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Material Performance to Reduce the UHI (Urban Heat Island) Phenomenon at Deo Airport, Sorong City

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ABSTRACT

Domine Eduard Osok Airport is a Class I Airport in the city of Sorong which is experiencing quite rapid development. This fairly rapid development has made airport managers think of ways to be able to provide maximum service to airport users. One of these services is to reduce the occurrence of the Urban Heat Island (UHI) phenomenon in the airport area by placing several types of materials around the airport. Several types of heat-absorbing materials are natural or synthetic materials that are used to withstand high temperatures. Nature provides a choice of materials that can be applied in this effort. Raw materials contained in nature will later be processed or used directly as an effort to reduce heat. The city of Sorong is a city that has problems with the occurrence of the UHI phenomenon because recently it has experienced an increase in population. To reduce the heat generated, various materials are used to be applied. These materials include Cast concrete, Asphalt, Soil, and Paving Materials. In this study, the material performance in reducing heat is determined for the four materials. The measuring instrument used is a measuring instrument commonly used to measure temperature. Measurements were made from morning to night. The results obtained are that cast concrete material has better performance compared to other types of materials when applied as a heat-absorbing material in buildings. Meanwhile, paving material is a good material if applied as a road material. With the average temperature produced for each material morning=25.2^{0}C, afternoon=26.2^{0}C, afternoon=26.6^{0}C, and night 25.9^{0}C and morning=32.7^{0}C, afternoon=33.9^{0}C, afternoon=29.0^{0}C, and night 28.8 ^{0}C.

Keywords: urban heat island (UHI); cast concrete materials; asphalt materials; soil materials; paving materials.

INTRODUCTION

Urban heat islands are one of the most frequently encountered urban environmental problems and have become important challenges for many cities, especially in recent decades. Over the last decade, there have been many studies on urban heat islands in big cities both at home and abroad, such as in Bandung, Indonesia (Muhammad Malik, 2019) and in Bangkok, Thailand (Khamchiangta and Dhakal, 2020).

The development of built-up areas in Sorong, especially in urban areas, greatly influences the local air temperature in urban areas, urban areas have hotter air temperatures compared to air temperatures that are on the outskirts of the city, causing urban heat islands to begin to appear due to a lack of cover. vegetation.

Currently, in Kota Sorong the temperature is much warmer compared to suburban areas, especially as the expansion of built-up areas reinforces this effect. This can be seen from the increase in temperature that occurred in the period 1997-2021 where in 1997 the temperature in Sorong City was still around 25^0 C-30^0 C, then experienced an increase in 2006 to 30^0 C-35^ 0 C and at the beginning of 2021 it was recorded that several areas in Sorong City had temperatures above 35^0 C.

Urban Heat Island (UHI) is a typical microclimate phenomenon in urban areas. The air temperature in urban areas is higher than in rural areas (Landsberg, 1981). In this case the roof and the surface of the city (land surface) are the parts that increase the temperature the most, where the rays from the sun are received by material materials that absorb heat. For that, the best reflector material is needed. So that the UHI phenomenon can be reduced which will later be tested for the

albedo value. Figure 1 shows the phenomenon of increasing the temperature of a city from materials that absorb and reflect heat.

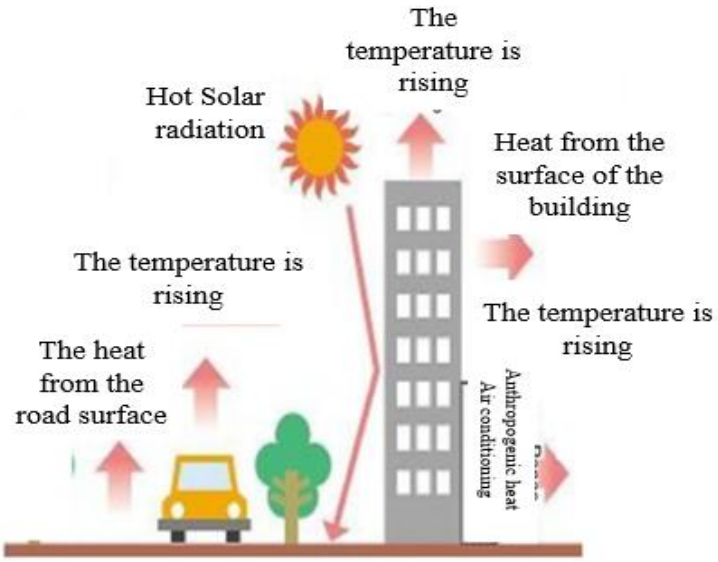

Figure 1. The phenomenon of increasing the temperature of a city from materials that absorb and reflect heat

Domine Eduard Osok Airport (DEO) is a Class I Airport located in Sorong City. The location of this airport is very strategic, making this airport one of the busiest and largest airports on the Bird's Head peninsula of Papua. Domine Eduard Osok Airport (DEO) experiences an average growth of 3.3 percent annually and there are more than 9,000 aircraft movements per year (BUREAU OF PUBLIC COMMUNICATION AND INFORMATION, 2016).

Concrete is a mixture of portland cement or other hydraulic cement, fine aggregate, coarse aggregate and water, with or without additives that form a solid mass (SNI 03 – 2847 – 2002). So far, the ingredients for concrete have been varied, for example using a mixture of styrofoam and sawdust mixed with portland cement (R. Buyung, 2010). Concrete has several advantages, including design flexibility, economy, durability, fire resistance, ability to be made on site, and artistic value. Of these advantages, the nature of fire resistance (heat) is widely used as an effort to reduce city heat.

Concrete is one of the heat retaining materials, so the performance of concrete in holding heat has been widely studied for a long time. Research related to this topic includes prevention of premature damage to fire-resistant concrete (Purnomo, 2007), the effect of the hydration heat of concrete with type II cement (Rochaeti, 2014), and the effect of mortar heating time (Widodo, 2002), the addition of a new nanocomposite accelerator (Lifeng Zhang et al, 2022), the performance of slag-based geopolymer concrete replaced by glass powder under high temperatures (Aslihan, 2022), the effect of storage room temperature on measurements of air permeability and water absorption (May, 2022), time-temperature profiles with mechanical properties and durability of high performance mass concrete (HPMC) (Abdulkader, 2022), and explosion resistance of fiber-reinforced ultra high performance concrete (UHPC) components after exposure to high temperatures (Zhenhuan, 2022).

Furthermore, on the other hand, concrete has the property of "Poor Thermal Conductivity" so that concrete with a large volume requires a relatively longer time to release the heat it contains. In the process of releasing heat, the surface of the concrete will release heat more easily than the inside. This results in a temperature difference always occurring between the concrete inside and the surface during the heat release process (Rochaeti, 2014). Efforts to increase the ability of concrete to retain heat are continuously being improved, such as adding foam in the manufacture of

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concrete (I Putu Widjaja, 2015). Figure 2 shows the phenomenon of the "Poor Thermal Conductivity" properties of concrete materials.

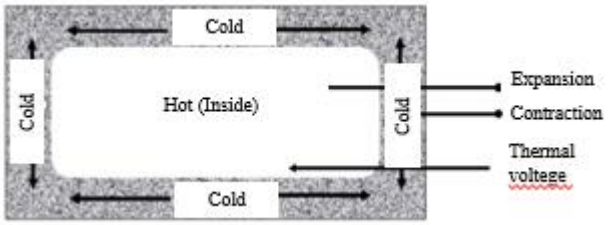

Figure 2. The phenomenon of "Poor Thermal Conductivity" properties

Furthermore, asphalt is a material other than concrete that is used to reduce heat. Asphalt material is a solid or semi-solid material that is black to dark brown in color, has adhesive (cementious) properties which softens and melts when heated. According to the American Society of Testing Materials (ASTM) asphalt is composed primarily of a large proportion of bitumen, all of which are present in solid or semi-solid form from nature or as a result of refining petroleum, or are mixtures of bituminous materials with petroleum or its derivatives (Asphalt Institute, 1994).

Asphalt has asphalt viscoelastic properties, due to temperature changes which are expressed as asphalt penetration index (IP). From this property, asphalt material has the property of easily absorbing heat or albedo. Albedo is a quantity that describes the ratio between sunlight arriving at the surface of the earth and being reflected back into space with a change in wavelength (outgoing longwave radiation). According to (Pomerantzetal, 2003), asphalt has an albedo value of 0.04 to 0.16, while concrete has 0.18 to 0.35. From these results, it appears that pavements with lower albedo tend to absorb more solar energy, resulting in higher pavement temperatures. Or in another explanation that the same level of hardness or penetration value does not necessarily have the same IP value. Conversely, bitumen with the same IP value does not necessarily have the same level of hardness. On asphalt with the same IP, the higher the hardness level of the asphalt the higher the durability of the asphalt mixture it produces (Brennen, 1999). Figure 3 shows the albedo phenomenon on asphalt. In Figure 3, it illustrates that asphalt material is a material that is widely used in urban areas compared to villages.

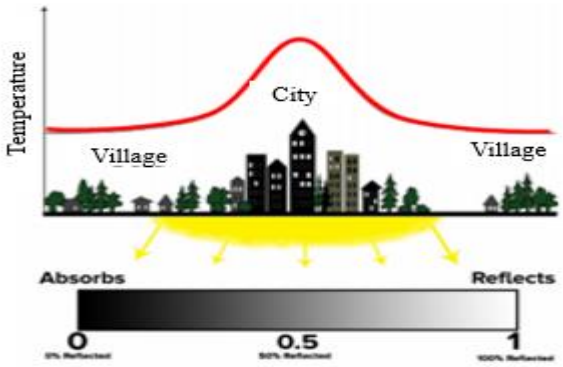

Figure 3. The albedo phenomenon on asphalt

Furthermore, much research has been carried out on the viscoelastic properties of asphalt due to temperature changes, including investigating the low temperature cracking resistance of asphalt mixtures, the low temperature properties of asphalt must be evaluated accurately (Kun Wei, 2022), the effect of pressure and temperature on the structure, mechanical properties and thermodynamic properties of hp10- WB4 (Ancang, 2022), determines the correlation between the critical value of the flexural strain energy density of the materials mentioned above and their ultimate fracture strength and strain under low temperature conditions (Chuanfeng, 2019), a model was developed based on the finite element method and allows to predict viscoelastic properties of mastic through

the mechanical properties and basic geometry of its constituents (Hassan Fadil, 2020), and analysis of the effect of the degree of penetration of the binder on the volumetric, mechanical and viscoelastic properties of cold recycled mixtures with foamed bitumen (Anna Chomicz-Kowalska, 2020).

Then apart from using cast concrete or asphalt materials in an effort to reduce city heat, the next choice is soil material. Soil is that part of the earth's crust that contains minerals and organic matter. Soil consists of several layers, top layer, middle layer, bottom layer, and parent rock layer. Figure 4 shows an overview of the soil layers in general.

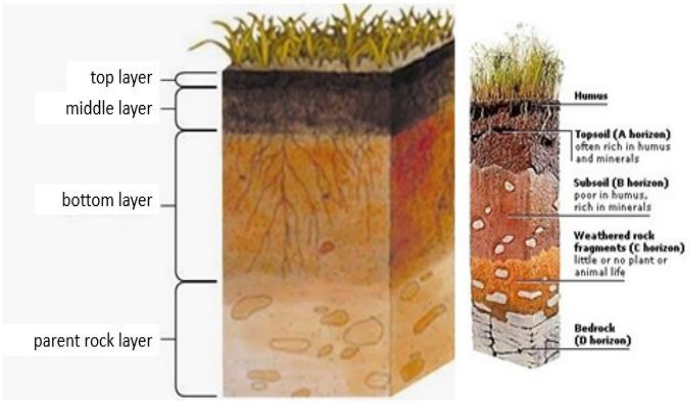

Figure 4. General soil layers

Soil has several layers that have different levels of density. This density level can be used to reduce heat. Because the level of soil density affects the speed of the material in releasing heat. To find out the performance of the soil in tackling the heat problem, several studies were carried out including measuring the temperature and humidity of the soil layers (Shi W, 2018) and modeling the seasonal soil temperature fluctuations and their impact on the shallow performance of the borehole heat exchanger (Sarwo Edhy, 2020).

Of the several types of heat absorbing materials presented in this study, it is necessary to have a performance review of materials that are suitable for application to the vicinity of Domine Eduard Osok Airport, Sorong City in an effort to reduce Sorong's heat.

RESEARCH METHODS

This research was carried out in the vicinity of Domine Eduard Osok Airport on February 6 2022. This research involved lecturers and students of the Sorong Maritime and Fisheries Polytechnic and Sorong Muhammadiyah University of Education. Figure 5 shows the research location.

Figure 5. Research location

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Methods

The stages of the research implementation which aim to find out the material performance in an effort to reduce the uhi phenomenon at Domine Eduard Osok Airport, Sorong City, are carried out in accordance with the activity flowchart as shown in Figure 6.

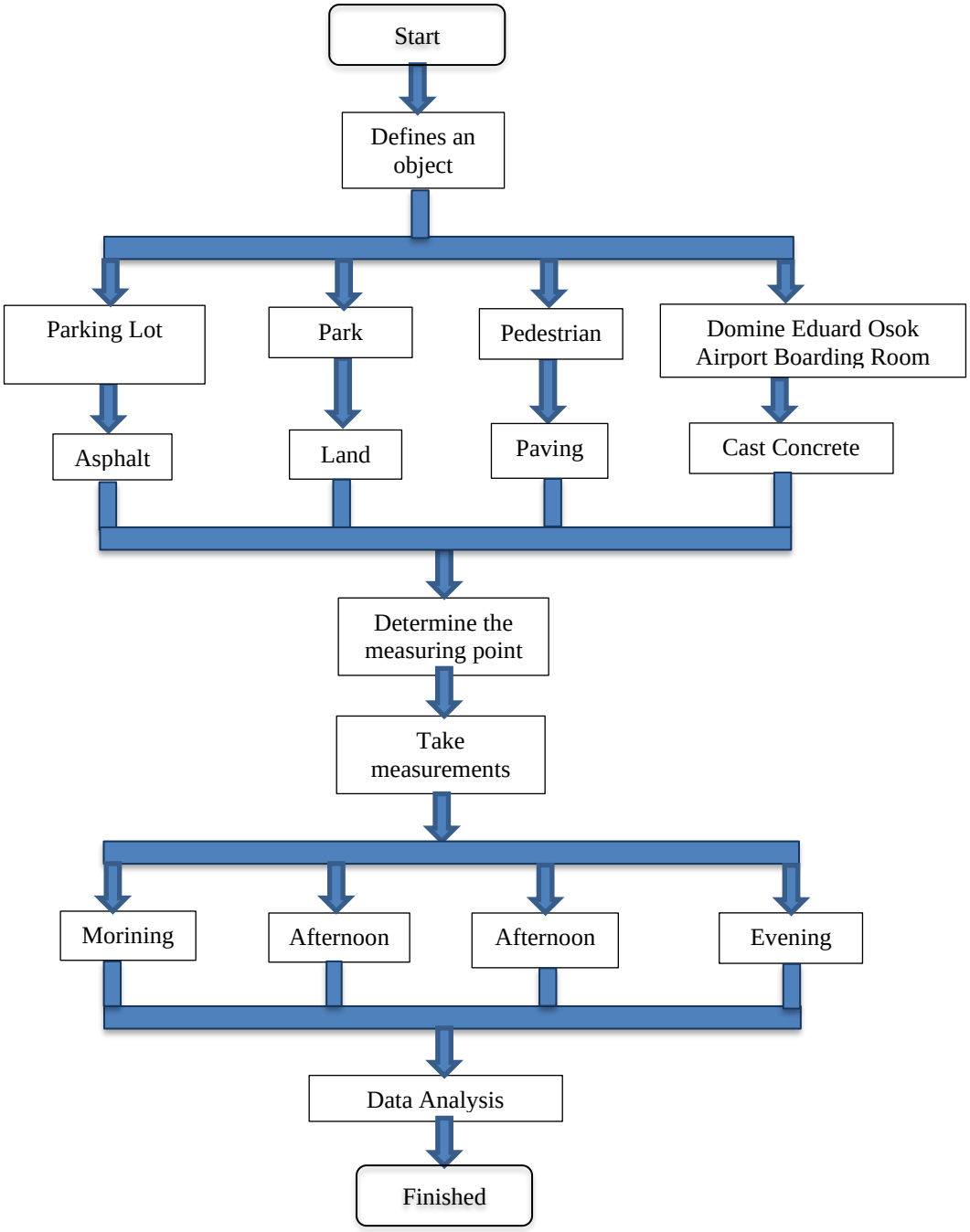

Figure 6. Flowchart of research activities at Domine Eduard Osok Airport, Sorong City

The research procedure used is to determine the object to be measured. The terms of the object to be measured have different constituent materials, including Asphalt, Soil, Paving, and Cast concrete.

Then for research objects including in the parking lot of Domine Eduard Osok Airport, Parks, Pedestrians, and Domine Eduard Osok Airport Boarding room. Figures 7a, 7b, 7c, and 7d respectively show the measurement objects for Domine Eduard Osok Airport parking lots (Asphalt), Parks (Soil), Pedestrians (Paving), and Domine Eduard Osok Airport Boarding rooms (Concrete Cor).

After determining the measurement object, then determine the measuring point. The measuring point is used as a marker so that the part to be measured does not vary. Because if it is different, it will show invalid data.

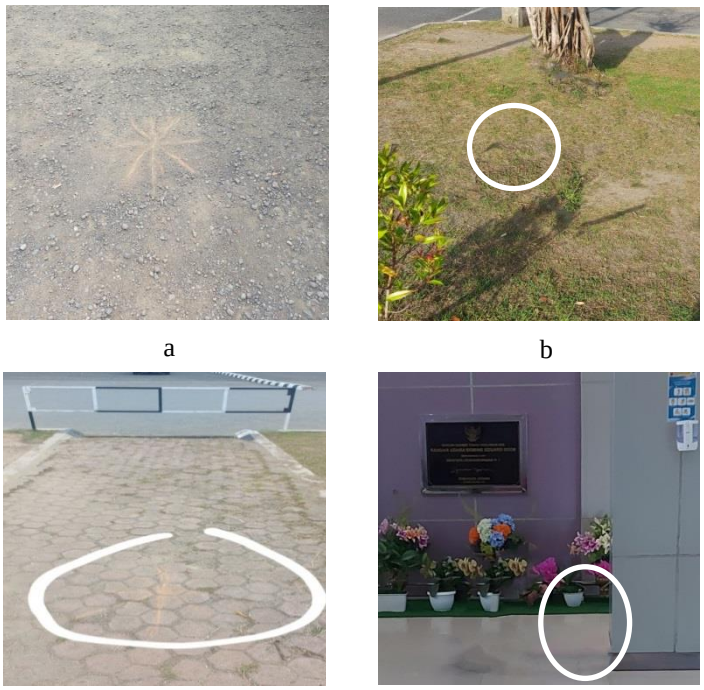

Figure 7. Objects of research: (a) Domine Eduard Osok Airport parking lot (asphalt); (b) Garden (Land); (c) Pedestrians (Paving); (d) Domine Eduard Osok Airport Boarding Room (Cast Concrete)

Furthermore, after determining the object and measuring point, measurements are made using a temperature measuring instrument. The measuring instrument used is a measuring instrument that is commonly used to measure temperature. In this study, the measuring tools used included measuring soil temperature using a soil thermometer (Electronic 4-in-1 soil meter), measuring surface objects using a thermo gun (Peak Meter PM6530D), and measuring room temperature using a room thermometer (UNI-T UT333). Figures 8a, 8b, and 8c respectively show a soil thermometer (Electronic 4-in-1 soil meter), thermo gun (Peak Meter PM6530D), and room thermometer (UNI-T UT333) used for data collection.

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Figure 8. Measuring tools used: (a) Soil thermometer (Electronic 4-in-1 soil meter); (b) Thermo gun (Peak Meter PM6530D); (c) Room thermometer (UNI-T UT333)

Then in carrying out the research, measuring temperature using the measuring instrument mentioned above. Temperature measurements were repeated three times and carried out from morning to midnight. The measurement results are then included in a table which is then analyzed. These results were then analyzed by comparing the results of the latest temperature measurements that had been carried out by the Sorong City BMKG. Table 1 shows the measurement table used in this research.

Table 1. Measurement point

Location	**Object**	**Temperature (^0C)**			
		Time (WIT)			
		Morning (08.00-09.00)	**Siang (12.00-13.00)**	**Sore (19.00-20.00)**	**Morning (08.00-09.00)**
Domine Eduard Osok Airport	Domine Eduard Osok Airport Parking Lot (Asphalt) Domine Eduard Osok Airport Park (Land) Domine Eduard Osok Airport Pedestrian (Paving) Domine Eduard Osok Airport Boarding Room (Cast Concrete)				

Data Analysis

The data that has been obtained, then analyzed descriptively based on the relevant literature. It is intended that the subject matter does not deviate from the topic.

RESULTS AND DISCUSSIONS

Data collection was carried out from morning to night around Domine Eduard Osok Airport. Figures 9a, 9b, 9c, and 9d respectively show the data collection process for the research object of the Domine Eduard Osok Airport parking lot (Asphalt), Park (Soil), Pedestrian (Paving), and Domine Eduard Osok Airport Boarding room (Concrete) cast).

Figure 9. The process of collecting data with objects: (a) Front page of flats (Land); (b) Pedestrian (Cast Concrete); (c) Pedestrian (Asphalt); (d) Roofed room (Cast concrete)

After measurements, it appears that the temperature fluctuates steadily. This is shown by Table 2 of the observations.

Table 2. Table of observations

Location	**Object**	**Temperature (^0C)**			
		Time (WIT)			
		Morning (08.00-09.00)	**Afternoon (12.00-13.00)**	**Afternoon (19.00-20.00)**	**Evening (00.00-01.00)**
Domine Eduard Osok Airport	Parking Yard (Asphalt)	33,1	34,4	29,2	27,3
	Park (Land)	33,0	35,0	33,0	30,7
	Pedestrians (Paving)	32,7	33,9	29,0	28,8
	Boarding Room (Cast Concrete)	25,2	26,2	26,6	25,9

As shown in Table 2, it can be seen that the temperature generated at several points fluctuated with changes in data collection time. For example, garden objects (soil) have an average temperature value of morning = 〖33.0〗^0 C, afternoon = 〖35.0〗^0 C, evening = 〖33.0〗^0 C, and night = 〖 30.7〗^0 C, Pedestrian (paving) has an average temperature value in the morning = 〖32.7〗^0 C, afternoon = 〖33.9〗^0 C, evening = 〖29.0〗^0 C , and night = 〖28.8〗^0 C, Parking Yard (Asphalt) has an average temperature value in morning = 〖33.1〗^0 C, afternoon = 〖34.4 〗^0 C, afternoon = 〖29.2 〗^0 C, and night = 〖27.3〗^0 C, and Boarding Room (Cast Concrete) which has an average temperature value in the morning = 〖25.2〗^0 C, afternoon = 〖 26.2〗^ 0 C, evening = 〖26.6〗^0 C, and evening = 〖25.9〗^0 C.

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Furthermore, based on the results of temperature measurements that have been carried out by the Sorong City BMKG, the average temperature obtained is as shown in Table 3.

Table 3. Air temperature in Sorong City

Month	Temperature (^0C)
	Year 2021
February	27,3

Based on the measurement results above, it can be seen that the temperature around Domine Eduard Osok Airport has increased slightly, when compared to the results of measurements taken by the BMKG in 2021 in the same month. It can be seen that from last year's data for 2021, the temperature in the city of Sorong was quite low, around 〖27.3〗^0 C. Many factors could influence this, including the intensity of the rain that occurred at that time was quite high. Several years ago, the intensity of rain in Sorong City was relatively high (Arif Faisol, 2020). So that causes the temperature of the city of Sorong is relatively low. These results were reinforced by the existence of a study of the effect of temperature and humidity on rainfall conducted in Sorong City (Muhammad Yusuf, 2022), the effect value obtained was 81.75%. Then airport activities are increasing, this can also increase airport temperatures. Based on information, DEO Airport has increased by 21.21% when compared to February 2021 (Editor, 2021).

Furthermore, when viewed from the results of measurements on several objects, it was found that the temperature had increased from last year. It can be seen that the results of the measurements that have been carried out, the average temperature produced is above 〖30.3〗^0 C. This may be caused by a lack of natural heat retention in some objects. If you pay attention at the time of data collection, natural heat barriers such as trees and grass are gone or even withered. Previously, the location of the airport park was overgrown with grass and flowers. However, at the time of data collection, both of them were not there. This could be one of the causes of increasing temperatures in several airport objects.

Judging from the performance of the constituent materials, cast concrete material has a good performance in reducing the heat of the city of Sorong. This is because cast concrete contains cement, fine aggregate, coarse aggregate, and water which meet the criteria for workability, strength, durability, and final finish according to specifications. So that it has different properties and unique characteristics of the constituent materials. The difference in properties and characteristics can reduce the resulting temperature.

Then when compared to the ground surface, cast concrete material has better performance. These results can be seen from the measurement results that have been done. For example, garden objects (soil) have an average temperature value of morning = 〖33.0〗^0 C, afternoon = 〖35.0〗^0 C, evening = 〖33.0〗^0 C, and night = 〖 30.7〗^0 C and the Boarding Room (Cast Concrete) has an average temperature value in the morning = 〖25.2〗^0 C, afternoon = 〖26.2〗^0 C, afternoon = 〖26.6〗^ 0 C, and night = 〖25.9〗^0 C. From the results obtained, it can be seen that the temperature of the Boarding Room (Cast Concrete) has a low result. The high ground temperature is due to the fact that there are cavities on the ground surface that heat can still enter, so that heat is still trapped inside. This is reinforced by data in the field, that the soil conditions at the time of data collection were dry and cracked. Therefore, it is natural that high temperature results are obtained. As for the Boarding Room (Cast Concrete), it is a material whose location and conditions are in an air-conditioned room. These two things are clearly very possible to make the cast concrete temperature low.

Furthermore, when compared to Parking Yard (Asphalt), cast concrete material has better performance. For example, the parking lot object (Asphalt) has an average morning temperature value = 〖33.1〗^0 C, afternoon = 〖34.4〗^0 C, afternoon = 〖29.2〗^0 C, and night = 〖27.3〗^0 C and Boarding Room (Cast Concrete) have an average temperature value in the morning = 〖25.2〗^0 C, afternoon = 〖26.2〗^0 C, afternoon = 〖26.6〗 ^0 C, and night = 〖25.9〗^0 C.

From the overall results obtained, the Boarding Room (Cast Concrete) as a whole has a low temperature value. This can be seen from the source of the material. Asphalt is produced from the crude oil refinery industry through a distillation process. From these sources, it is clear that the asphalt material easily absorbs heat and is difficult to remove it. Therefore, the heat that is in the asphalt is still trapped in the material. So if measurements are taken, the temperature produced by the asphalt material has a high temperature when compared to the Boarding Room material (Cast Concrete). From these results, there is a lower asphalt temperature value compared to cast concrete. This is because at the time of measurement, previously there was quite heavy rain. Therefore, the bitumen temperature drops quite a lot. In addition, at the time of measurement, the number of cars visiting the airport was not too many. Therefore, the asphalt temperature at that point is quite low. From the results of these measurements, overall the cast concrete material has the lowest temperature value.

Finally, cast concrete compared to paving, the two types of materials are compared. The results show that pedestrians (paving) have an average temperature value in the morning = 〖32.7〗^0 C, afternoon = 〖33.9〗^0 C, evening = 〖29.0〗^0 C, and night = 〖 28.8〗^0 C and in the Boarding Room (Cast Concrete) has an average temperature value in the morning = 〖25.2〗^0 C, afternoon = 〖26.2〗^0 C, evening = 〖26.6〗^0 C, and malam = 〖25.9〗^0 C. From the results obtained, it can be seen that the temperature of cast concrete has a low yield. The high temperature of the paving is caused because the paving is in direct contact with sunlight, while the cast concrete is covered with a roof and is located indoors. Therefore, it is natural that high temperature results are obtained. When compared to adjacent land, the paving temperature value is lower. This is because the cavities in the paving material are smaller than the soil, therefore the paving material transfers heat faster than the soil. In addition, the condition of the paving material that has been treated is in the form of a coating using red paint. This treatment is also one of the efforts to close the paving pores so that the heat received is not easily absorbed.

CONCLUSION

From the results of observations at Domine Eduard Osok Airport, it appears that cast concrete material has better performance compared to other types of materials when applied as a heat retaining material. Meanwhile, paving material is a good material if applied as a road material. With the average temperature produced by the cast concrete and paving materials, each morning = 〖25.2〗^0 C, afternoon = 〖26.2〗^0 C, evening = 〖26.6〗^0 C, and night = 〖25.9〗^0 C and morning = 〖32.7〗^0 C, afternoon = 〖33.9〗^0 C, afternoon = 〖29.0〗^0 C, and night = 〖 28.8〗 ^0 C. From the results shown, cast concrete material produces good performance in reducing heat, but there are drawbacks that need attention. Cast concrete materials have low tensile strength, low ductility and some shrinkage. Therefore, there are several civil applications that are less efficient when using cast concrete material.

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