THE EFFECT OF GROUND SURFACES – MATERIAL, COLOR & TEXTURE TOWARDS THE ADJACENT THERMAL ENVIRONMENT: A CASE STUDY OF PLAZAS IN PUTRAJAYA, MALAYSIA

Aniza Abu Bakar[1] and Noor Aziah Hj. Mohd. Ariffin[2]

[1] Dept. of Landscape Architecture
[2] Dept. of Architecture
Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia, P.O. Box 10, 50728 Kuala Lumpur, Malaysia.

ABSTRACT

Urban heat island (UHI) is the terminology used to describe a condition whereby the temperature within an urban area or a city is often warmer than the outer suburbs and surrounding rural environments. Cities in Malaysia are also facing this environmental issue. Buildings and urban infrastructure such as road are among the component that made up the urban fabrics. The increment of air temperature among others is due to these components that apply materials that retain heat. The modification of land surfaces following urban development such as change of land use where natural environment is being replaced with hard surfaces also contributes to the UHI phenomena. Urban geometry, evaporative cooling source and wind pattern are other factors that contribute to the formation of urban heat island. This phenomenon negatively affects the social outdoor activities, health and economy. Therefore, this paper aims to study the impact of surface material in urban plazas on their microclimate by investigating plazas in Putrajaya, Malaysia. The investigation is divided into two sub-categories where the first one is focusing on three different plazas: shaded, partially shaded and exposed plazas where these plazas are studied to compare and contrast on their landscape settings and surface temperature of various surface materials. The second sub-category is focusing on another two plazas – Dataran Wawasan (exposed plaza) and Dataran Rakyat (partially shaded plaza) that have similar orientation, dimension and physical site context. Environmental variables considered in this research are wind speed, solar radiation and cloud cover. This study aims to explore the influences and significance of certain types of pavement surfaces that vary in term of its material, color, and texture towards the surrounding thermal environment of the studied sites subsequently provide few recommendations through design initiatives that are feasible to mitigate the UHI effects in urban areas.

Keywords: Urban heat island, surface material, landscape setting, urban plaza, thermal environment

1 Introduction

The urbanization process where land are being cleared to allow physical development such as building, road network, paved surfaces and other man made structure has in a way give an adverse impact on the environment, which later affects the society in various aspects such as health, economy and social. The urbanization process leads to the increment of hard surfaces that absorb solar radiation and reradiate the heat back to the surrounding environment. The amount of heat absorbed/stored on the earth's surface depends very much on the properties of the surfaces among others. Thus, this contributes to the increasing ambient temperature. This research aims to investigate the impact of ground surface material with focus on the pavement materials and their surface temperatures in an attempt to study on its contribution to the occurrence of Urban Heat Island (UHI) phenomenon in urban area.

The research was conducted at Putrajaya, Malaysia because it is a relatively new urban area being developed comprising among others the government institutional, commercial area and green spaces, and is surrounded by rural area. Putrajaya has a lot of paved surfaces and it has been reported that Putrajaya is 5°C hotter than other cities in Malaysia and making it as one of the cities that is ranked as a new urban heat island (Krishnan, 2007-online). Therefore this research seeks to investigate several plazas where these plazas are further divided into two parts of the investigations. The first part involved three plazas which are categorized as fully shaded, partially shaded and exposed plaza. The first two plazas are adjacent to each other and are located in front of the Ministry of Finance, while the other plaza - Dataran Putra is located in front of Putra Mosque. The second part of the investigations involved two plazas with similar orientation and dimension but differ in terms of the amount of paved-turfed surface materials and exposure to the sun – namely: Dataran Rakyat and Dataran Wawasan. The distance between these two plazas is approximately 200metres.

2 Urbanization, environmental issues, microclimate and users' thermal comfort

2.1 Urbanization and its impact on the environment

Urbanization can be defined as a transformation from rural to urban society which covers all different aspects of life such as socioeconomic and landscape features (Kamarudin et al., 2011). Rapid urban growth has resulted in most of the soil and natural environment being replaced with paved surfaces and barren terrain shifted to concrete built environment. The urban fabrics are made up from composition of hard surfaces networks such as buildings, roads and paved open spaces (plaza, courtyard or square). All these changes may have directly alter and modify the local climate or microclimate of the place. When the effect is combined between cities/urban areas, these modifications of microclimate, might influence the climatical conditions at a larger scale.

As observed the urbanization process had led to the several environmental issues such as urban heat island (UHI) and green house effect that leads to the global warming which significantly affect the urban area and the people. In a hot and humid climate the people are struggling to live comfortably due to the increment of air temperature which is further exaggerated by the UHI effect.

"Urban heat island is characterized by significantly high air temperature in densely built environment as compared to rural temperatures. This is caused by the rapid urbanization and change of the land profile where more impervious surfaces such as asphalt, concrete and glass are found rather than grass or green area" (Sheweka and Magdy, 2011:592). Thus, UHI is the phenomenon where urban area is warmer than its surrounding rural area. Among others this is due to the significant amount of hard surfaces as compared to vegetation that can be found in an urban area. This allows more heat from the solar radiation being absorbed and then reradiated from these hard surfaces and further heated-up the ambient temperature. Paved surfaces such as brick, asphalt and concrete have a higher percentage of heat conductivity than soil and grass surface. Therefore, they absorb and emit more heat to the environment, thus increasing the ambient air temperature. The heat is effectively stored during day time in the urban structure. Both cities and rural areas are then cooled after sunset but the urban structures cools at a slower rate because of the high heat capacity causing a warmer night condition (Shahidan, 2011).

The other factor that contributes to the global warming is the greenhouse effects. The greenhouse effect refers to the phenomenon in the atmosphere, whereby the presence of greenhouse gases disturbs the energy balance of the atmosphere. Heat is being trapped in the atmosphere, hence warm the environment. This is unfavorable for those who are already living in hot and humid climate.

2.2 Understanding the environmental parameters influencing the microclimate and thermal comfort

ASHRAE defined thermal comfort as "*…the condition of mind which expresses satisfaction with the thermal environment, absence of thermal discomfort or conditions in which 80 or 90 % of people do not express dissatisfaction"*, and the variables that affect thermal comfort are air temperature, radiant temperature, relative humidity, air velocity, activity and clothing (see Abu Bakar, 2007).

Shahidan (2011) mentioned that human body temperature needs to be maintained at a constant level in order to achieve a level of comfort and that man is said as achieving thermal comfort when the energy restore is in balance with the amount of energy released. Therefore, factors that affect human thermal comfort need to be understood in order to be able to manipulate the outdoor elements in controlling the microclimate.

"*Microclimate is the condition of the solar and terrestrial radiation, wind, air temperature, humidity, and precipitation in a small outdoor space*" (Brown and Gillespie, 1995, p.1). The component in microclimate can be identified as air temperature, wind, solar radiation, humidity and precipitation. These environmental parameters are influencing the human comfort level thermally and affect their activities as well as the livability of a space in urban area. In contrast to the indoor environment, the outdoor environment is rather hard to control due to natural factors such as solar radiation, sky condition, wind speed and relative humidity. However, through the application of certain landscape design elements, these factors might be modified as to 'control' the microclimate, thus modify the thermal comfort level of the people (Brown and Gillespie, 1995) as human body responds to the change in the surrounding environment.

An example on the application of landscape design elements that can help to modify the microclimate is the provision of lush vegetation that filter the solar radiation penetration to the ground while providing shade. This helps to reduce the amount of heat being absorbed by hard surfaces, thus reduce the chances of heat being radiated back to the environment. This helps to mitigate the increment of the ambient temperature. Lush vegetation might break the wind that flows within the area. However, this condition is in a way being compromised by the effect of shades. Direct radiation uptake of glare by humans and buildings can be controlled by the plantation of trees as trees can influence the microclimate by controlling the amount of radiation (Shahidan et.al, 2010). He also mentioned that the physical aspects of trees are one of the main paramount in moderating climate to achieve thermal comfort level especially in hot and humid countries. Shade from tree is created by the foliage geometry and the tree crowns which are structured by the branches may reduce wind speed. The heat absorbed from building and its surrounding surfaces can be altered by shade cast from trees as it reduces glare effect and block the diffuse light from the sky. *"During the day, shade trees also indirectly reduce heat gain in buildings by altering terrestrial radiation and ultimately reducing ground surface temperature"* and the ground surface temperature is reduced when the amount of radiation underneath the tree canopy is lower (Shahidan et.al, 2010). This will improve the relative humidity as it triggers evapotranspiration process. The evapotranspiration is a process of transportation of water into the atmosphere from surfaces, including soil and vegetation (Burba, 2010). Evapotranspiration process requires solar radiation absorbed by the plant leaves and water from the root. The output of the process is oxygen and water. Therefore in hot day, the rate of evapotranspiration is high due to high gain of solar radiation and it depends on the foliage geometry of the plant. The air temperature may decrease because the amount of water is being evaporated to the air and transpiration process by the plant. This can be controlled by selection of the plant which depends on the leaves form and root types.

2.2 Modification of landscape design through characteristic of surface material

The overheated surfaces (building, road or open spaces) in urban areas where surface temperature is normally higher than the air have significantly influence the air temperature of the surrounding environment especially those within 200m of the lower atmosphere (Taha et al., 1988), thus affecting the raising of surrounding temperature through three ways - convection, conduction, and solar and infrared radiation (the law of thermal or thermodynamics) as mentioned by Gui et al. (2007). The basic principle of atmospheric heating process stated that the air is heated from bottom to top (Yilmaz et al., 2006). Oke (1987) affirmed that temperature of the urban area due to urban heat island can be in the range of 1.11-4.44 degree Celsius higher than the surrounding temperature (see Rosheidat and Bryan, 2010). The ability for a surface to absorb, reflect or emit heat depends on certain property's criteria which are thickness, color and roughness (texture), thermal conductivity, heat capacity, density, humidity, and emissivity (Taha et al., 1988). "*The thermal performance of the materials is characterized by the surface temperature they can reach and is responsible for their radioactive cooling and determines the amount of thermal radiation that is radiated*" (Prado and Ferreira, 2005). Suitable selection of materials as a cooling factor in urban environment can improve the thermal comfort condition especially during hot seasons (Doulos et. al, 2004). Synnefa (2011) stated that pavement surface with lower temperature will contribute in reducing air temperature. Surface with higher solar reflectance and infrared admittance have a lower surface temperature when it is exposed to solar radiation.

Normally, the urban hard surfaces are made up of impervious type such as asphalt, tiles and concrete. All these impervious surfaces are poor in term of its reflectivity but good in term of conductivity. These impervious pavement received radiation from terrestrial and solar during the day, where they absorb and store the heat until they become hotter than the ambient temperature. Then, these hard surfaces will start interacting with the cooler surrounding environment where the heat will flow in the three processes mentioned earlier. Impervious ground surfaces contribute to the increment of surface water runoff as the rainwater is channeled directly into the monsoon drain, river and so on. Hence, the amount of rainwater being absorbed into the ground is decreasing. This has resulted in the reduction of urban moisture which has increased the local Bowen ratio (ratio of sensible latent heat fluxes) and the surrounding temperature (Taha et al., 1988). Permeable pavement that allows water to infiltrate helps to decrease air temperature by reducing the rate of heat being released to the environment (Mark, 2008).

Another aspect to be considered is the albedo. Albedo is defined as "…*the reflective power of a material indicated by the percentage of incident radiation reflected by a material*" by Christensen, (2005) and "…*the physical sciences, the percentage of radiation falling on a surface that is reflected back from it*" by Ashworth (1991). Albedo is one of the factors affecting the surface temperature and a high albedo surface reflects higher percentage of solar radiation, thus less heat is absorbed by the material. Another material characteristic to be considered is color. Light color pavement might create glare problem but the amount of heat being absorbed is less thus, creating a mechanism of cool pavement and on the other hand, darker color will absorb and emit more solar radiation heat to the environment (Synnefa, 2011). Therefore a suitable selection of the surface material is important to create a thermally comfortable environment. A combination of color also can make a different in controlling the solar reflection and heat been absorbed by the surface of the material.

3 Methodology

The development of Putrajaya has resulted in its area being covered by buildings, and about 36% of this city is made up of open spaces with and without paved surfaces as well as large water bodies (King, 2008:153). Thus, the various open spaces especially the paved plazas within Putrajaya give a good opportunity to study the effect of various pavement materials and particularly the surface temperature on the ambient air temperature of plazas.

3.1 The studied sites

In studying the impact of surface material on the microclimate of urban plazas, five plazas in Putrajaya were identified and they are further divided into two parts as mentioned earlier due to the difference in focus of investigation and analysis.

Part 1: investigation on plazas - shaded (plaza A), partially shaded (plaza B) and exposed (plaza C).
These plazas were selected based on three categories – refer to Table 1 for the categories, their definition and locations; and Figure 1 for images of these three plazas.

Plaza	Plaza category	Definition of the category/ Criteria of plaza	Location
A	Shaded	The majority of the ground surfaces are covered by tree canopies and tensile	In front of Ministry of Finance
B	Partially shaded	There are small numbers of trees and the tree canopies are not big enough to provide sufficient shades.	
C	Exposed to the sun	No significant element to provide shade	Dataran Putra in front of Masjid Putra

Table 1: Plazas' categories and locations

Figure 1: Images of the three plazas

.

Part 2: Investigation on Dataran Rakyat and Dataran Wawasan – plaza with similar orientation
Dataran Rakyat and Dataran Wawasan have similar orientation and dimension. The former is considered as greener and cooler than the later due to grass covering part of its ground surfaces by 42.7% and shadow cast by buildings surrounding provide partially shaded areas at certain time of the day. Dataran Wawasan is regarded as 100% covered by hard surfaces, and exposed to the sun. These aspects provide certain key elements for investigation and comparisons of the landscape setting on the microclimate.

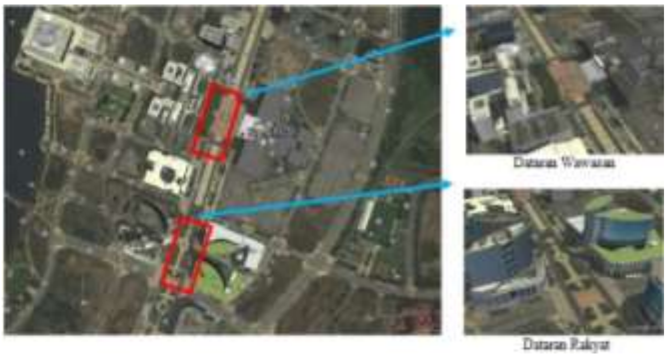


Figure 2: The location of Dataran Wawasan and Dataran Rakyat, Putrajaya
(source: http://maps.google.com.my)

Dataran Rakyat and Dataran Wawasan are located in between the Federal Government office buildings. Dataran Rakyat is surrounded by the buildings of Wisma Tani, Wisma Sumber Asli, Kementerian Belia dan Sukan (KBS) and Jabatan Penerbangan Awam Malaysia, while for Dataran Wawasan are Perbadanan Putrajaya and Istana Kehakiman.

3.2 Date & time for the field work, and the weather conditions.

Data collection at Plaza A, Plaza B and Plaza C was conducted simultaneously. However, as for Dataran Rakyat and Dataran Wawasan, it was conducted alternately due to several constraints such as limitation of equipment available and enumerators. The process depended very much on the weather conditions as it had to stop once it rained. March is commonly regarded as among the hottest months in Malaysia, however it turns out quite different this year where it rains from time to time in March. Hence, it affected the field work greatly.

Plaza A, Plaza B and Plaza C					
Day	**Date**	**Time**	**Weather Condition**		
			9.30am-12noon	12noon-3pm	3pm-5pm
D1	2nd March 2012	9.45am – 3.00 pm			
D2	9th March 2012	9.45am – 5.00 pm			
D3	11th March 2012	9.45am – 3.00 pm			

Table 2: Data collection at Plaza A, Plaza B and Plaza C – summary of date, time and weather conditions

Day	**Date**	**Site**	**Time**	**Weather condition**		
				10am-12noon	12noon-3pm	3pm-5pm
D1	2nd March 2012/	Dataran Rakyat	10:30 a.m. – 3:15p.m.			
D3	10th March 2012/	Dataran Rakyat	10:15a.m. – 2:15p.m.			
D5	26th March 2012/	Dataran Rakyat	10:00a.m. – 2:30p.m.			
D2	9th March 2012/	Dataran Wawasan	10:00a.m. – 5:00p.m.			
D4	11th March 2012/	Dataran Wawasan	10:00a.m. – 3:15p.m.			

Table 3: Data collection at Dataran Rakyat and Dataran Wawasan – summary of date, time and weather conditions

3.3 Techniques adopted for data collection

This study is field work based where environmental data are collected using several equipment as well as some observation on the sky condition. Generally, the methodology of the data collection can be divided into three stages as shown in the following Figure 3:

Figure 3: Stages of the data collection

The preparatory stage involves site identification, training a group of enumerators, preparation for the field work, pilot study and identification of days for the field work.

There were several techniques employed during the field work (data collection) and they are as follows:

- studying the landscape design elements of the plaza – types and width of pavement materials, and shading elements (vegetation and tensile structure)
- recording the environmental parameters such as solar radiation, wind speed, light intensity and surface temperature – as shown in the following Table 4 ;and
- observing and recording the sky condition with reference to *oktas* unit

No.	Reading Taken / SI unit	Equipment	Photo
1.	Air temperature / (°C)	Portable Weather Station	
	Relative humidity /(%)		
	Solar radiation / (w/m^2)		
	Wind speed / (m/s)		
	Wind direction / (°)		
2	Light / (lx)	Heavy Duty Lux Meter	
3	Surface temperature / (°C)	Infrared thermometer	
4	Wind speed (m/s)	Anemometer	

Table 4: Equipment used for data collection

Site inventory was conducted where various type of pavement materials were identified together with their color, texture and width as well as the vegetation. During the field work, the sky condition was also observed based on the cloud cover and recorded in *oktas.* This is because the sky condition affects the amount of solar radiation received by the surfaces. As for the portable weather station, it was located at the Putra Mosque for security reason. The reading recorded by this equipment reflects the general weather condition or regarded as the microclimate for Putrajaya.

As a conclusion on the field work, collecting environmental data is rather challenging due to the dynamic changes in the weather as well as having to be in outdoor environment of hot-humid condition in a longer span of time.

4 Analysis and result

The data was analysed using the Microsoft Excel software. Shadow analysis using the SketchUp software was further conducted for the Dataran Rakyat and Dataran Wawasan due to the nature of the built environment surrounding these plazas which can may influence the microclimate of these plazas and should be further analysed. The analysis and result for Plaza A, Plaza B & Plaza C, and Dataran Rakyat & Dataran Wawasan are presented separately in the following sections.

4.1 Inventory and analysis of surface materials for Plaza A, Plaza B and Plaza C

Table 5 summarizes the types of surface materials,the texture and color of the pavement, and the width of these surfaces for the three plazas. The total width of paved and turfed surfaces was then turned into percentage to see the distribution.

		Material	Texture	*	Colour	**	Area (m^2)	***	****
PLAZA A (6335.5 m^2)	A.	Granite Slab	Very Fine	41.2% Fine texture 32.8% Coarse texture	Light	61.3 Light color 12.7 dark color	95.03	1.5	74
	B.	Granite Slab	Very Fine		Dark		982.01	15.5	
	C.	Granite Slab	Coarse		Light		633.56	10	
	D.	Granite Slab	Coarse		Light		715.92	11.3	
	E.	Concrete Slab	Fine		Light		886.98	14	
	F.	Concrete Slab	Fine		Light		570.2	9	
	G.	Pebble Wash	Very Coarse		Dark		728.59	11.5	
	H.	Granite Slab	Fine		Dark		63.36	1	
	I.	Granite tile	Very Fine		Very Dark		12.67	0.2	
	J.	Grass	Very Coarse		green		1647.3	26	26
PLAZA B (2347 m^2)	A.	Granite Slab	Coarse	64.6% Fine texture 33.8% Coarse texture	Light	63.8 % Light color 34.6% Dark color	105.6	4.5	98.4
	B.	Granite Slab	Very Fine		Dark		112.7	4.8	
	C.	Concrete Slab	Fine		Light		990	42.2	
	D.	Pebble Wash	Very Coarse		Dark		295.7	12.6	
	E.	Concrete Slab	Fine		Light		270	11.5	
	F.	Granite tiles	Very Fine		Very Dark		105.6	4.5	
	G.	Granite Slab	Coarse		light		18.76	0.8	
	H.	Homogeneous tiles	Fine		Very Dark		176	7.5	
	I.	Grass	Very Coarse		green		37.5	1.6	1.6
PLAZA C (20201 m^2)	A.	Homogeneous tiles	Very Fine	8.2% Fine texture 69.3% coarse texture	Light	74% Light color 3.5% Dark color	105	0.5	77.5
	B.	Pebble Wash	Very Coarse		Light		300	1.4	
	C.	Homogeneous tiles	Very fine		Light		1574	7.7	
	D.	Granite Slab	Fine		Dark		725	3.5	
	E.	Granite Slab	coarse		Light		13010	64.4	
	F.	Grass	Very coarse		green		4554	22.5	22.5

* Percentage of total light to dark colour material
** Percentage of total fine to coarse texture material
*** Percentage of surface material to the area of plaza
**** Percentage of total paved surface to grass

Table 5: Inventory and analysis of surface materials

Plaza C is the largest with the total area of 20201m^2, while Plaza B is the smallest of these three plazas. Plaza C is 8.6 times bigger while Plaza A is 2.7 times bigger when compared to Plaza B. However, if looked in terms of the total paved surfaces, Plaza B seems to have the largest paved surfaces (98.4%) with the least turfed area compared to the other two plazas. In terms of paved surfaces, Plaza C seems to have the highest percentage of coarse paved surfaces (69.3 %) followed by Plaza B (33.8 %) and Plaza C (32.8 %). In terms of colours of paved surfaces, plaza B has the highest percentage of dark coloured materials (34.6 %) followed by Plaza A (12.7%) and Plaza C (3.5%).Based on list of materials for three plazas, granite slab and pebble wash are found to be in all plazas.

4.1.1 Sky conditions on days of data collection

Referring to Table 2, it can be seen that only on Day 2 the field work was conducted up until 5pm. It can be said that Day 3 is the sunniest day. The weather condition is in a way implies the sky condition and the solar radiation intensity that reached the ground surface.

Figure 4 demonstrates the solar radiation intensity of Putrajaya for two days of the field work (note: Reading for Day 3 was not captured by the weather station due to some technical problem. However, it is noted that Day 3 was the sunniest day). Normally solar radiation is intense between 11am until 3pm (Abu Bakar, 2007). However, looking at the data collected during the field work, generally the solar radiation started to give high reading at 11.30am. Based on these two days, Putrajaya's solar radiation ranged from 154 Watt/m^2 (1.30pm) to 950 Watt/m^2 (12.15pm). However, the readings fluctuated. As for Day 1, the reading is relatively low. This might be caused by the cloud cover (refer to Figure 5), where it can be seen that the cloud cover is significantly affect the amount of sunlight that reached the ground surfaces. As mentioned earlier, Day 1 and Day 2 were rather cloudy (refer to Table 2).

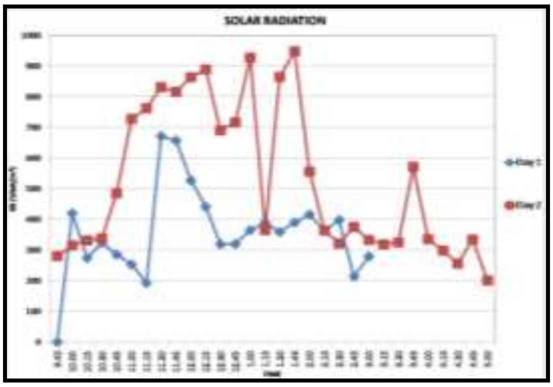


Figure 4: Solar radiation intensity in Day 1 and Day 2

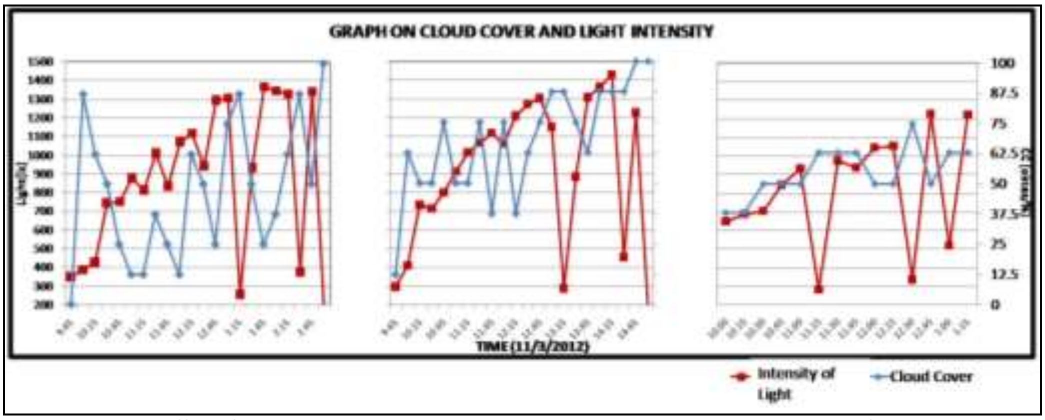


Figure 5: The effect of cloud cover (%) on light intensity (sunlight)(lux) reaching the ground surface at Putrajaya

4.1.2 The wind environment of the plazas

Wind plays a vital role in giving comfort to the people in particular in hot-humid condition. Thus, the wind environment of the studied plazas is shown in Figure 6. Generally, Day 2 can be said as having the most dynamic wind environment with generally consistent wind. When compared between these three plazas, it can be said that Plaza C experienced stagnant wind environment the most as it recorded the highest amount of 0m/s reading. The highest wind speed recorded at Plaza C is slightly below 1.5m/s. As for Plaza A and B, the wind environment is more dynamic with less stagnant condition and the highest reading recorded is slightly above 2.5m/s and 3m/s respectively.

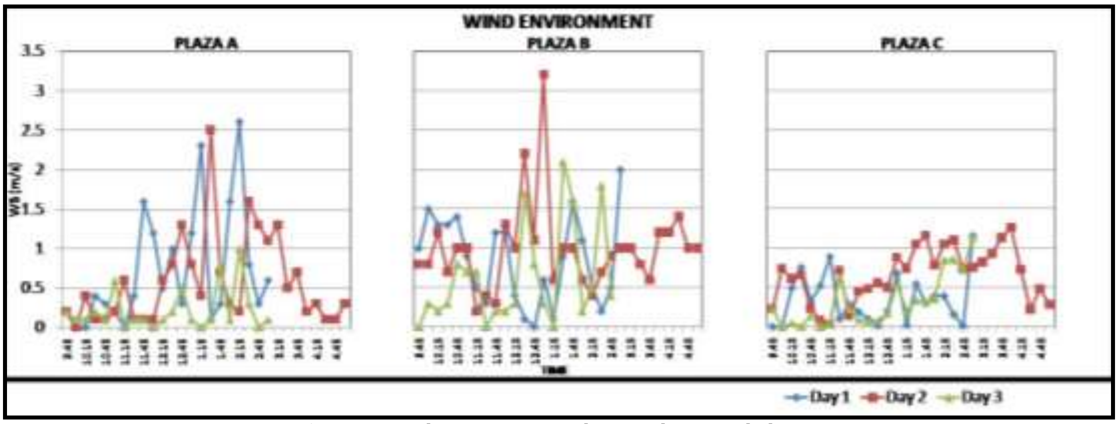


Figure 6: Wind environment in Plaza A, Plaza B and Plaza C

4.1.3 Surface temperature of ground surface materials - comparison made on the sunniest day

For comparison purposes, the surface readings for Day 3 are being considered as it was the sunniest day as mentioned earlier. Referring to Figure 7, at Plaza A: material I (granite tile – very dark – very fine) and J (grass) pose the highest and lowest temperature respectively; while in Plaza B: material F (granite tile – very dark – very fine) and H (homogenous tile – very dark – very fine) are identified as materials with the highest and lowest surface temperature respectively; and for Plaza C: materials B (Pebble wash – very coarse - light) and E (homogenous tile – very dark – very fine) recorded the highest and lowest surface temperature respectively. The different performances posed by each materials can be due to their heat conductivity, color and texture where most of the materials with highest surface temperature recorded are characterized with darker color with very fine texture as observed at Plaza A and Plaza B (no fine texture for pavement at Plaza C except for one material which is covered by water element). It is to be noted that coarse texture would absorb heat more than fine texture (Sustainable Energy Authority - online). Hence, it can be suggested that color of the material seems to influence the rate of heat being absorbed and consequently affect the surface temperature reading more than texture.

In Plaza A, material J which is grass has the lowest surface temperature. While material H (homogenous tile-very dark-very fine) and material E (homogenous tile-light-very fine) in Plaza B and C respectively (same material), show the lowest surface temperature. When compared between grass and homogenous tile being covered with water elements, the later gives even lower reading. When further comparison is made between material H and E, the surface temperatures do not show significant difference. As such, it can be suggested that, the presence of water on these surfaces significantly affect the heat absorbed by the homogenous tiles even though their color differ significantly.

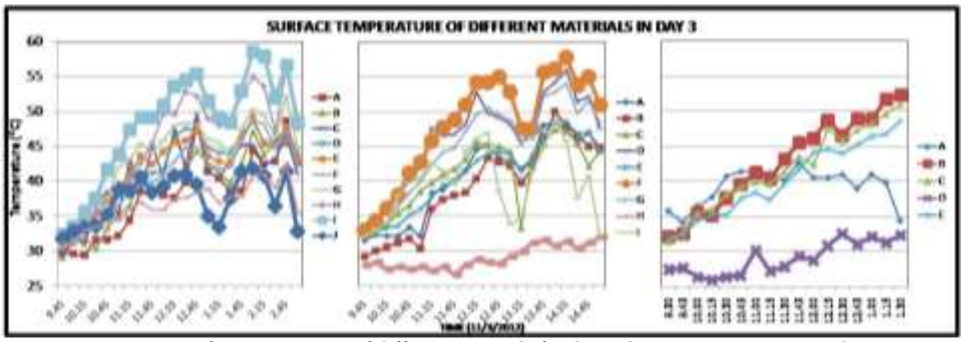


Figure 7: Surface temperature of different materials for three plazas in Day 3 (sunniest day)

4.1.4 Comparison on surface temperature of the same material available at these three plazas

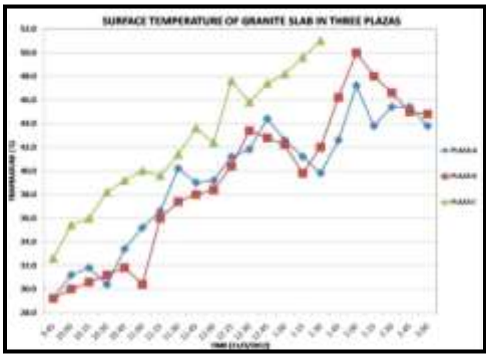
Referring to Table 5, there are only two types of material that are similar at these three plazas which are granite slab and pebble wash. Thus, the surface temperatures of these materials are further compared within these three plazas. The following Table 6, shows the differences and similarities of these materials. As can be seen, granite has the similar criteria for each plazas while the pebble wash at Plaza C differs in terms of its color.

Plaza	Granite		Pebble Wash	
	Colour	Texture	Colour	Texture
A	dark	fine	dark	coarse
B	dark	fine	dark	coarse
C	dark	fine	light	coarse

Table 6: The criteria of granite and pebble wash at Plaza A, B and C

Granite

Figure 8 shows the comparison between the surface temperature of granite at Plaza A, Plaza B and Plaza C, where granite at Plaza C (exposed) demonstrates the highest reading, followed by Plaza A (shaded) and Plaza B (partially shaded). In order to identify the cause to this, the cloud cover observed at these three plazas are compared - refer Figure 9. It can be seen the percentage of cloud cover for Plaza C does not show the lowest reading. Thus, the highest surface temperature could be due to the characteristic of Plaza C being exposed directly to the sun- with no shading element at all. Generally, the surface temperature of granite at Plaza B is lower than Plaza A. This seems to be in line with the percentage of cloud cover where the cloud cover for Plaza B seems to be relatively higher than Plaza A.



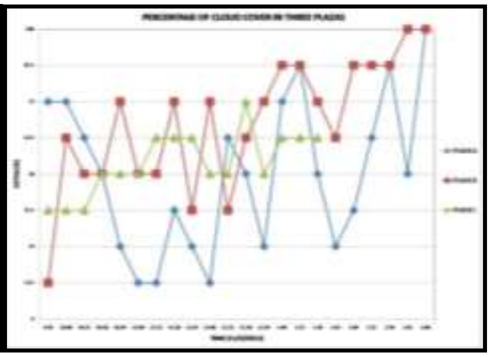


Figure 8: Graph on granite slab surface temperature in different plazas in Day 3

Figure 9: Graph on percentage of cloud cover in different plazas in Day 3

Pebble wash

Figure 10 shows the comparison between the surface temperature of pebble wash at Plaza A, Plaza B and Plaza C. Plaza B (partially shaded) seems to demonstrate the highest reading followed by Plaza C and Plaza A. Both pebble wash in Plaza A and Plaza B have the same criteria but plaza B poses a higher surface temperature due to the landscape settings where Plaza B provides minimal shades compared to Plaza A. Comparing the surface temperature of pebble wash for Plaza B and C, it seems that Plaza B shows a higher reading as the color for pebble wash in Plaza B is darker than Plaza C. This can be seen that even though Plaza C is an exposed plaza, the light colored pebble wash seems to give a lower reading than dark colored pebble wash in Plaza B which is partially shaded and dark colored pebble wash in Plaza A gives the lowest surface temperature reading due to the shades provided by the trees.

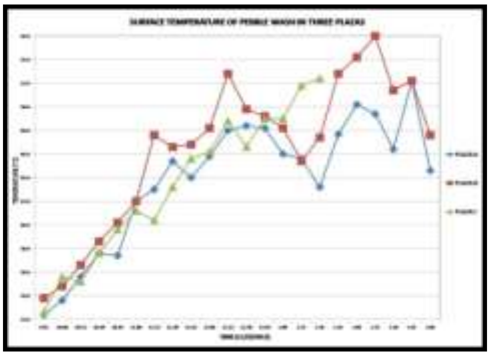


Figure 10: Graph on pebble wash surface temperature in different plazas in Day 3

4.2 Inventory and analysis of surface materials for Dataran Rakyat and Dataran Wawasan

Dataran Rakyat and Dataran Wawasan which are located along the boulevard of Putrajaya are quite similar in term of their shape which is rectangular but the dimension of the area is different. Referring to Table 7, the total area of Dataran Wawasan is 5280m^2, about 7.2% larger than Dataran Rakyat (4573 m$^{2)}$. In terms of ground surfaces, Dataran Wawasan is 100% covered by hard surfaces while Dataran Rakyat is covered by grass by 42.7% and water element by 0.21%. Thus, it can be said Dataran Rakyat is 'greener' than Dataran Wawasan. Looking at the types of paved material, similar materials are observed for these plazas. When combined between concrete slab and stamp concrete (due to similar material), it can be seen that Dataran Wawasan is covered by this material by 65.2%, while Dataran Rakyat is 34.48%. Granite and pebble wash made up 34.7% of the paved surfaces for Dataran Wawasan and 13% for Dataran Rakyat. As can be seen from Table 7 the stamp concrete used at Dataran Wawasan varies in color and texture. For both plazas, it can be said that the majority of surface materials were categorized as fine in texture and light in color. The difference in terms of size between these two plazas may not be that significant; however, when compared between the paved and green surfaces, Dataran Rakyat seems to have significantly larger green area compared to Dataran Wawasan.

Dataran Wawasan						
No	**Material**	**Color**	**Texture**	**Categories**	**Area, (m^2)**	**Percentage, (%)**
1	Concrete Slab A*	Yellow	Fine	Light	1294.3	24.5
2	Concrete Slab B	Dark Yellow	Fine	Dark		
3	Concrete Slab C	Peach	Fine	Light		
4	Concrete Slab D	Dark Peach	Fine	Dark		
5	Concrete Slab E	Orange	Fine	Light		
6	Stamp Concrete F	Orange	Very Coarse	Light	2152.9	40.7
7	Stamp Concrete G	Light Grey	Very Coarse	Light		
8	Stamp Concrete H	Dark Brown	Very Coarse	Very Dark		
9	Granite A*	Light Grey	Very Fine	Light	1689.0	32.0
10	Granite B	Light Brown	Very Fine	Light		
11	Granite C*	Dark Grey	Very Fine	Very Dark		
12	Granite D	White	Very Fine	Very Light		
13	Granite E	Light Grey	Coarse	Very Light		
14	Granite F	White	Coarse	Very Light		
15	Pebblewash	Light Brown	Very Coarse	Light	143.8	2.7
Dataran Rakyat						
No	**Material**	**Color**	**Texture**	**Categories**	**Area, (m^2)**	**Percentage, (%)**
1	Concrete Slab A*	Yellow	Fine	Light	1562.4	34.20
2	Stamp Concrete B	Light Grey	Very Coarse	Light	13.2	0.28
3	Granite A*	Light Grey	Very Fine	Very Light	222.6	12.87
4	Granite B	Maroon	Very Fine	Light		
5	Granite C*	Dark Grey	Very Fine	Very Dark		
6	Granite D	Brown	Very Coarse	Dark		
7	Pebblewash	Light Brown	Very Coarse	Dark	5.7	0.12
8	Grass (exposed)	Green	-	Light	1952.3	42.7
9	Grass (Shaded)	Green	-	Light		
10	Water Element	Blue	-	Dark	9.99	0.21

Note: * - materials available at both plazas

Table 7: Inventory and analysis of surface materials for Dataran Rakyat (partially shaded) and Dataran Wawasan (exposed)

4.2.1 Sky condition during field work

Figure 11 illustrates the relationship between solar radiation of Putrajaya and light intensity in Dataran Rakyat and Dataran Wawasan. Since these two plazas are quite close from one to another (200 metres), thus the sky condition for these two sites can be regarded as the same. Hence, for the purpose of the analysis of sky condition, the reading for the light intensity for five days for these two plazas are combined in a graph to be compared with the solar radiation taken using the portable weather station located at the Masjid Putra.

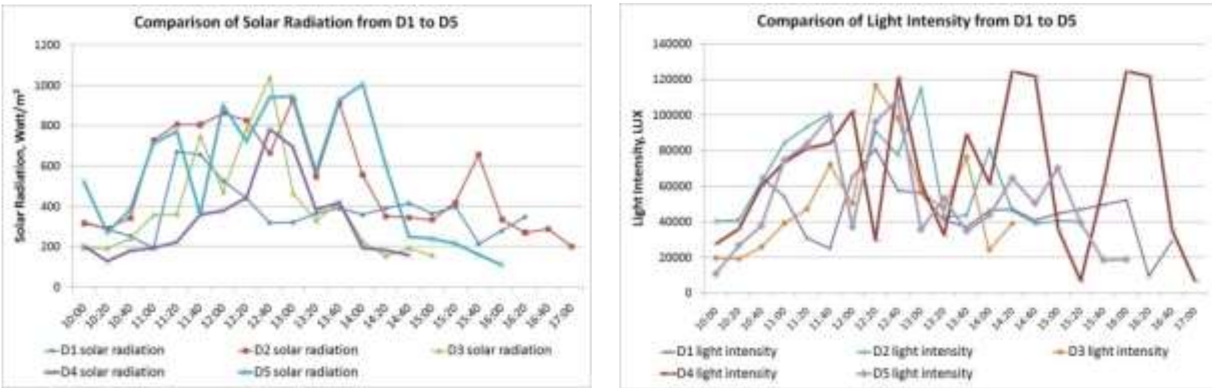


Figure 11: Show the relationship between solar radiation of Putrajaya and light intensity in both plazas from D1 to D5

The reading of solar radiation indicates an increase toward the afternoon from the generally low reading in the morning, however it gradually decreases toward the evening as the sky was partially or totally overcast – refer also to Table 3. This is due to the sun position where in the afternoon the sun can be said as located above the head. Thus, it is observed that solar radiation reach its highest intensity between 11:00am to 3:00pm. It is also worth to be mentioned that the sun is at its highest latitude at noon time in late March (Abu Bakar, 2007). The other factor that may affect the intensity of solar radiation is the cloud cover where thick cloud would reduce the amount of solar radiation from reaching the ground surfaces. As mentioned earlier, the sky condition for D4 and D5 was rather sunny compared to D1 and D2 which was cloudy (refer to Table 3).

Figure 11 illustrate that D4 and D5 can be said as the hottest day throughout the field work, thus focus is given on these two days for comparison. On D4 the solar radiation data recorded within the range of 128 Watt/m² (9:40am) to 783 Watt/m² (12:00noon) while in D5 it range between 271 Watt/m² (10:15am) to 1006 Watt/m² (13:00pm). Based on the data, D5 is the hottest day followed by D4 where the readings for surface temperature were taken at Dataran Rakyat and Dataran Wawasan respectively.

4.2.2 Shadow Analysis of Dataran Wawasan and Dataran Rakyat during the Sunniest Day

The following Table 8, shows the shadow analysis for Dataran Wawasan and Dataran Rakyat. From the images generated using the SketchUp software, it can be seen that the buildings surrounding Dataran Wawasan do not cast any shadow on the plaza at any time. In contrast to Dataran Wawasan, Dataran Rakyat is partly shaded by the buildings. It is to be noted that generally the buildings surroundings Dataran Rakyat is higher (about 11 storeys) and close to the plaza, compared to buildings surrounding Dataran Wawasan (about 9 storeys) and a bit further from the plaza.

LOCATION	DAY	MORNING	AFTERNOON	EVENING
Dataran Wawasan	D4 11/03/12			
Dataran Rakyat	D5 26/03/12			

Table 8: Show the shadow analysis in the morning, afternoon and evening

4.2.3 Surface temperature – comparison made on the sunniest day of Dataran Rakyat and Dataran Wawasan

The following Figure 12 shows comparison of surface temperature of surface materials in both plazas.

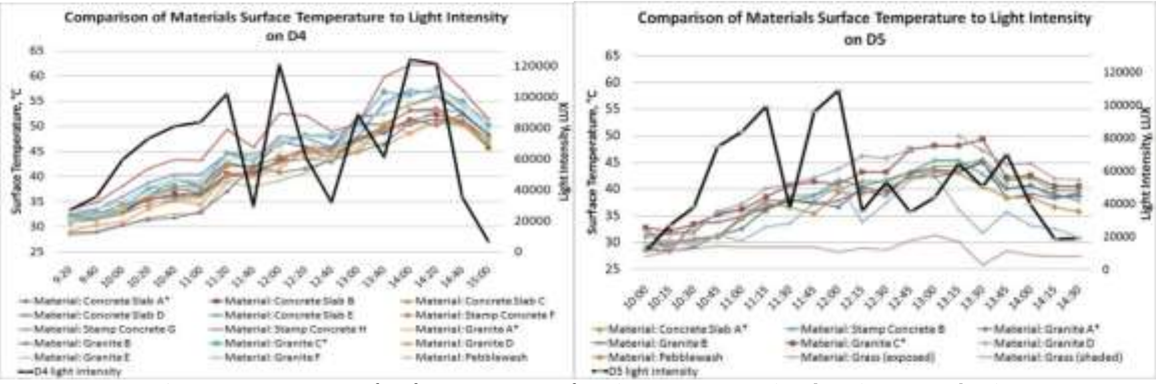


Figure 12: Comparison of surface temperature of D4 (Dataran Wawasan) and D5 (Dataran Rakyat)

Comparing the highest and lowest surface temperature readings of Dataran Wawasan and Dataran Rakyat

Due to the similar weather condition on D4 and D5, surface temperatures of pavement at these two plazas on these two days are compared. Referring to Figure 12, Stamp Concrete H (very coarse–very dark) demonstrates the highest reading whereas Granite A (very fine–light) demonstrates the lowest reading in at Dataran Wawasan. During D5 Granite D (very coarse–dark) and Pebble Wash (very coarse–light) recorded the highest and lowest surface temperature respectively at Dataran Rakyat.

The materials that give the highest surface temperature readings seem to have similar characteristic which are generally dark color and coarse texture. However for the lowest surface temperature reading, the two materials (Granite A and Pebble Wash) have similar color but differ in terms of texture. When looked in detail, Granite A gives lower reading compared to pebble wash. It is worth to be noted as mentioned earlier, D5 is hotter than D4. This suggests that Granite A is a cooler material compared to pebble wash - showing the influence of material on the surface temperature reading. This might due to the heat storage capacity. Coarse texture materials would absorb heat more than fine texture materials (Sustainable Energy Authority - http://www.energy.gov.lk/). Hence, generally the fine texture and light color materials shall demonstrate lower surface temperature compare to coarse texture and dark color materials in the same environmental condition.

Comparing the surface temperature of similar materials available at Dataran Rakyat and Dataran Wawasan

Figure 13: The comparison of surface temperature from same materials type available in Dataran Rakyat and Dataran Wawasan

There are similar materials available both in Dataran Rakyat and Dataran Wawasan which are Concrete Slab A (fine – light), Granite A (very fine–very light) and Granite C (very fine–very dark) as stated in Table 7. Thus, their surface temperatures are further compared between these plazas for D4 and D5.

Figure 13 illustrates the surface temperature reading for Concrete Slab A, Granite A and Granite C in Dataran Wawasan and Dataran Rakyat. It can be seen that Granite C (very fine–very dark) demonstrate relatively high surface temperature reading in both of the days while Granite A (very fine–very light) demonstrate the lowest surface temperature reading compare to the other materials. However, there are significant differences between the surface temperature reading of Granite C during D4 and D5. The highest surface temperature reading of 57.4°C was recorded on Day 4 at DW and 49.4°C was recorded on Day 5 at Dataran Rakyat although referring to Figure 11, Day 5 recorded highest solar radiation and considered as the hottest day. The differences of 8°C might be due to the effect of shades by the surrounding building and trees, as well as Dataran Rakyat being 'greener' than Dataran Wawasan which is rather exposed to the sun – refer Table 8. Being 'greener', some surface materials in Dataran Rakyat were protected from the direct solar radiation, thus the amount of heat absorbed by these surface materials might be reduced. Hence, the heat radiated from these surfaces to the surrounding could also be less, and might result to lower ambient temperature. The same phenomena also occur to the other two materials, demonstrating high reading during D4 and lower reading during D5. Based on this finding it can be suggested that shade and greener landscape setting play an important role in reducing surface temperature reading.

Comparing the highest and lowest reading of similar materials within each plaza

For Dataran Wawasan, there are two types of surface materials that can be further compared which are: Concrete Slab C and Stamp Concrete H, and Granite A and Granite E. Referring to Figure 14 (left), for material type concrete, Concrete Slab C (fine–light) demonstrates the lowest surface temperature reading while stamp concrete H (very coarse-very dark) gives the highest reading with the biggest range of 12ºC. For Dataran Rakyat, there are also three types of surface materials that can be compared which are: Concrete Slab A and Stamp Concrete B, Granite A and Granite D, and Grass (exposed) and Grass (shaded). Concrete slab A (fine–light) and concrete slab D (fine–dark) share the same texture category but show a significant different between the reading of surface temperature (refer to Figure 14). During the hottest time of the day, concrete slab A (fine–light) recorded maximum surface temperature reading of 52.4ºC while concrete slab D (fine–dark) recorded reading of 56.0ºC. During the day the differences between surface temperature readings range from 2ºC to 4ºC. This justify that the color give significant effect towards the heat absorption of materials.

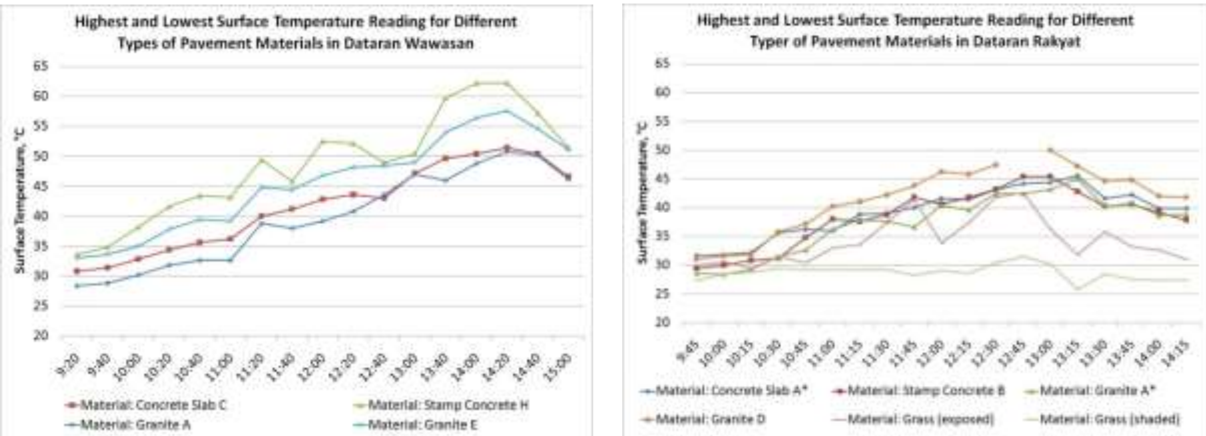


Figure 14: The highest and lowest surface temperature reading for different types of pavement materials in DW (left) and DR (right)

5 Conclusion

Based on the investigation for the first part, it can be suggested that surface temperature with darker color and coarse texture will result in a higher reading of surface temperature. Between these two factors, color seems to be the influencing factor on the absorption of heat that leads to a higher surface temperature more than texture. When comparing the surface temperature of exposed plaza to the other two plazas, it seems that the readings are higher. This could be due to the solar radiation as well as the heat absorbed and radiated back to the surrounding from the various elements within the exposed plaza. Cloud cover also seems to influence the surface temperature reading as it affects the amount of solar radiation received by the ground surfaces. The surface materials in shaded area tend to demonstrate lower reading of surface temperature. Hence, it can be said that the landscape setting also influence the amount of heat absorbed. The findings also show that the presence of water on top of surface material will reduce the surface temperature significantly regardless of its color. Based on the analysis, concrete surfaces with light color and fine texture shows a medium reading of surface temperature. Therefore, it can be concluded that the most preferable criteria for the surface material is lighter color and fine texture. Referring to this study, when compared between granite, concrete and pebble wash, granite is preferred due to the lower surface temperature reading. However, grass plays a very important role in reducing the ambient temperature due to the evapotranspiration effect. Thus, whenever possible, grass and trees should be incorporated in plazas design as much as possible as to avoid the ambient temperature from being heated up greatly.

As for the second part of the investigation – Dataran Rakyat and Dataran Wawasan, based on the analyses and results, it can be concluded that materials with darker color and coarse texture tend to demonstrate higher reading of surface temperature. Based on the investigation, it is also found that color seems to be an influencing factor that enhances the materials heat absorbing capability more than texture. It can also be seen that exposed materials to the sun demonstrate high surface temperature reading due to the high intensity of solar radiation reaching the materials, thus more heat being absorbed by the materials. Hence, this can be mitigated by providing shade to the exposed area. Greener landscape setting seems to help in producing lower surface temperature reading too. In terms of the hard surface materials, granite with very light color and fine texture shows low reading of surface temperature while concrete slab with light color and coarse texture gives medium reading. Therefore, it can be suggested that the most preferred surface material is granite as it reflect more heat and absorbed less heat - less heat restoration shall result in less heat being released to the surrounding environment, thus the ambient temperature might not be affected greatly.

This research has provided some insight on the influence of landscape design – the setting and material, on the microclimate of urban plazas in tropical region. Thus, it is hope that the analyses and results could provide some guidelines to the designer in choosing cooler material and appropriate greenaries for the landscape setting as to create a thermally comfortable environment. A cooler outdoor environment is anticipated to have certain influence on the use of outdoor spaces as well as certain impact to the indoor environment.

Acknowledgements

This research was funded by the Research Management Center of IIUM: EDW B11-271--0749.

The following students were involved in this research where the data became part of their topical studies: Amira Nadhirah Mohamad, Arinah Rozhan, Mohd Faiz Mahamad Suhaimi, Ahmad Kamal b. Azim, and Zafirah bt Ahmad

References

Abu Bakar, A.(2007).*User response to thermal comfortof outdoor urban spaces in hot-humid region*. PhD thesis, University of Nottingham, United Kingdom.

Ashworth, W.(1991).*The Encyclopedia of Environmental Studies*. New York, William Ashworth

Brown, R. D., and Gillespie T.J. (1995). Human Thermal Comfort, *Microclimatic Landscape Design: Creating Thermal Comfort and Energy Efficiency.* Canada, John Wiley & Sons, Inc.

Burba, G. (2010). *Evapotranspiration - The encyclopedia of earth.* Available at : <http://www.eoearth.org/article/Evapotranspiration> [Accessed: 9th April 2012].

Christensen, A.J. (2005). *Dictionary of Landscape Architecture and Construction*, USA, Mc-Graw Hill Professional.

Doulos, L., Santamouris, M., and Livada., I.(2004). Passive cooling outdoor urban space, *Solar Energy,* 77, 231-249.

Gui, J.G., Phelan, P.E., Kaloush, K.E., and Golden, J.S. (2007). Impact of pavement thermophysical properties on surface temperatures. *Materials in Civil Engineering (ASCE),* 19(8), (pp. 683).

Krishnan, G., (2007), *Putrajaya is 5°C hotter than other local cities*. Available at :<http://thestar.com.my/metro/story.asp?file=/2007/6/19/central/17992083&sec=central> [Accessed: 16th February 2012].

Mark, C. (2008).*Florida Field Guide to Low Impact Development*.Program for Resources Efficient Community. Florida, University of Florida

Oke, T.R., (1987), *Boundary layer climates*, Cambridge, University Press

Prado, R.T.A., and Ferreira, F.L.(2005). Measurement of albedo and analysis of its influence the surface temperature of building roof materials, *Energy and Building*, 37, 295- 300

Rosheidat, A., Bryan, H. (2010), Optimizing the effect of vegetation for pedestrian thermal comfort and urban heat island mitigation in a hot arid urban environment, In: *Fourth National Conference of IBPSA-USA. New York*.

Sheweka, S., and Magdy, N.(2011). The Living walls as an Approach for a Healthy Urban Environment, *Energy Procedia,* 6 , 592- 599,

Shahidan, M.F. (2011).*The Potential of Optimum Cooling Effect of Vegetation with Ground Surface Physical Properties Modification in Mitigating the Urban Heat Island Effect in Malaysia,* Ph.D thesis, Cardiff University, UK

Shahidan, M.F., Shariff, M.K.M., Jones, P., Salleh, E., and Abdullah, A.M.(2010), A comparison of Messuaferrea L. and Huracrepitans L. for shade creation and radiation modification in improving thermal comfort, *Landscape and Urban Planning,* 97, 168- 181

Synnefa, A., Karlessi, T., Gaitani, N., Santamouris, M., Assimakapoulous, D.N., and Papakatsiakas, C., (2011), Experiment testing on cool colored thin layer asphalt and estimation of its potential to improve the urban microclimate, *Building and Environment,* 46, 38-44

Taha, H., Akbari, H., Rosenfeld, A., and Huang, J. (1988). Residential cooling loads and the urban heat island- the effects of albedo. *Building and Environment,* Vol. 23(4), (pp 271-283).

Yilmaz, S., Toy, S., and Yilmaz, H. (2007). Human thermal comfort over three different land surfaces during summer in the city of Erzurum, Turkey. *Atmosfera*, Vol. 20(3), (pp. 289-297).