof change the urban heat island effect?

1.3 Scope

Green landscape or gardening will be a component of the building. For understanding the thermal performance of rooftop greenery of buildings in urban areas and to promotes it into the contemporary building as a thermal comfort strategy for the modern design.

1.4 Benefits of Rooftop Garden

1. Rooftop garden influences the microclimate of the building to provide more comfort for occupants. It enhancing the natural image in the building and provides an amenity space for residents. Adding identity and enhancing the aesthetic appeal of a building and improvement of the micro-climate of the surrounding outdoor environment.

2. With rapid urbanization, high concentrations of buildings create many environmental issues, such as Urban Heat Island (UHI) effect. The UHI effect is started mainly due to the loss of green areas in the urban environment. Green strategically placed around roofs can be considered as a complement of urban greens. These are providing visual enhancement, air and noise control. Green roof as a natural solution also contributes to the thermal benefits in buildings and their surrounding environments. Greenery placed around buildings serves to reduce the surface temperature through direct shading on hard surfaces. It also provides cooling the ambient air through consuming solar heat gain for transpiration and photosynthesis. The shaded surface also emits less long-wave radiation due to lower surface temperature (Wong, 2002). All these will contribute to less the energy consumption for cooling and mitigating UHI effect in the urban environment.

3. A considerable body of research shows that contacts with nature and viewing nature or participating in nature can generate positive and progressive effects to human well being. The green nature provides many benefits to human functioning and healthy life. The emotional and psychological benefits of each human receive with the ability of simply viewing open greened spaces. Some hospitals have reported that comparing patients recovering from similar operations- those with views of landscaped courtyards required less post-operative days, strong and medium level of painkillers and complained less than patients who are looking at a bare brick wall. This appears to be one of many benefits of the developing field known as "Horticultural Therapy", whereby patients gain exposure to living plants and thus they are able to remove themselves from their injury (Green Roofs for Healthy Cities Website, 2001).

4. Canadian sources have calculated that, on an average, eleven square feet of grass can remove one-half pound of air particles each year. This may not sound like a lot, but consider how much material there is in a half pound of dust! Furthermore, they calculated that sixteen square feet of grass could produce enough oxygen to supply one human with his yearly need. These filtering actions combined with the temperature reducing nature of plants will go a long way in improving the air quality in urban centers. So the green rooftop is act

as an air filter which combined with passive cooling means (Green Roofs for Healthy Cities Website, 2001).

5. Additional benefits exit from rooftop gardens on the buildings are in the form of insulation, use of lower energy expenses, and extended lifespan of roofing materials. Fifteen inches of grass and growing medium can have the same insulating effects as six inches of standard fiber building insulation. This can save the building operating system and hundreds of dollars for cooling and heating expenses. It has also been estimated that a roof top gardens can also help to retain as much as fifty percent of the heat that is normally lost through cold air movement across a typical roof (Kuhn, Monica, 2001). Finally, even greater cost reductions which exist by the extended life span for the roofing materials that do not experience as great a change in temperature due to the protecting effects of the garden (Liu, 2001).

2. Literature Review

Researcher	Methodology	Findings
Onmura et al (2001)	Field measurement on a planted roof in Japan	The surface temperature decrease of around 30–60°C was observed on site
Onmura et al (2001)	Wind tunnel experiment and a numerical calculation	Evaporative cooling effect of the green roof was also confirmed
Niachou et al (2001)	Field measurement of surface and air temperature on a planted roof and complemented by a mathematical approach	Thermal properties of green roofs and energy savings were examined
Elean Palomo Del Barrio (1998	Mathematical analysis	Thermal behavior of green roofs
Wong, (2006	Field measurement	Green roofs act as the insulation devices rather than cooling the roofs
Ekaterini Eumorfopoulou (1998)	Calculation to examine the thermal behavior of planted roof	Green roofs can contribute to the thermal performance of buildings but it cannot replace the insulation layer
Researcher	Methodology	Findings
Onmura (1994 and 2001)	Field measurement on thermal protection techniques of green roof	Reduction in the local air temperature near canopy thus reducing (4–5°C)the incoming heat flux into the building
Del Barrio (1998) and Good (1990)	Prediction	Worth mentioning on the works of thermal performance of green roofs

Dominguez (1998); Lozano (1990); Eumorfopoulou and Aravantinos (2003); Takakura (2000) et al; Capelli et al (1998)	Implementation of green roof in the buildings	Thermal behavior and effectiveness of vegetation covers with different average absorption for solar radiation and diffusive properties
Niachou et al (2001),	Field investigation on green roof and mathematical approach	Both indoor and outdoor thermal properties are considered for thermal performance of green roof.
Hoyano (1988 and 1994)	Experimental study	Effect of rooftop lawn planting on thermal environment and also described for climatologically uses of plants for solar control and the efforts on the thermal environment
Rakesh, 2005	Mathematical formulation	Green roof provide a cooling potential
Wong (2002).	Field measurement	Thermal benefits of roof top garden

3. Methodology

The field measurement was carried out on a rooftop of a high-rise 10 storied residential building in Malaysia. The field measurement was not influenced by any shadows or reflected solar radiation since there are no high-rise buildings around it. The extensive type of rooftop garden is organized by 50 nos. of pot plants to cover the rooftop surface. Plants are arranged densely, the layout of the rooftop garden shows in figure 1. Pot plants are used for this research because it is easy to maintain, cost effective to construct, easy to drainage of rain water from rooftop and less affects on the roof surface. All plants are selected base on their density of foliage or leaf Area Index (LAI).

Bare rooftop before Greenery   Construction of Greenery   Dense Greenery on rooftop

Figure 1: Bare roof top and roof top greenery

The field measurement were done in two phase. The first phase of measurement was carried out when the roof top was empty, in the date of 26th to 29th November, 2008. After the rooftop garden was built then the second phase of the experiment was conducted, in the date of 30th November to 2nd December. In this phase the field measurements were carried out on the same type of two roof top, one was bare roof and another was pot planted greenery roof. Because the direct effect of green roof and bare roof within the same condition of the outdoor ambient environment is wanted to compare.

The physical measurements were carried out using the temperature and humidity data loggers and surface temperature data loggers. The temperature and the relative humidity for both internal and external data were recorded at every 15 minutes interval. The data were averaged for every hour to obtain the hourly values. The positions and the measured variables of the data loggers are described in table 1. The building was fully occupied by resident and any mechanical cooling was not used during the field measurements period. The instrumentations used in field measurements are summarized as follow.

1. Dickson Data Logger
2. Inferred ray gun data logger
3. Air temperature & Humidity sensor logger

Figure 2: Internal view of experimental room and entry of the room

Table 1: Description of data logger positions and measured variables installed at roof top of the tested apartment in UTM.

Sl no.	Position and Description	Measured variable
1	Rooftop surface under the green shade and without green shade	Rooftop surface temperature
2	Earth surface of the pot plants under the green	Earth surface temperature
3	Indoor ceiling surface of the test room	Indoor ceiling surface temperature
4	Indoor space of the test room 1.5m from floor level	Indoor air temperature and relative humidity
5	Outdoor environment 2m above the rooftop surface	outdoor air temperature and relative humidity

2.1 Comfort zone for Malaysia

The analytical method of evaluating the comfort zone for Malaysia have been studied by several authors (Rajeh, 1988, Jones, 1993), using the "Neutrality Temperature". This study uses the neutrality temperature as a base to determine the thermal performance of the rooftop greenery system in topical climate of Malaysia. In various studies, neutrality temperature is defined as the temperature that gives a thermal experience neither warm nor cool, which is a state of "neutral" or "comfortable". It is the mid point of the comfort zone, as an average value for many experimental subjects. According to Auliciems, A. and S. Szokolay (1997) with the range of the comfort zone is taken as 5°C, thermal comfort temperatures extends approximately about 2.5°C above and below the neutral temperature. According to Szokolay comfort formula, the neutral temperature needed to maintain at 26°C. With the width of the comfort zone taken to be 5°C (Auliciems, A. and S. Szokolay, 1997), thermal comfort temperatures extends approximately about 2.5°C above and below the neutral temperature. The neutral temperature is 26°C in free running building; this neutral temperature is for conditions without air movement. So the upper and lower limits of the comfort zone would then be 28.5°C and 23.5 °C respectively. In this research evaluating the comfort environment according to comfort zone is 23.5°C to 28.5°C.

2.2 Construction and Maintenance policy of the rooftop greenery

For tropical climate maximum month of the year on average rainfall occurs almost everyday. February is the only dry month in the whole year. So for the rooftop garden no need everyday maintenance and watering. From nature the plants get enough water, air and sunlight for their growth. So nature gives all prosperity to maintain the plants. Pots plants are densely arrange on rooftop, shown in figure 3 .There are three to five half inch holes in the bottom of the pots, by which the plants are drainage the extra water from pots to roof. The flat concrete roof slab has one inch slop from the middle of the slab to the end of the slab for rainwater damage. The mouth of water drainage 100mm pipes are covered by steel nets (figure 3) for preventing rubbish to entering into the pipes. Also use some brick or stones cheeps over the net as a protection of the net. For better growth of the plants every six months require fertilizer to the plants. The lift room and the water tank is placed side by side and one side of the roof. One main staircase continues upon the roof for access to the rooftop for maintenance.

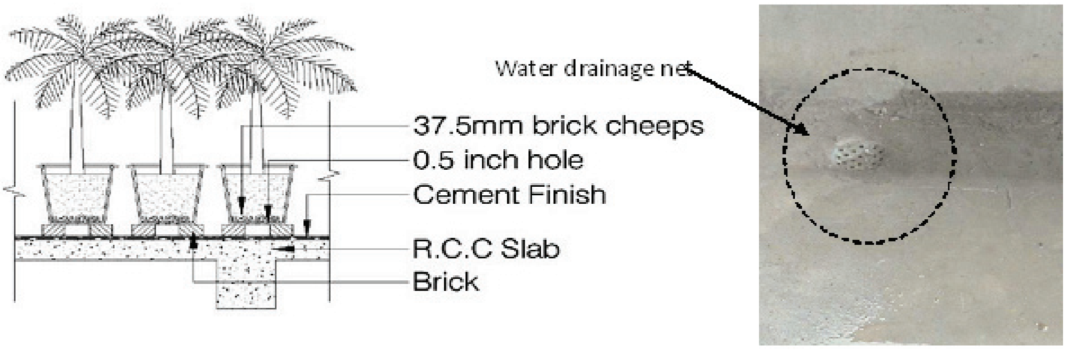

Figure 3: Section of pot plants arrangement (Left) and net on water drainage pipe (Right)

3. Result and Analysis

3.1 Comparison of external surface temperature

The thermal performance of roof top greenery and bare roof was compared to identify the green roof abilities on reducing indoor air temperature of the high-rise building and the surrounding environmental effects on micro climate of the ambient environment. The result is analyzed by comparing the internal and external surface temperature, ambient air temperature and relative humidity.

The surface temperature is a major indicator to determine the thermal performance of building. The surface temperature comparison is presented in figure 4. Surface temperatures on exposed bare roof top were much higher than green roof. The rooftop surface maximum temperature was decreased around 11.2°C to 19.8°C in field experiment. The maximum surface temperature of the bare rooftop (BRs) was 56.0°C; the rooftop surface after greenery (GRs) was 36.2°C. The maximum temperature of potted earth surface (Es) under plants shade was 32.2°C. The relationship is derived Es< GRs< BRs.

So the plant's shaded earth surface is cooler (24°C) than the bare roof surface. Higher surface temperature of the bare roof indicates that such level of solar radiation is absorbed in concrete bare roof during daytime and it emits as long-wave radiation at night. This phenomenon causes the formation of Urban Heat Island (UHI) effect in surrounding areas. Moreover green roof surface shows lower surface temperature than the bare roof surface because greenery plays a vital role to reduce the surface temperature through direct shading of exposed bare roof surface. Greenery helps to cool the ambient air through consuming solar energy for transpiration and photosynthesis of the plants. With rapid growth of urbanization, the UHI effect is aggravated mainly due to demolishing the greenery in the urban environment. However rooftop greenery system is a natural ecological solution for reducing the effect of UHI, improving air quality by reducing the CO_2 emissions.

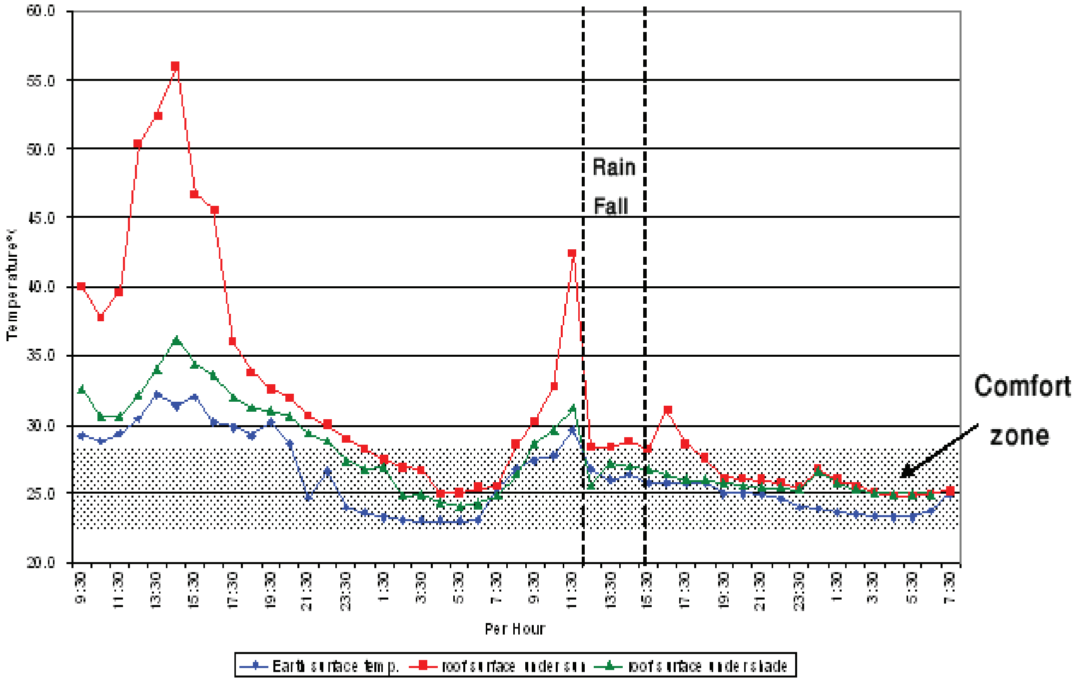

Figure 4: Profile of earth surface, bare roof top and roof top with greenery temperature

The surface temperature fluctuation is understandable from the thermal protection of the rooftop greenery system which is covered the rooftop surface. Shaded earth surface temperature under the plants is lower than shaded concrete surface temperature because the dark black color concrete roof absorbed more solar energy. So shade is essential for the concrete rooftop. It will be more effective if the concrete surface is fully covered by proper densely arranged of pot plants in tropical climate of Malaysia.

During rainy day when earth surface is wet, the thermal performance of rooftop greenery with higher moisture is performing better than bare roof. From the graph profile (figure 4) of shaded concrete roof surface and wet earth surface temperature difference is very minimal most of the time of the whole day after rainfall.

So the rooftop greenery performed well on the period when the pot plants earth surface is wet. The maximum difference of temperature between bare roof surface and wet earth surface is 22°C. Most of the day surface temperatures of the green roof are stayed within comfort temperature range (23.5°C to 28.5°C). It is caused by evaporation of wet soil and shade of densely arranged pot plants. The evaporative cooling effect of the green roof was also confirmed by this phenomenon.

3.2 The Comparison of the internal ceiling Surface Temperature

The thermal benefit of the green roof is reducing the surface temperature of the ceiling and prevent the solar heat transfer into the indoor environment and improving the thermal performance of the building (figure 5).

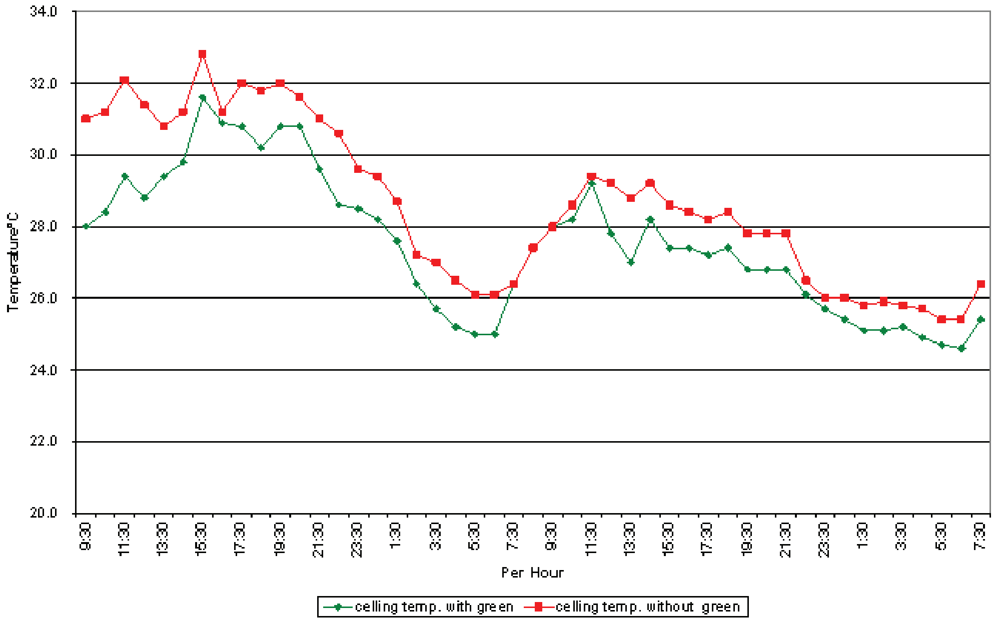

Figure 5: Profile of with green roof ceiling temperature and bare roof ceiling temperature

From the graph profile (figure 5) green roof reduces the ceiling surface temperature is maximum 3.0°C and on average temperature 1.7°C, compare to bare roof.

3.3 The Comparison of the Internal and External Air Temperature

The thermal performance of the green roof evaluation with reduction of indoor air temperature in the building is extended over the validation of cooling energy potential. Effect on indoor air temperature is also shown in figure 6. It is found that the average indoor air temperature is reduced 2.4°C by green roof during sunshine hours. However the reduction of air temperature follows a pattern. A maximum reduction of temperature is observed during peak heating period 1:30 pm to 3:30 pm and minimum occurred in off sunshine period. An amount of heat energy entering in indoor through green roof compared with the bare roof is decreased more than 3 times (figure 6). The temperature fluctuation with outdoor is less for green roof as compared to bare roof at night.

Effect in the microclimate of the building is shown in the figure 6. Daily average indoor air temperature is 33.0°C with bare roof. This is reduced 3.0°C by green roof and leading an average the indoor air temperature of 30.0°C.

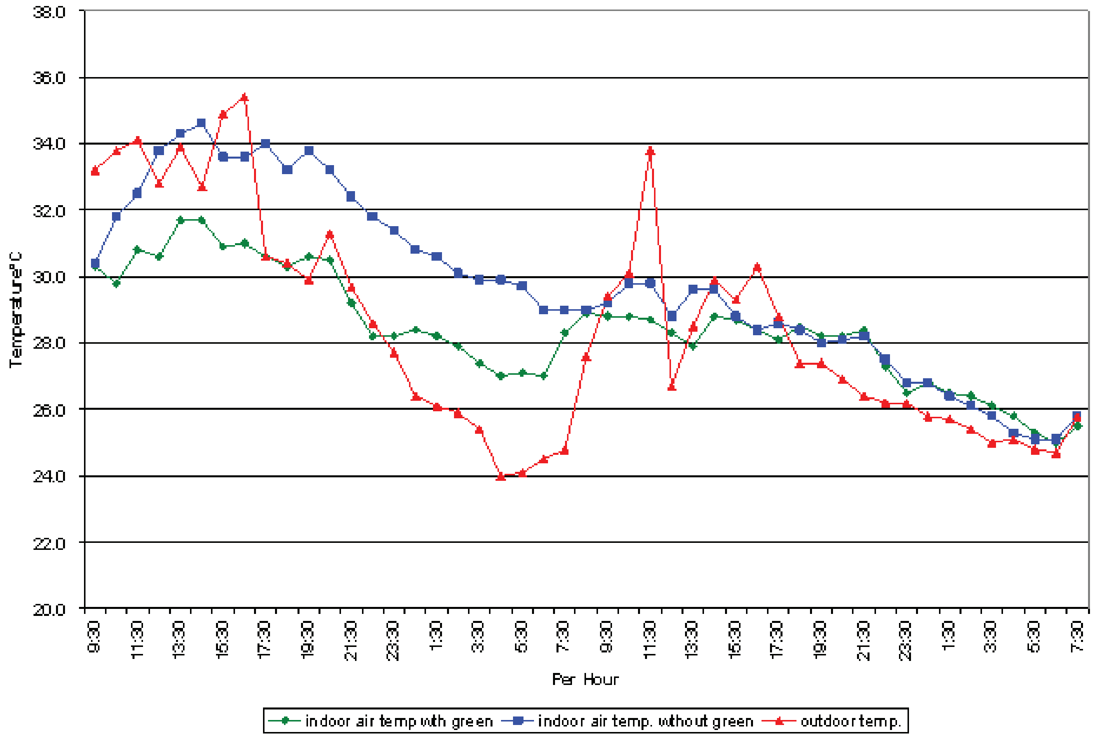

Figure 6: Profile of outdoor, with green roof indoor and without green roof indoor temperature

Figure 7: Profile of outdoor, lift lobby, with green roof indoor and without green roof indoor temperature

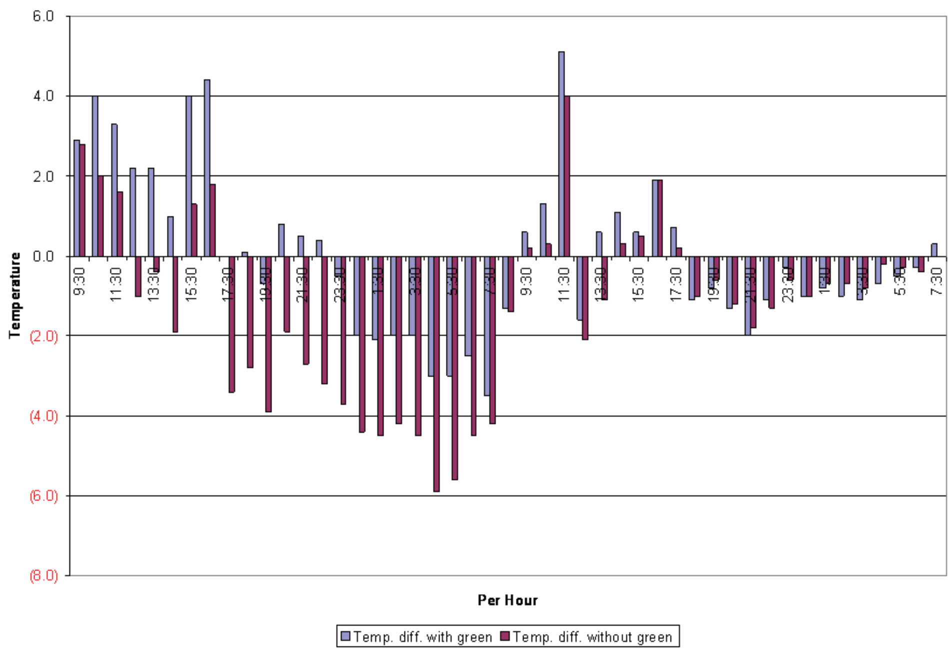

Figure 8: Profile of outdoor, with green roof indoor and without green roof indoor temperature

With diurnal variation, the indoor air temperature is reducing by green roof. Hence it is seen from figure 8 that the maximum temperature difference between indoor and outdoor is 4.4°C with green roof during day time. Bare roof is reducing indoor air temperature only 2.8°C from the outdoor. While proper ventilation is provided in indoor than the indoor air temperature is more dropped 1.5°C from general indoor temperature with green roof (figure 7). Roof top greenery plays a vital role for thermal protection which may reduce the thermal load applied to building.

4.Conclusion

From the result it has been confirmed that roof top greenery contribute thermal benefit to both micro climates of indoor environment and surrounding outdoor ambient environment of the building. It contributes to reducing energy consumption for cooling load, mitigating the UHI effect in urban environment and also reduces the effect of global warming by controlling the CO_2 level.

The heat transfer from outdoor to indoor through the bare roof was greater than the green roof. Actually, the thermal benefits caused by the proper shade and densely arranged of potted plants. Green roof also can reduce the average indoor air temperature more than the bare roof.

Green roof can reduce the indoor air temperature 4°C to 5°C during day time and at night 2°C lower than bare roof. Proper night ventilation can reduce more indoor air temperature. So the combination of green roof and proper night ventilation can reduce the indoor temperature almost same to the outdoor temperature. It provides a cooling potential of the thermal comfort in indoor environment of the room which is found to be adequate. Green roof as a passive cooling means and related thermal benefits are essential for architectural design strategy in hot-humid tropical climate of Malaysia.

Roof top covering greenery system which is easy to construction, maintaining and replaceable pot plants for thermal protection. It's provided a very effective solution for the contemporary building in tropical Malaysia. Peoples are in habituation for present state of affairs being very energy efficient and an applicable nature responsive eco-systemic well being. Roof top greenery design includes economic and social concerns as well as environmental aspects of sustainability.

Acknowledgement

In the name of Allah, the most Gracious, the most Merciful, for giving me the determination and will to complete this study. I would like to say thanks to Universiti Teknologi Malaysia,

I would like to say special thanks to Sultan Noman Qasem, Yemen, for Arabic translation.

Reference

A. Hoyano, Climatological uses of plants for solar control and the efforts on the thermal environmental of a building, Energy and Buildings **11** (1988), pp. 29–36.

A. Hoyano, J. He, T. Horiguchi and G. Wang, Experimental study on heat budget for foliage layer on lawn planting. Part 1. Effect of rooftop lawn planting on thermal environment, Journal of architecture Planning and Environmental Engineering, Transactions of AIJ **462** (1994), pp. 31–39.

A. Niachou , Analysis of the green roof thermal properties and investigation of its energy performance. Energy and Buildings **33** (2001), pp. 719–729.

Anand Krishnan, A journal of the architects regional council Asia, Dec 2005-Feb 2006.

Barrio Elean Palomo Del , Analysis of the green roofs cooling potential in buildings. Energy and Buildings **27** (1998), pp. 179–193.

E. Eumorfopoulou and D. Aravantinos, The contribution of a planted roof to the thermal protection of buildings in Greece, Energy and Buildings **27** (2003), pp. 29–36.

E.P. Del Barrio, Analysis of the green roofs cooling potential in buildings, Energy and Buildings **27** (1998), pp. 179–193.

Eumorfopoulou Ekaterini , The contribution of a planted roof to the thermal protection of buildings in Greece. Energy and Buildings **27** (1998), pp. 29–36.

Green Roofs For Healthy Cities Website http://www.peck.ca/grhcc/about.htm printed 11/13/01.

J. Dominguez and A. Lozano, Green roof systems, Comput. Mech. Publication **1** (1998), pp. 615–624.

Kubuta, T. & Ahmed, S. (2005) questionary survey on behaiviour for natural ventilation and electricity consumption in terraced houses, a case study of Johor Bharu City, Conference APSA, Penang, Malaysia.

Kuhn, Monica. “Roof Greening” http://www.interlog.com/~rooftop/greening.html printed 11/12/01.

Liu, Karen Ph. D. “A Progress Report on the Environmental Benefits and Energy Efficiency of Green Roofs.” The Green Roof Infrastructure Monitor. 2001 Vol.3, No.2 pg. 14.

M. Cappelli, C. Cianfrini and M. Corcicone, Effects of vegetation roof on indoor temperatures, Heat Environment **16** (1998) (2), pp. 85–90.

Mustapa S I, Yusop Y. Mitigating the adverse impact of climate change through sustainable use of energy: in Energy smart, issue 0021. Malaysia Energy Center.

S V Szokolay, Huminity And Technology, Proceeding 9th Senvar + 2nd Isesee, 2008

S. Onmura , Study on evaporative cooling effect of roof lawn gardens. Energy and Buildings **33** (2001), pp. 653–666

S. Onmura, M. Matsumoto and S. Hokoi, A study on evaporative cooling effect by roof lawn garden, Proceedings of the European conference on energy performance and indoor climate in buildings (1994), pp. 634–639.

S. Onmura, M. Matsumoto and S. Hokoi, Study on evaporative cooling effect of roof lawn gardens, Energy and Buildings **33** (2001), pp. 653–666

T. Takakura, S. Kitade and E. Goto, Cooling effect of greenery cover over a building, Energy and Buildings **31** (2000), pp. 1–6.

W. Good, Factors in planted roof design, Constructions Specification **43** (1990) (11), p. 132.

Wong Nyuk Hien, "Investigation of thermal benefits of roof top garden in the tropical environment" Building and Environment volume **38, issue 2, January 2003,** pp. 261–270.

Wong Nyuk Hien, "Study of thermal performance of extensive roof top greenery system in the tropical climate" Building and Environment volume **42, issue 1, January 2007,** pp. 25–54.

Zain-Ahmed, A. (2008a). Intrigating sustainable energy in building: Case study of Malaysia. FAU conference Copenhagan Business School. Denmark. 14-15 May.

الأداء الحراري لنظام السقف الخضير في المناخ الإستوائي الماليزي

دراسه ميدانيه أجريت في مدينة دكا في بانجلادش

رومانا راشد
طالبة دكتوارة في الهندسة المعمارية
قسم الهندسة المعمارية، كلية بيئة المباني
الجامعه التكنولوجيه الماليزيه - ماليزيا
rashid__rumana@yahoo.com

أ.د. محمد همدان بن أحمد
قسم الهندسه المعماريه
كلية بيئة المباني
الجامعه التكنولوجيه الماليزيه – ماليزيا
drmedan@yahoo.com

الملخص:

في سقف البلدان الاستوائيه الخضير اكثر تعاطفا الى المناخ السائد ويزود البيئة الداخلية المريحة. هذة الورقه تحلل الفرضيه أعلاة في عشر شقق سكنية في الجامعة التكنولوجيه الماليزية. تحليل الأداء الفعلي للسقف الخضير يستطيع ان يزود المعلومات علـى تأثـير تطبيق على البيوت المعاصرة للمنـاخ الاستوائي في ماليزيا. الدراسات الامبراطوريـه أديت درجة حرارة السقف السطحـي الداخلـي والخارجـي في درجة حرارة الجوقيست لمدة ثـلاث ايام في مرحلتين. المرحلـه الأولى من القياس نفذت عندمـا السقـف كان فارغا. بعد خضير السقف بنيت ثم المرحله الثانيه مـن القياس أجريت . النتائج المتوقعه من البحث هي أن السقـف الأخضـر سوف يميـل الى مواجهة درجة الحرارة السطحيـة السفلى ثم سطح السق المكشـوف الأصلي. لذا عمل هـذا البحث سوف يزود مقدمة أو خط توجيه تمهيدي للهندسة المعماريه المتجاوبه حراريا على أساس الأداء الحراري لنظام السقـف الخضـير. درجة الحرارة هي المعايير الأساسيه لراحة الأنسان . لتزويد بيئة السعة الداخليه بخضرة السقف للمبنى هي اكثر ملائمة في المناخ الاستوائي الماليزي.