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The utilization of paving blocks as environmental heat reduction materials

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ABSTRACT

Global warming increases the overall temperature of the earth's surface and leads to climate change. Therefore, it plays an important impact on human life, especially in the architecture field. This study aims to identify the rise in environmental temperature due to parked cars with running engines and the use of paving blocks as heat-reducing material. This is a quantitative research with data collected and measured directly in the field, before being processed and explored of natural and waste materials in the laboratory. The results showed: (1) an increase in environmental temperature of ±34.8ºC - 39.4ºC, or 5ºC to 10ºC due to parked cars with running engines, (2) the use of rectangular and hexagon paving blocks as heat-reducing material. Therefore, the increase in environmental temperature is reduced by the use of paving blocks, which comprises of basic (cement, sand, and water), natural (grass and fibers), and recycled materials (sawdust and styrofoam).

Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), the greenhouse effect of human activities has been a significant factor of global warming since the mid-20th century (Suarsana and Wahyuni 2011; Abduh 2017). According to Imran, Wuisang, and Rahmat (2019), overheating in urban areas due to excessive emissions, is called urban heat island (Imran et al. 2019). An increase in the average earth temperature above 20ºC leads to an unmanageable impact by both humans and nature (Samidjo and Suharso 2017).

Therefore, it is important to carry out all forms of activities, and environmental changes due to temperatures, using appropriate, measurable, and adaptive methods, especially in urban areas (Sangkertadi and Syafriny 2014). An increase in environmental temperature leads to continuous complaints on the rise in skin temperature on the human body (Dede 2019). Therefore, it is important to ensure the thermal comfort aspects of outdoor space (Sazali et al. 2017). Similarly, Purwanto (2019) stated that thermal comfort had become part of human life to interact with the physical environment (Purwanto 2019; Munawaroh and Elbes 2019).

Jefrey Ignatius Kindangen (2016) researched outer space in Manado City trade areas to determine the regions' ability to develop into an open and strategic area, which provides national and international scale needs the patterns and structures of the city (Kindangen 2016). The Manado City functions as a strategic economic and tourism area (Prijadi, Sangkertadi, and Tarore 2014).

The increase in outdoor heat activity had an impact on the earth and all living things based on the phenomena regarding global warming. Therefore, the research questions are described as follows: (1) how does a rise in environmental temperature affect trading activity in Manado city? (2) how can environmental heat be reduced?

The purpose of this study is to identify the rise in environmental temperature due to parked cars with running engines, and the use of paving blocks as heat-reducing material. This research innovates and contributes to the ideas/concepts for the development of architectural science specifically for thermal comfort material outside space and enables urban communities, to use paving blocks as a heat reduction prototype.

Method

This is a quantitative research with data collected and measured directly in the field, before being processed and explored of natural and waste materials in the laboratory.

The study was conducted for ±2 (two) years: (1) the first year started from March-August 2018 and (2) the second year from March-August 2019.

Data source

a) Primary data were collected from the following:
   1 Solar thermal radiation levels taken directly at the point of data retrieval location;
   2 Car characteristics include type; color and glass type (transparent or dark);
   3 The number of existing cars taken directly at the point of collection;
   4 Ground cover material characteristics, shade plant, and function of the data collection area;
   5 Characteristics of natural materials and waste used in exploring the development of paving block materials.
b) Secondary data needed including:
   1 Daily average temperature of the Manado city;
   2 Physical characteristics of the urban areas,
   3 Daily average humidity;
   4 Data on heat absorption rate (albedo) material;
   5 Heat standard data for the trade function area in accordance with the provisions of government and related ministries.

Research instruments

Increase in temperature due to motor vehicle activity is detailed as follows:

a) Measurement and observation area

The measurement and observation area at the Mall parking is divided into 2 and both are 50 meters in front behind the Mall. The measurement and observation area around Manado Town comprises of Pierre Tendean Street at 220 meters and Square 3 parking area of 100 meters.

At the Pierre Tendean Street, vehicles with heavy volumes move slowly, while the tenuous ones are allowed to run fast.

b) Shooting and recording

The shooting was taken at the data collection locations according to their parking conditions, traffic, car characteristics, and the presence of fences, trees or materials, and road cover material such as asphalt and paving blocks. Furthermore, the shooting was also carried out while exploring the material for developing paving blocks in the laboratory.

Environmental heat was measured by identifying solar radiation, the surface temperature of the material, and wind velocity.

Classification and synchronization of data use mahoney tables with the "*Matahari*" and Microsoft Excel software.

c) Data collection instrument

A total of 9 instruments were used for data collection at the research location, including shooting, recording, processing, and exploring natural materials and waste carried out at the laboratory. Details of the instruments used are in accordance with table 1.

Table 1. List of instruments used

No.	Parameter	Total	Tool's name
1	Environmental temperature	8	Outdoor Digital Thermometer
2	Material Surface Temperature (solid)	4	Thermometer Infra Red
3	Physical area wide of the data collection location	4	Meter
4	Visual Documentation	4	camera
5	Wind velocity	4	Anemometer
6	Record measurement and observation data	4	Stationary

No.	Parameter	Total	Tool's name
7	Anticipate rain and heat	4	Umbrella
8	Adjust the shape and size of paving block	2 (1 rectangular shape and 1 hexagon shape)	Molding
9	Compact material mix and print paving blocks	1	Printing Equipment with Vibrator and Drop Gravity System

Research scheme

The principle of the research scheme is describer as follows (figure 1):

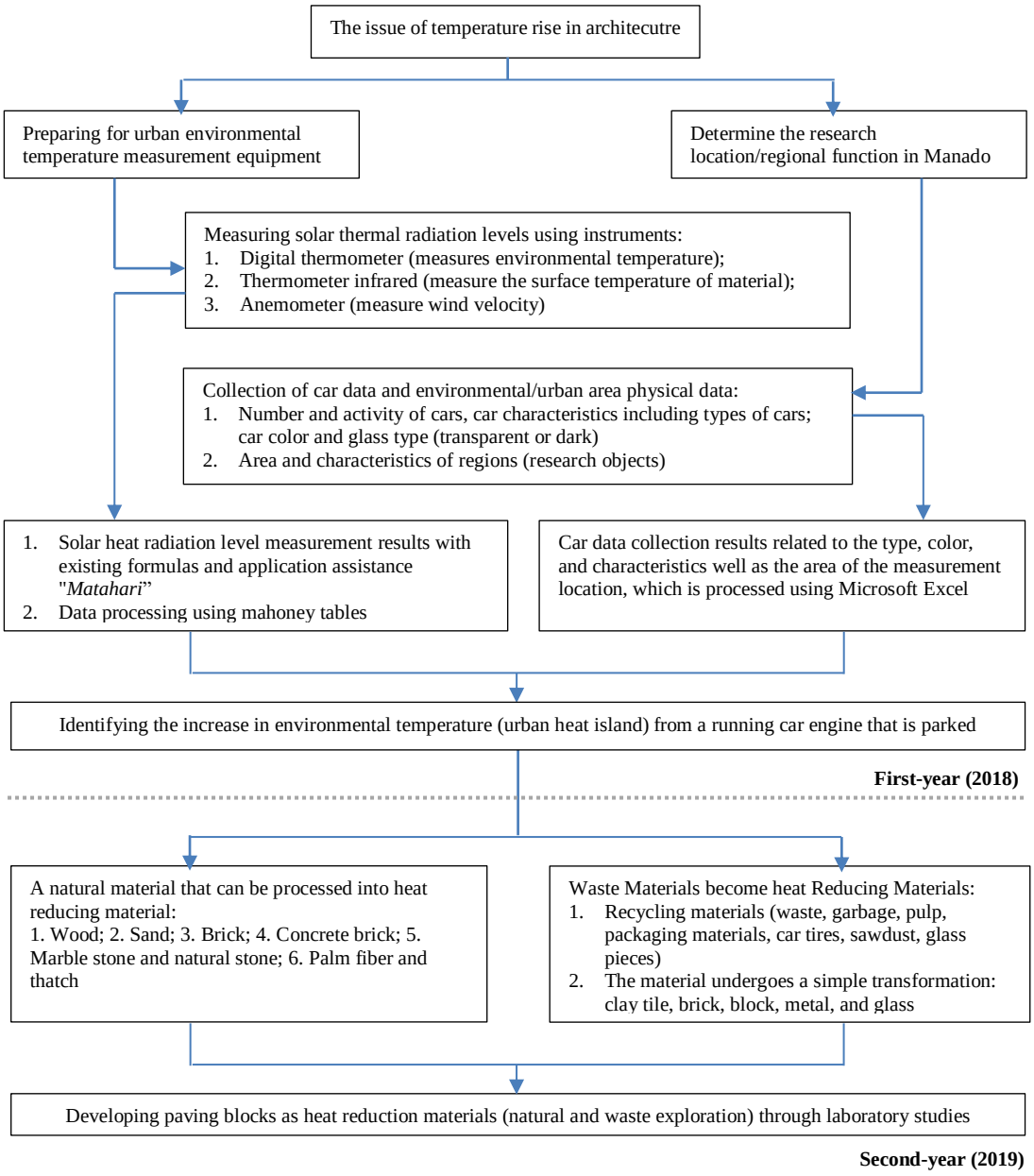

Figure 1. Research Scheme

Data collection

Measurement and collection of data on the air heat level in the central area of the Manado City trade services are as follows:

1. In July and August 2018, due to the increase in solar radiation to the earth's surface.
2. Data were collected for 10 (ten) days in a month with the weather conditions, adjusted in the following dates/days:
   a. July 2018: on the 5th (Thursday), 6 (Friday), 8 (Sunday), 9 (Monday), 16 (Monday), 17 (Tuesday), 27 (Friday), 28 (Saturday), 29 (Sunday) and 30 (Monday).
   b. August 2018: On the 2nd (Thursday), 6 (Monday), 8 (Wednesday), 9 (Thursday), 18 (Saturday), 19 (Sunday), 24 (Friday), 27 (Monday), 29 (Wednesday) and 30 (Thursday).
3. The data collection of air temperature is adjusted to the position of the sun and the heat level in a day at (1) 08.00 am, (2) 09:30 am, (3) 11.00 am, (4) 1:00 pm, (5) 2:30 pm and (6) 4:00 pm.
4. Dates that with collection points were carried out in 4 (four) places as follows:
   a. The parking Area in front of the mall is 50 m x 12 m. Placement of the measuring points is T1 to T10 and spaced 10 meters from each other, as shown in figure 2. The area is shaded blue, and data is collected using a measuring instrument such as a digital outdoor thermometer, anemometer, and infrared, as shown in figure 3.
   b. The parking area behind the Mall is 50 m x 12 m, with the measuring points placed from T1 to T10 and spaced 10 meters, as shown in figure 4. The area is shaded blue, and data is collected using a measuring instrument such as a digital outdoor thermometer, anemometer, and infrared, as shown in figure 5.
   c. The area on Pierre Tendean street is 220 m with the measuring points placed from T1 to T22 and spaced 10 meters, as shown in figure 6. The area is shaded blue, and data is collected using a measuring instrument such as digital outdoor thermometer, anemometer, and infrared, as shown in figure 7.
   d. Manado Town Square 3 parking area is 1000 m x 12 m with the measuring points placed from T1 to T10 and spaced 10 meters, as shown in figure 8. The area is shaded blue, and data is collected using a measuring instrument such as a digital outdoor thermometer, anemometer, and infrared as shown in figure 9.

Figure 2. Parking area in front of the mall

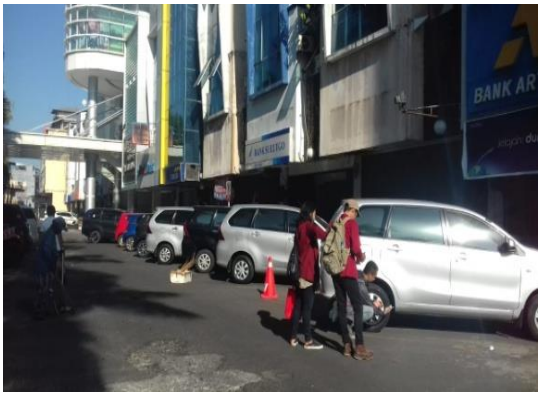

Figure 3. Collecting data in the parking area in front of the mall

Figure 4. Parking area behind the mall

Figure 5. Data collection in the parking area behind the mall

Figure 6. Area along Pierre Tendean Street (int front of Manado Town Square 3)

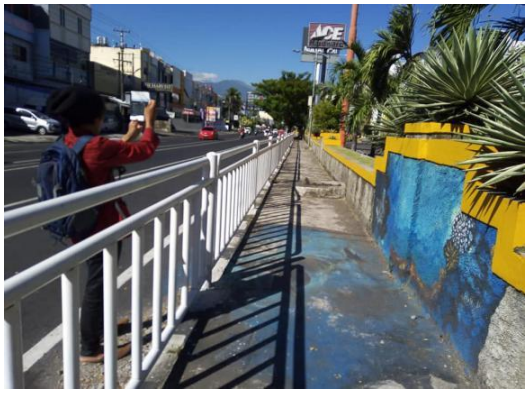

Figure 7. Data collection in the parking area on Pierre Tendean Street

Figure 8. Manado Town Square parking area 3

Figure 9. Data collection in the Manado Town Square parking area 3

Result and discussion

The first-year findings

The data processing results showed several measuring samples with an average maximum value of 4 (four) as follows:

1. Parking area in front of the mall

   The air temperature in the parking area of the front of the mall is 36.10ºC.
2. Parking area behind the mall

   The air temperature of the parking area behind the Mall is 34.80ºC.
3. The areas along Pierre Tendean Street (in front of Manado Town Square 3)

   Air temperature at Pierre Tendean Street area is 36.40ºC.
4. Manado Town Square parking area 3

   The air temperature in the Manado Town Square 3 parking area is 39.40ºC.

The data processing result recapitulation for the maximum air temperature at the four points is shown in table 2.

Table 2. Heat level recapitulation

Average temperature (ºC)	Research sites
36,1	Parking area in front of the mall
34,8	Parking area behind the mall
36,4	Piere Tendean Street (in front of Manado Town Square 3)
39,4	Parking area in front of Manado Town Square 3

Discussion

Data were analyzed using the Mahoney table, which is combined with the average air temperature from January to September 2018. Manado's highest air temperature occurs in August, in which it can reach 31.9ºC, while the lowest was in January at 26.6ºC. The highest and lowest temperature and humidity data are shown in figure 10 and table 3.

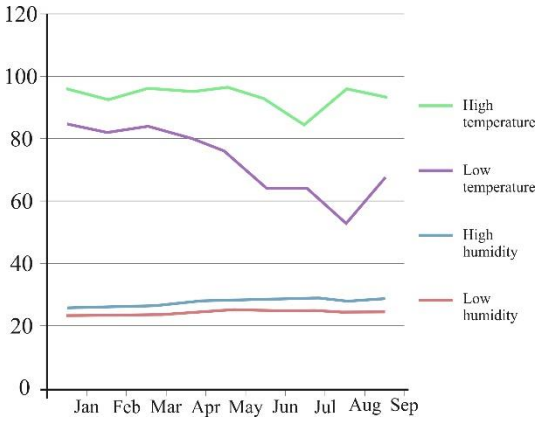

Figure 10. High and low temperature and humidity

Table 3. Average temperature and humidity

Month	Temperature (ºC)	Humidiy (%)
January	26.6	89.5
February	28.8	87.1
March	28.5	90.2
April	29.3	87.9
May	29.6	85.3
June	29.9	82.7
July	30.3	75.6
August	31.9	71.6
September	29.6	83

Based on data processing at the four collection points, the environmental temperature increased between 5ºC to 10ºC. This is due to the number of cars and activities in the Mall area, along with Piere Tendean street and the Manado Town Square 3.

The second-year findings

It is necessary to use a material that reduces heat, such as solid objects (Munir et al. 2018). Environmental architecture contributes to the utilization of natural materials that are processed from waste products to reduce heat. Mediastics in Imran, Wuisang, and Rahmat (2019), stated that sustainability and environmentally friendly factors are the main heat-reducing materials which are conducted in urban areas through the following considerations (Imran et al. 2019):

1. Benchmarks (landscape) especially green open spaces in urban areas use city parks to reduce heat (Mulyandari and HS. 2011).
2. Increase the types of plants and trees to reduce the quantity of solar radiation that falls to the earth surface and the ground (Mediastika 2013).
3. It is better to use a soil layer with grass material, garden, and brick to reduce soil pavement (Sangkertadi and Syafriny 2014).

According to Mediastika (2013), Indonesia is a tropical country rich in natural diversity (Mediastika 2013). A variety of natural materials are used to reduce heat, namely: (1) wood, (2) sand, (3) bricks, (4) building block, (5) marble and natural stones, (6) palm fiber, and thatch. Meanwhile, according to Frick (2007), natural materials such as stone, wood, bamboo, and clay do not contain substances that interfere with health (Frick and Mulyani 2006). Some artificial materials also function as heat-absorbing materials that are safe for health, such as (1) Recycling materials: waste, garbage, pulp, packaging materials, car tires, sawdust, pieces of glass. (2) Simple transformations: red stone, tiled clay, brick, con-block, metal, glass, and cement. Land and soft materials are used to develop contextual concepts with nature, which is central to human synergy with the environment (Srinaga and Prakoso 2019).

The energy performance of a material used to store heat is determined by simply knowing the insulation value of a material. This is because the entire surface area is not completely filled with insulation materials (Purwanto 2019). Therefore, when waste materials are explored, the original characteristics and properties produce heat,

reducing material mix, which is relatively large, as shown in table 4.

Table 4. Heat absorbance numbers

Material	Surface absorption numbers (αw)
Thick concrete	0,91
Redbrick	0,89
Bitumen sheet	0,88
Slatestone	0,87
Lightweight concrete	0,86
Asphalt trail	0,82
Smoth surface wood	0,87
Exposed concrete	0,61
White tile	0,58
Dark yellow brick	0,56
White roof	0,50
Aluminum paint	0,40
Gravel	0,29
White zinc	0,26
White glazed brick	0,25
Shiny aluminum sheet	0,12

Sumber: (Satwiko 2008)

The materials used as a mixture in the manufacture of paving blocks include grass, fibers, sawdust, and styrofoam. The use of natural material such as wood and sawdust in a mixture of cement and sand is absorbed on the surface of the mineral/concrete particles. Therefore, it provides additional bonding strength between particles due to the adhesion and dispersion properties and inhibits the diffusion of water in the material due to its hydrophobic nature (Saifuddin, Edison, and Fahmi 2013). Furthermore, natural materials mixed with concrete, such as coconut fiber, can also be used as reinforcing concrete because it has lighter density than sand (Prahara, Liong, and Rachmansyah 2015). Furthermore, the mixture of sand and fibers also meet the standard of non-structural or construction compressive strength. Natural fibers such as sawdust, grass, and fibers reduce energy consumption and air pollution (Prastyatama and Maurina 2018). The heat-reducing material, which functions as a water provider, is a type of paving block that is part of the landscape's hard materials acting as a footpath for pedestrians, and parking areas (Prasetyo, Yuliarso, and Suparno 2019).

Furthermore, mixing materials to manufacture paving blocks as a heat-reducing material is carried out as follows:

1. Material mixing process

The composition of the mixture is 15% grass, 15% palm fiber, 15% wood powder, 15% streform, 15% sand, 20% cement and 5% water. Dough mixing need to be evenly distributed manually as shown in figure 11.

Figure 11. Material mixing process

2. Manual paving block molding equipment

The simplest paving block used as printing tool are manually made of wood. The mixed dough is put into a closed molding, and beaten for condensation. This process is shown in figure 12.

Figure 12. Molding tool

3. Molding process

The molding process is carried out on this dough in order to get optimum quality and strength of the paving blocks. This process is shown in figure 13.

Figure 13. Molding process

4. Molding tool with vibrator and drop gravity system

In addition to manual molding tools, this study also used a vibrator and drop gravity molding machine. The mixture is put in molding and compacted by the force of gravity. Paving blocks have high quality with a power level of ± 160 kg/cm, 2-180 kg/cm^2.

5. Drying process

The next step is the drying which is placed and arranged in the Building Materials Technology and Physics Laboratory, Department of Architecture, Faculty of Engineering, Sam Ratulangi University and Structure and Materials Laboratory, Department of Civil Engineering, STITEK Bina Taruna as shown in figure 14.

Figure 14. Drying process

Discussion

This research developed 2 (two) types of heat reducing material products, as follows:

1. Rectangular paving blocks have characteristics:
   (a) More solid;
   (b) It has a compressive strength of 14.94 MPa which is equivalent to 180 kg/cm^2;
   (c) The heat reducing material contained grass, fibers, sawdust and styrofoam. This material are evenly mixed and compacted in each part to obtain paving blocks with a size of 21 cm x 10.5 cm x 6 cm;
   (d) Static form;
   (e) The level of heat reduction ±0.5^{o}C-1.5^{o}C/square meter (44 pieces).
2. Hexagon paving blocks have characteristics:
   (a) Solid;
   (b) It has a compressive strength of 13.28 MPa which is equivalent to 160 kg/cm^2;
   (c) The heat reducing material contained grass, fibers, sawdust, and styrofoam. This material is mixed evenly and evenly compacted in each section with a size of 21 cm x 21 cm x 6 cm;
   (d) Dynamic form;
   (e) The level of heat reduction ± 0.5oC-1.8^{o}C/square meter (25 pieces).

Conclusion

Based on the results of this study, it can be concluded that: (1) the maximum environmental temperature is in the Manado Town Square 3 parking area, which is 39.4 oC due to the large number of motorized vehicles parked with their engine running. Furthermore, there are no trees or shade in the parking area, which is directly adjacent to the Piere Tendean shaft road, thereby, leading to high average ambient temperatures. (2) the increase in environmental temperature tends to be reduced by the use of paving blocks, such as sand, water, cement, grass, fibers, sawdust, and styrofoam. The paving blocks are developed in the rectangular and hexagon forms. The placement of this material prototype in open space/border area effectively reduces the impact of global warming (urban heat island).

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