

The Impact of Surface Material on Thermal Comfort in Bandung City Hall Park/ Taman Balai Kota Bandung, Indonesia ¹

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Abstract

Bandung City Hall Park is a park located in the center of Bandung City which is part of the Bandung mayor's office. Bandung City Hall Park consists of Sejarah Park, Labirin Park, Badak Park and Dewi Sartika Park. Bandung City Hall Park in 2015 experienced a significant change in surface material, previously the ratio of vegetation area was much greater than the pavement. In 2019, the Bandung City Hall Park had a ratio of 50.29% pavement and 49.71% vegetation. In this study, testing and analysis of the Bandung City Hall Park was carried out by measuring the temperature of the air and material at each point for 3 months from October to December to determine the effect of the impact of each material and vegetation on temperature in the Bandung City Hall Park area. The analytical methods used are quantitative and qualitative methods. Qualitative methods are carried out by field observations and quantitative methods by collecting data in the field and processing it. The measurement results of surface temperature and air temperature in the area, found that in the Sejarah Park, the average air temperature was 29°C-30°C, this was caused by pavement 87.40%, softscape 6.1% and water 6.45%, the material is dominated by pebble coral which reaches temperatures of 40°C-44°C during the day, and andesite stone which reaches temperatures of 38°C-49°C. Labirin Park has an average temperature of 24°C-33°C, this park is dominated by 69.22% softscape and 30.77% hardscape consisting of asphalt with an average surface temperature of 40°C during the day. Badak Park has an average temperature of 26°C-33°C with a predominantly 65% pavement and 35% softscape, the low temperature caused by lots of big trees so that andesite stone and pebble coral tend to have low temperatures ranging from 25°C-35°C. Dewi Sartika Park has an average temperature of 26°C-34°C with pavement and softscape compared to 53% and 47%,

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this comfort air temperature caused by many shady trees that protect the pavement from exposure from direct sunlight. From the results of field observations, it was concluded that the highest heat contribution to the Bandung City Hall Park was obtained from the Sejarah Park from coral and andesite rock material which reached an average temperature of 38°C-49°C. The lowest heat contribution is obtained from Labirin Park which is dominated by softscape. The material used in Bandung City Hall Park has an influence on the surrounding air temperature, and from the results of the analysis of measurements of air temperature, the Bandung City Hall Park air temperature in the range of 24°C-34°C, which is the threshold for outdoor thermal comfort is between 22.1°C - 30°C.

Keywords: Pavement, Air Temperature, Material Surface Temperature, Bandung City Hall Park

1. INTRODUCTION

Global warming in the world has been a big issue which is caused by the increase in urban development. Buildings, road, pavements impact urban open space decreased (Tursilowati, 2002), cities are getting denser and denser so green open spaces are disappearing over time, and parks are increasingly scarce being replaced by shopping centers and housing (Dwiyanto, 2009) and this impact in surface heat at the meso, micro, local urban scale Street design and urban canopy layer climate. Energy and buildings (Oke, 1988). On an urban scale it will cause the Urban Heat Island (UHI), which is an island of surface heat caused by increasing land surface to become pavement (Benrazavi et al., 2016).

The increase in temperatures will have serious impact on the health of urban residents (Heaviside et al., 2017). Studies have shown that high temperatures can lead to fatigue, dizziness, increased breathing, and increased heart rate (Xiong et al., 2015). More serious situations can even endanger life and cause death (Wang et al., 2019).

In order for urban development to be sustainable for the future, city development is required to refer to the parameters of sustainability (USGBC, 2019) and green building (Green Building Council Indonesia, 2013; Sassi, 2006) which includes the design of cities and areas using sustainability site plan criteria, considering ecology (Olgyay et al., 2004; Yudelson, 2009; Cohen, 2006), It is stated that the use of materials in area design must be considered in order to reduce heat surface (Green Building Council Indonesia, 2013; Santamouris et al., 2012).

In every day life people needs basic needs and so all another needs too, and the city have to provide all the facilities including open public space (Shirvani, 1985). Open space in cities is very much needed by people whose daily activities are schooling, working to earn a living and doing other routine activities. Indonesian people generally come to open spaces to meet family or friends use open spaces as picnic tourism destinations (Kohori et al., 2017), so public open spaces is one of the important role in Indonesian people.

In the science of urban architecture, the public open space is part of urban that greatly influences the image of the entire city (Stevens, 2006), the success of a city depends on the life of its open space (Fuller et al., 2017). Public open space must be provided by the government for people (Travlou, et al., 2007), as the lungs of the city, infiltration of water, and also as the flow of wind. In the science of architecture, the function and form of space will determine the activity of the people, the material and landscaping are determinants of the function of an public open space. Public open spaces are needed by the urban people for social activities and relaxation (Gehl, 2011).

Outdoor thermal comfort is the most important factor to attract urban residents to urban parks. Thermal comfort is defined as the “condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation” (ASHRAE, 2010). In recent years, with the deterioration of urban climate, people pay more and more attention to the urban environment, which

makes researchers all over the world focus on outdoor thermal comfort, and the number of research results about outdoor thermal comfort is increasing year by year. The outdoor environment has many factors affecting thermal comfort, such as (1) meteorological factors air temperature, relative humidity, wind speed and direction, solar radiation, etc. and (2) personal factors gender, age, length of stay, length of residence, etc (Zhang et al., 2020).

Changes in the surface material of an open space will result in changes in temperature in the area, these temperature changes are caused by the change of soil to pavement and the type of pavement material (Tursilowati, 2002). Less trees and green area will also increase the temperature of the city's open spaces, and cause discomfort to the visitors (Oke, 1988).

Bandung City Hall Park has developed and changed from time to time since it was built by the Dutch Colonial, the park consisting of 4 park names : Sejarah Park, Labirin Park, Badak Park, and Dewi Sartika Park each experienced changes in material surface (Astri et al., 2013). With the change in the surface of the material and the reduction of trees in this area, it is important to measure the temperature, both the material temperature and the air temperature.

This study aims to examine the impact of the use of surface materials on air temperature and thermal comfort in Bandung City Hall as one of the main public open space in Bandung City. The observations include 1) the functions, forms, and elements of open space, 2) the surface materials including softscape and hardscape, and 3) the material surface and air temperature.

The benefit of this study is to provide knowledge to the urban designers, architects and architect landscape fields how the the success of a city depends on the life of its open space. That the function optimisation of open space can be increase depend on shape, the use of material, and thermal comfort in open public space.

The benefits for the Government as a stakeholder is to provide input that by revitalizing public open space for the community in a good way will be get well appreciated by the community. That people needs open spaces in the city not only limited to passive green spaces, because the public also needs free space for recreation with their families. People need entertainment from routine work activities and from house crowded, and the container is an urban open space.

2. MATERIAL AND METHOD

Bandung City Hall consist four parks namely Sejarah Park, Labirin Park, Badak Park, and Dewi Sartika Park. The park is the object of analysis for Land Surface Temperature (LST) measurements, and measurements of the surface temperature of the material. There have been significant changes in the City Hall Park Area in 2015 and 2019 with addition of new Sejarah Park pavement area which is approximate 90% from total area, and the Labirin Park green area which is reduced for vehicles parking area as shown in the picture below.



Figure 1. Bandung City Hall Park

Source: Field Survey

The research was conducted by measuring the air temperature and pavement material, as well as vegetation. The purpose of measuring the area is to determine the ratio of pavement use and vegetation and to find out which material causes the temperature of an area to increase, which will then have an impact on the LST (Voogt et al., 2003).

The pavement surface shaded by object shadows has a temperature of 21% lower than air temperature, and 40% cooler than sun-exposed surfaces (Chatzidimitriou et al., 2006; Shahidan et al., 2007). Human thermal comfort in open space is influenced by wind speed, humidity, air temperature (Sangkertadi, 2013), as well as shading vegetation (Nikolopoulou et al., 2001). The comfortable air temperature in the outdoor open space is between 22.1°C to 30°C (David et al., 2014), it depends on the activities of people who are carried out in the outdoor open space.

The method used in this research is quantitative and qualitative methods. Qualitative methods are carried out by field observations, such as observing the physical characteristics of each park in Bandung City Hall, and with quantitative methods by collecting data in the field, such as types of material and vegetation, and by measuring the air and material temperature during 3 months from October to December, and processing it. Nikolopoulou et al. (Nikolopoulou et al., 2001; Nikolopoulou et al., 2006) pointed out in published papers that field monitoring is the main method for evaluating outdoor thermal comfort. Field monitoring is the use of relevant measuring instruments for the study site for outdoor

meteorological parameters (such as air temperature-Ta, relative humidity-RH, black globe temperature-Tg, wind speed-v, global solar radiation-G, etc.)

Basic to the aim of the study, this study will measure the air temperature and the temperature of all materials that cover the surface of this park, and there are two measurement tools that will help in obtaining data, the hygrometer (Surmi et al., 2016) for measuring air temperature which provides measurement results precisely, and infrared thermometer which is a tool for measuring the temperature of material surface objects in the area (Warren, 1990 ; Rogalski et al., 2017).



Figure 2. Thermometer and Hygrometer

Source: <https://digital-meter-indonesia.com/thermo-hygro-alat-pengukur-suhu-udara-dan-kelembaban/>



Figure 3. Thermogun Thermometer Infrared

Source: https://id.wikipedia.org/wiki/Termometer_inframerah

3. RESULT AND DISCUSSION

The results of observations and measurements in the field obtained data on air temperature and pavement materials, as well as calculating pavement area and materials used in the Bandung City Hall Park area. The air temperature data displayed in this section is the air temperature range for that period, while the material temperature is the sample of the material in the largest area in each park.

The results of these observations and measurements can be seen as follows:

Sejarah Park

In the analysis of Sejarah Parks, this park has a fairly large percentage of pavement compared to its green area. Therefore the material temperature measured has a high temperature, especially during the day. The following is a table of the results of measuring air temperature in Sejarah Park and a detailed diagram of the percentage of pavement.



Figure 4. Sejarah Park

Source: Redrawing

Table 1. Table of comparison of air temperature in Sejarah Park from morning to night

Air Temperature in Sejarah Park				
Daytime at 09:00-11:00	Afternoon at 12:30 – 14:00	Afternoon at 13:30 – 15:00	Evening at 17:15 – 18:00	Night at 18:00 - 20:00
29°C-30°C	26°C	31°C-33°C	26°C-27°C	25°C

Source: Field Measurement

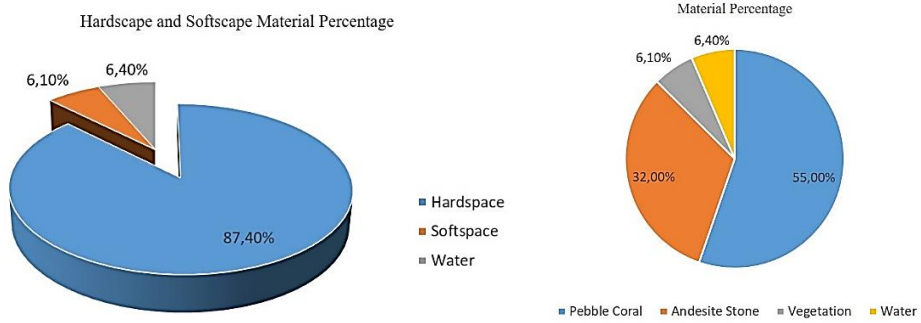


Figure 5. Pie Chart of the percentage comparison of pavement and green area in Sejarah Park

Source: Analysis Result

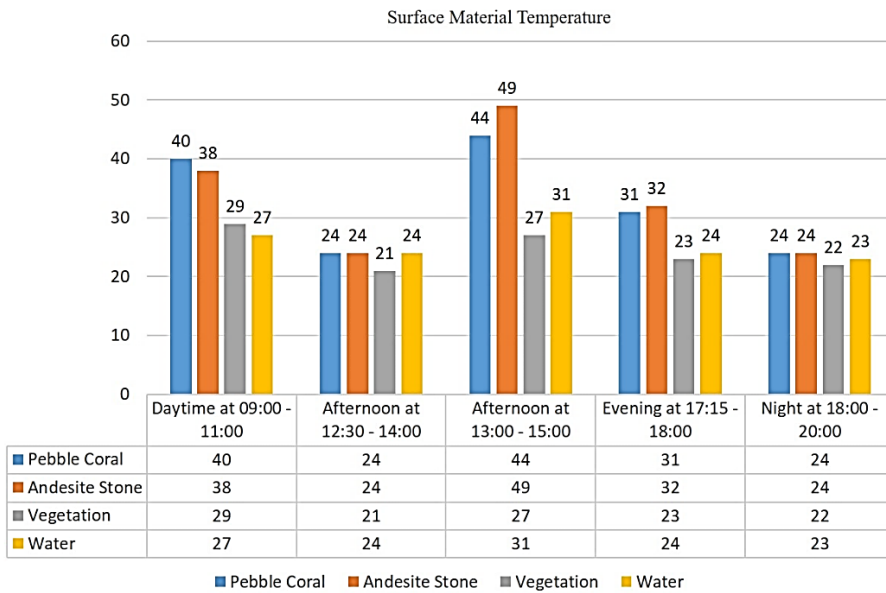


Figure 6. Bar Chart of temperature comparison of pavement and green area in Sejarah Park

Source: Analysis Result

The ratio between pavement and vegetation in Sejarah Park is significantly far, i.e 87.40% of pavement to 6.10% of vegetation. The material that generates the highest heat during the day is andesite

stone, which is 49°C, then pebble coral 44°C, and the lowest are vegetation and water, which is 21°C-23°C. Sejarah Park has a widest ratio of pavement to vegetation which causes the air temperature in the this area is 1°C-2°C higher than in other areas.

Labirin Park

The percentage results, in Labirin Park has a larger percentage of green area than the pavement area, so that if visitors are in the Labirin Park area, they do not feel hot, and the temperature of the material is comfortable. The following is a table of the results of measurement the air temperature in Labirin Park and a detailed diagram of the pavement percentage.



Figure 7. Labirin Park

Source: Redrawing

Table 2. Table of comparison of air temperature in Labirin Park from morning to night

Air Temperature in Labirin Park				
Daytime at 09:00-11:00	Afternoon at 12:30 – 14:00	Afternoon at 13:30 – 15:00	Evening at 17:15 – 18:00	Night at 18:00 - 20:00
29°C-33°C	27°C	24°C-33°C	26°C	24°C

Source: Field Measurement

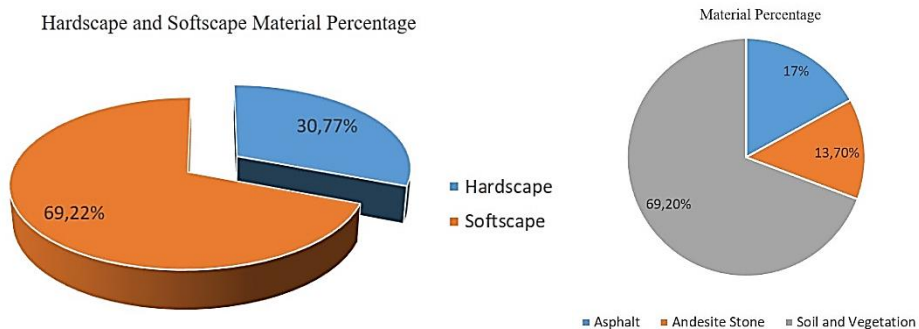


Figure 8. Pie Chart of percentage comparison of pavement and green area in Labirin Park

Source: Analysis Result

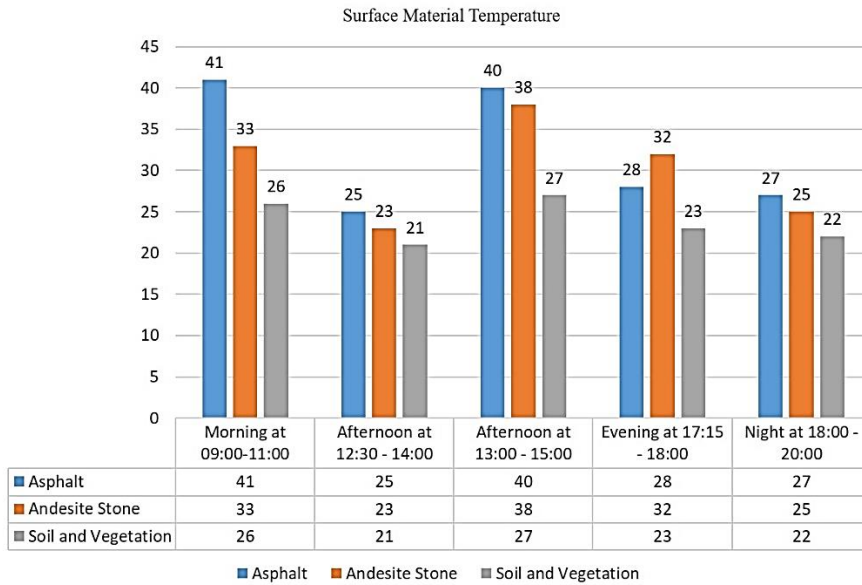


Figure 9. Bar Chart of temperature comparison of pavement and green area in Labirin Park

Source: Analysis Result

Comparison between pavement and green area in Labirin Park has a fairly large ratio i.e. 30.77% of pavement to 69.22% of green area. The material that generates the highest heat during the day is asphalt , which is 41°C, then andesite stone 38°C, and the lowest are soil and vegetation, which is 21°C-23°C. Labirin Park has a wider green area ratio than pavement which results the air temperature lower 2°C-3°C than the other parks.

Badak Park

Badak Park has a ratio 1:2 of the pavement area and green area, and it is resulting material temperature not too high, and with addition of fish ponds that can provide a cool effect on the area around the Badak Park. The following is a table of the results of measurements of air temperature in Badak Park and a detailed diagram of the percentage of pavement.



Figure 10. Badak Park

Source: Redrawing

Table 3. Table of comparison of air temperature in Badak Park from morning to night

Air Temperature in Badak Park				
Daytime at 09:00-11:00	Afternoon at 12:30 – 14:00	Afternoon at 13:30 – 15:00	Evening at 17:15 – 18:00	Night at 18:00 - 20:00
30°C	26°C	31°C-33°C	26°C	24°C

Source: Field Measurement

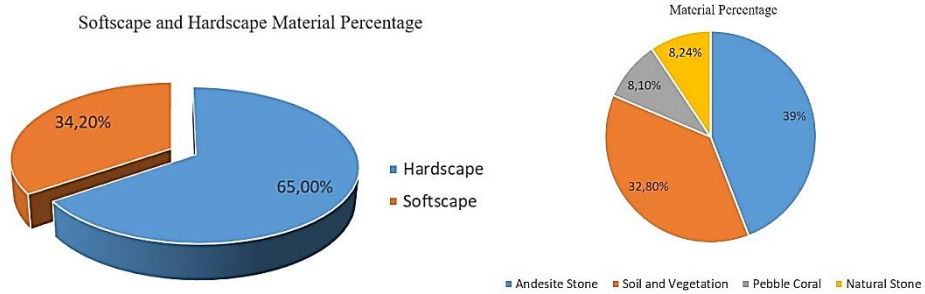


Figure 11. Pie Chart of percentage comparison of pavement and green area in Badak Park

Source: Analysis Result

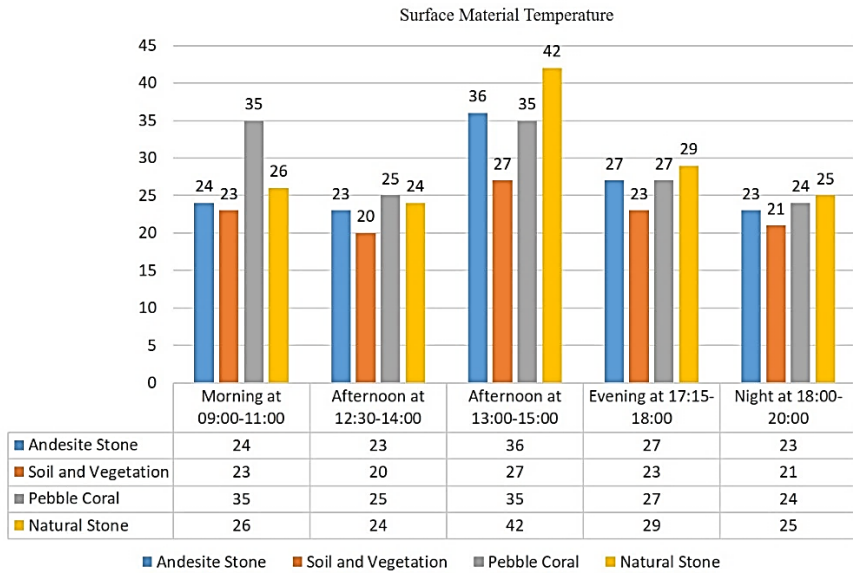


Figure 12. Bar Chart of temperature comparison of pavement and green area in Badak Park

Source: Analysis Result

The ratio between pavement and green area in Badak Park is 65% pavement and 34.20% green area. The material that generates the highest heat during the day is natural stone, which is 42°C, then andesite stone 36°C, and the lowest are soil and vegetation and, which is 21°C-27°C. Badak Park has a much wider

pavement ratio than vegetation but in Badak Park there is soil and water material which makes the Badak Park area not too hot. The temperature of the Badak Park is 1°C lower than the Sejarah Park because the Badak Park area has lush trees and the area of vegetation in the Badak Park is much wider than the Sejarah Park.

Dewi Sartika Park

Dewi Sartika Park has a ratio of green and pavement areas i.e. 1:2, and still has soil or reforestation areas that have not been completely converted into pavement. The following is a table of the results of measurements of air temperature in Park Dewi Sartika and a detailed diagram of the pavement percentage.



Figure 13. Dewi sartika Park

Source: Redrawing

Table 4. Table of comparison of air temperature in Dewi Sartika Park from morning to night

Air Temperature in Dewi Sartika Park				
Daytime at 09:00-11:00	Afternoon at 12:30 – 14:00	Afternoon at 13:30 – 15:00	Evening at 17:15 – 18:00	Night at 18:00 - 20:00
29°C-34°C	26°C-27°C	30 °C -31°C	26°C-27°C	24°C-29°C

Source: Field Measurement

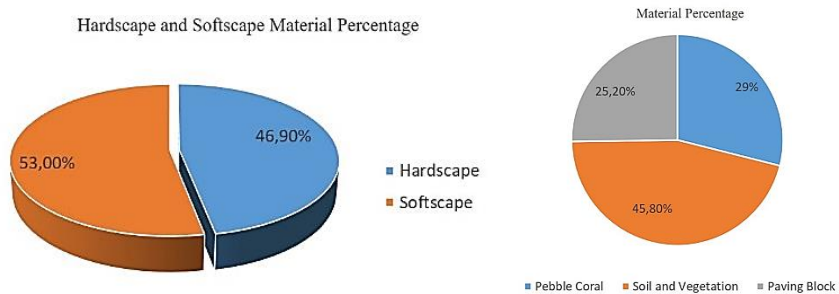


Figure 12. Pie Chart Comparing percentage of pavement and green area in Dewi Sartika Park

Source: Analysis Result

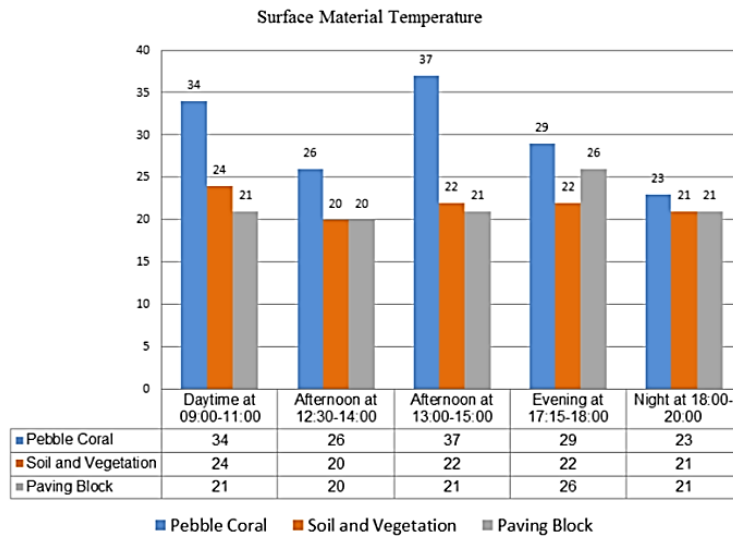


Figure 14. Bar Chart of temperature comparison of pavement and green area in Park Dewi Sartika

Source: Analysis Result

Comparison of the ratio of pavement and green area in Dewi Sartika Park i.e. 53% green area and 46.90% pavement. The material that generates the highest heat during the day is pebble coral, which is 34°C, then soil and vegetation 24°C, and the lowest are paving block, which is 21°C. The air temperature of Dewi Sartika Park is not much different from the temperature in the Badak Park or Sejarah Park because in Dewi Sartika Park there are a lot areas that are covered by lush trees so Dewi Sartika Park have 1°C lower temperature from Badak Park and Sejarah Park.

Type of pavement material used in open spaces has a various impact on micro air temperature. Measurements were carried out for 3 months from October to December at the beginning and the middle of each month, i.e. 1-3 October, November, and December and 14-16 October, November, and December 2019. In 1 day, 5 measurements were taken at 5 different times, namely daytime (09.00-11.00), afternoon (12.30-14.00), afternoon (13.00-15.00), evening (17.15-18.00) and night (18.00-20.00). So the number of samples for each material (N) is 30. The material temperature shown in the table are representative of each material that dominates 4 parks in Bandung City Hall.

Here is a table of air and material temperatures measured as well as the difference in material temperature from day to evening and evening to night in the Bandung City Hall Park.

Table 5. Comparison and Differences of Material Temperature and Its Impact to Air Temperature

Day	Time	Material							
		Asphalt		Andesite		Pebble Coral		Paving Block	
		Air Temp. (°C)	Material Temp. (°C)	Air Temp. (°C)	Material Temp. (°C)	Air Temp. (°C)	Material Temp. (°C)	Air Temp. (°C)	Material Temp. (°C)
1	1	33	41	30	22	30	40	29	21
1	2	27	25	28	30	26	24	26	20
1	3	30	40	33	36	33	37	30	21
1	4	26	28	28	29	26	31	26	26
1	5	24	27	24	20	25	24	24	21
2	1	30	38	30	24	29	38	30	21
2	2	31	39	26	23	26	23	26	22
2	3	24	35	31	36	31	40	30	37
2	4	29	36	26	27	26	31	27	30
2	5	32	35	24	23	25	23	29	26
3	1	31	33	30	24	30	30	30	40
3	2	24	29	26	23	26	23	30	35
3	3	31	25	31	36	33	37	25	34
3	4	24	34	26	27	26	31	24	31
3	5	25	33	24	23	25	24	24	28
4	1	26	31	30	24	30	35	24	32
4	2	33	35	26	23	26	25	33	35
4	3	24	26	31	36	33	35	31	38
4	4	25	32	26	27	26	27	27	30
4	5	33	31	24	23	24	24	24	26
5	1	25	32	30	22	30	35	33	40
5	2	30	30	26	25	26	25	31	39
5	3	33	31	32	30	33	35	32	39
5	4	26	27	26	26	26	27	27	28
5	5	30	25	24	22	24	24	25	27
6	1	30	30	29	23	34	34	33	40
6	2	30	35	29	25	27	26	33	40
6	3	26	28	33	36	31	37	31	38
6	4	24	26	29	25	27	29	25	27
6	5	24	26	26	25	24	23	24	26
Means		28.00	31.43	27.93	26.50	27.93	29.90	28.10	30.60
Std. Deviation		3.34	4.68	2.83	4.91	3.15	5.84	3.23	6.89
p Value in T Test		0.000197202		0.043092957		0.006127743		0.019526892	
Correlation Coefficient		0.434		0.66		0.837		0.612	
Difference in Material Temperature		Daytime to Evening: 12°C		Daytime to Evening: 17°C		Daytime to Evening: 8°C		Daytime to Evening: 7°C	
		Afternoon to Night : 12°C		Afternoon to Night: 10°C		Afternoon to Evening: 3°C		Afternoon to Night: 4°C	

Source: Analysis Result

The table shows the dynamics of the correlation between material and air temperature in Bandung City Hall Park. From the correlation coefficient value, it can be seen that the material temperature is directly proportional to the air temperature. It means, the material temperature has a contribution to the increase of air temperature. However, because each park has different physical characteristics, the air temperature is not only influenced by the pavement materials used in the park, but also by the amount of

vegetation, green area and water surface, and other influencing factors apart from physical characteristics that are not discussed in this research.

The range of thermal comfort used in this research was taken from similar research that have been done before, which states that the comfortable air temperature in the outdoor open space for children, young people and adults is between 22.1°C - 30.0°C. Indonesia has thermal comfort standard by the National Standardization Agency of Indonesia which is categorized into: 1) cool comfort (20.8°C-22.8°C), 2) optimal comfort (22.8°C-25.8°C), and 3) warm comfort (25.8°C-27.1°C), but this standard is for buildings, which are less relevant to this research. Another research result that can be used as a comparison is the thermal comfort research by the Agency for the Assessment and Application of Technology which states that the comfort range of Bandung City people is 22.2°C-28°C. But this research was also carried out indoors and the results would be different if done outdoors.

As an overview, the air temperature of Bandung City at October 2019 is between 19°C-35°C, at November 2019 is 17°C-34.2°C and at December 2019 is 19°C-32.6°C. From the results of the measurements, the Bandung City Hall Park air temperature is between 24°C-34°C. The air temperature mostly shows an average of 26°C-28°C or below 30°C, meaning that it still meets the range of outdoor thermal comfort (22.1°C - 30.0°C), especially Labirin Park and Badak Park which has a air temperature lower 1°C -3°C than other parks. At some times, the temperature reaches over 30°C but only occasionally and mostly during daytime (09.00-11.00) and afternoon (13.00-15.00).

4. CONCLUSION

The results based on the parameters of the US Green Building Council conclude that the Open Space in the Bandung City Hall Park meet the requirements from the landscape aspect, and can be seen from the vegetation which is mostly maintained as well as several criteria that include landscape problems. From the pavement material aspect, Bandung City Hall Park has implemented the use of paving material which is able to absorb the remaining rainwater quite well.

The measurement results of surface temperature and air temperature in the area, found that in the Sejarah Park, the average air temperature was 29°C-30°C, this was caused by pavement 87.40%, softscape 6.1% and water 6.45%, the material is dominated by pebble coral which reaches temperatures of 40°C to 44°C during the day, and andesite stone which reaches temperatures of 38°C-49°C. Labirin Park has an average temperature of 24°C-33°C, this park is dominated by 69.22% softscape and 30.77% hardscape consisting of asphalt with an average surface temperature of 40°C during the day. Badak Park has an average temperature of 26°C-33°C with a predominantly 65% pavement and 35% softscape, the low temperature caused by lots of big trees so that andesite and coral rocks tend to have low temperatures ranging from 25°C-35°C. Dewi Sartika Park has an average temperature of 26°C-34°C with pavement and softscape compared to 53% and 47%, in this park there are many large trees so that the pavement is not

too hot, paving blocks and coral stones have a temperature of 21°C-34°C. From the results of field observations, it was concluded that the highest heat contribution to the Bandung City Hall Park was obtained from the Sejarah Park from coral and andesite rock material which reached an average temperature of 38°C-49°C. The lowest heat contribution is obtained from Labirin Park which is dominated by softscape. In addition, Dewi Sartika Park with 53% pavement results air temperature between 26°C-34°C, this is because there are many large, shady trees that protect the pavement from exposure to direct sunlight.

Type of pavement material used in open spaces has a various impact on micro air temperature. From the analysis, it can be seen that the material temperature has a contribution to the increase of air temperature although the air temperature is not only influenced by the pavement materials used in the park, but also by the amount of vegetation, green area and water surface. The air temperature in Bandung City Hall is between 24°C-34°C and mostly shows an average of 26°C-28°C or below 30°C, meaning that it still meets the range of outdoor thermal comfort (22.1°C - 30.0°C).

The vegetation that grows in the 4 Parks in Bandung City Hall has a big influence on the temperature of the pavement material, especially the shady trees that cover the pavement area. Therefore, in addition to choosing a pavement material that has low heat capacity and is able to absorb the remaining rainwater, another thing that needs to be considered is the type and the size of other materials, such as using surface materials with low reflectivity such as soil and grass blocks, increasing the water surface (ponds) which allows evaporation and passive cooling, and adding vegetation for shading the area and also having evaporation ability that can lower the temperature.

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