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Correlation of Air, Surface and Pavement Temperatures using MPU 6050 Accelerometer Sensor

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ABSTRACT

This research analyses the correlation between air temperature, road surface temperature and pavement temperature using the MPU 6050 accelerometer sensor and the Pearson correlation method. Temperature measurements were taken at several predetermined locations, with the data analysed to identify the correlation between the three types of temperature. The analysis showed a very strong correlation between air temperature and road surface temperature, with a correlation coefficient of 0.7845 at night and 0.9663 during the day. Similarly, there is a very strong correlation between road surface temperature and pavement temperature, with a correlation coefficient of 0.8482 at night and 0.9673 during the day. These findings indicate that an increase in road surface temperature leads to an increase in pavement temperature. It was concluded that the correlation method can be used to predict temperatures at other points without invasive direct measurements, thus preventing damage to the road due to destructive measurements. This method is recommended as an alternative in pavement temperature monitoring.

Keywords: *Accelerometer Sensor MPU 6050; Pearson Correlation Method; Temperature Correlation.*

INTRODUCTION

Roads are the most frequently used transport infrastructure by most people, affecting their daily activities [1], [2], [3]. Road infrastructure plays a vital role in everyday life, and efficient maintenance is essential to ensure the sustainability and safety of the transport system. One of the critical aspects of road maintenance is an in-depth understanding of the interaction between various factors, including air temperature, surface temperature, and pavement temperature [4], [5], [6].

Significant temperature changes can cause variations in the physical and mechanical properties of pavement materials [7], [8]. High temperatures can cause pavements to become soft and deformable, while low temperatures can make them brittle. These temperature fluctuations can have a significant impact on the mechanical properties of the pavement, altering its structural response. Currently, the process of collecting pavement temperature data often involves pitting the existing asphalt layer, which is invasive and damaging to the integrity of the road.

Research by Johnson et al. (2016) showed that variations in air temperature can cause changes in the physical properties of road surfaces. Increases in temperature can result in changes in the strength and elasticity of asphalt, affecting traffic stability and safety. Chen et al. (2020) found a positive relationship between air temperature and road surface deterioration, but have not considered the effects specifically on pavements. Diana Rendarini (2019) showed that air temperature fluctuations contribute to pavement susceptibility to deformation. Nola Riwibowo (2023) concluded that the higher the air temperature, the less the road life.

This research aims to analyse the correlation between air temperature, road surface temperature, and pavement temperature using the MPU 6050 accelerometer sensor. The use of this sensor is expected to provide more accurate and efficient measurements without damaging the road surface. The Pearson correlation method will be used to analyse the data obtained from several predetermined locations, ensuring the validity of the results.

This research introduces an innovation in the use of the MPU 6050 accelerometer sensor for road temperature measurement, which has not been widely discussed in previous literature. This method offers a more accurate and efficient solution compared to conventional techniques that are often destructive. The findings from this study can be used to predict the temperature at other points without direct measurement, thus preventing road damage and reducing maintenance costs. Thus, this method has the potential to be widely adopted in monitoring and maintaining road infrastructure.

METHOD

This study used an experimental approach to measure the correlation between air temperature, road surface temperature, and pavement temperature over a 24-hour period in the Cijawura Girang V area, Bandung City, which was chosen for its air temperature variation and diverse surface and pavement conditions.

Data was collected using MPU 6050 accelerometer sensors for road surface temperature and digital thermometers for air temperature and pavement temperature.The tools used have passed the QC process to ensure accuracy.Air temperature measurements were taken at a height of 2.5 metres from the road surface and were taken every hour.The road surface temperature is measured with an accelerometer sensor placed in the centre of the asphalt briquette surface, while the pavement temperature is measured with a thermometer at the appropriate depth.

Once the data was collected, the temperature data was processed to remove outliers and ensure its integrity, and then analysed using descriptive statistical techniques to calculate the mean and standard deviation, and visualised in a timeline graph.Pearson correlation analysis is used to explore the relationship between air temperature, surface temperature and pavement temperature. The correlation coefficient will indicate the strength of the relationship between the variables, with results close to 1 indicating a perfect positive correlation, while results close to -1 indicate a perfect negative correlation.This analysis aims to provide an in-depth understanding of the temperature dynamics and relationships between variables in the context of this study.

RESULTS AND DISCUSSION

Temperature Measurement Results

Temperature measurement involves collecting data on air, surface and pavement temperatures to understand temperature variations over time.The method used affects the accuracy of the data for correlation analysis.The air temperature measurement results showed significant fluctuations between summer and winter, with the highest temperatures occurring in summer and the lowest in winter.

Air Temperature Measurement Results

Air and pavement temperature data were measured hourly for 24 hours using a digital thermometer and MPU 6050 sensor, with day and night categories.Results showed significant daily temperature variations: the highest temperature was recorded at 10:00 am (33.00°C) and the lowest at 7:00 am (25.20°C).Temperatures were higher during the day and lower at night, influenced by daylight and night cooling.

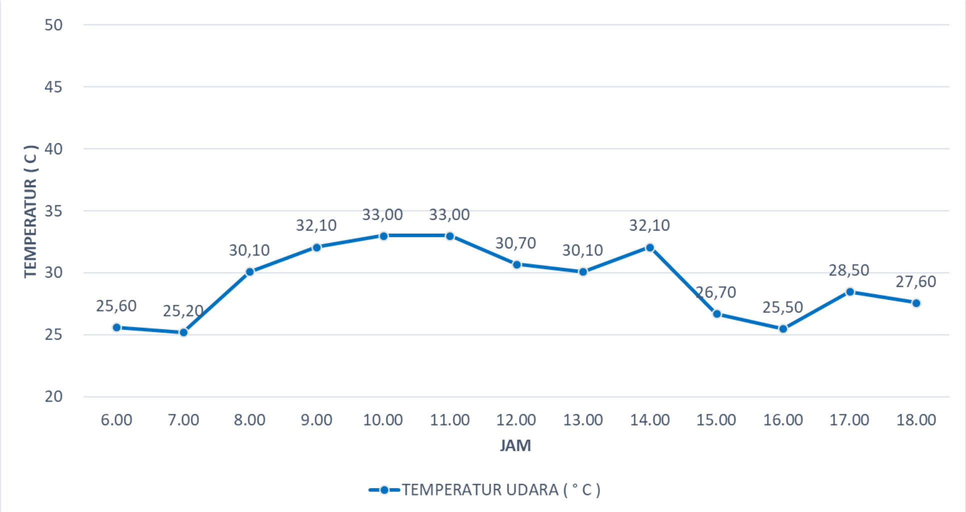

Figure 1. Graph of Daytime Air Temperature Measurement Results

This graph shows the change in air temperature over time, with the x-axis representing time and the y-axis representing temperature.
This makes it easy to monitor temperature patterns and identify daily or seasonal changes.

The results of the nighttime air temperature measurements are also presented in the graph to show the correlation between road surface and pavement temperatures. The data from 06:00 to 18:00 shows that the air temperature is higher during the day and lower at night, with the lowest temperature of 25.90°C at 01:00 am and the highest temperature of 27.80°C at 21:00 pm. These changes may be influenced by daylight and nighttime cooling.

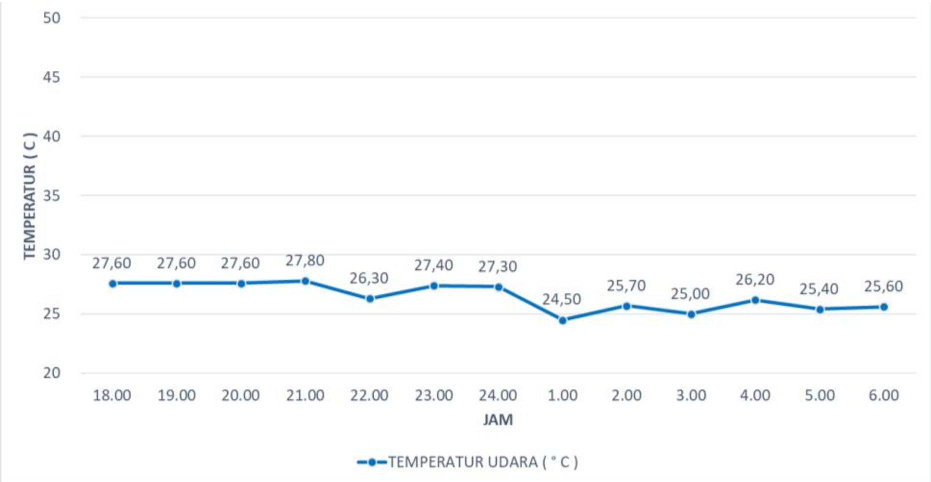

Figure 2. Graph of Nighttime Air Temperature Measurement Results

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This graph shows the change in air temperature over time, with the x-axis representing time and the y-axis the temperature value.
It visualises air temperature patterns, helping to identify daily or seasonal trends.

Surface Temperature Measurement Results

Road surface temperature measurements show the temperature of the top layer of the road and are important for understanding how roads respond to changes in ambient temperature. These temperature variations are influenced by sunlight, weather and traffic activity, and have an impact on road comfort, safety and maintenance.

Road surface temperature measurements were taken every hour from 6am to 6pm using an MPU 6050 accelerometer sensor. The data showed the lowest temperature at 06:00 (25.90°C) and the highest at 14:00 (40.61°C), before decreasing due to rain. Air temperature graphs reveal daily fluctuations with higher temperatures during the day and lower at night, and identify temperature patterns that influence other variables in the study.

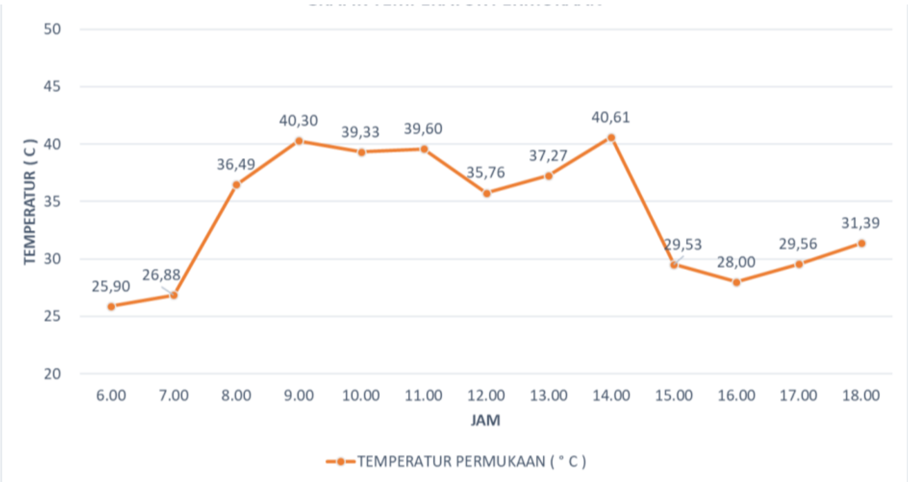

Figure 3. Graph of Daytime Surface Temperature Measurement Results

Nighttime surface temperature measurements using the MPU 6050 accelerometer sensor were taken every hour from 06.00 to 18.00 WIB. The data shows the highest temperature at 18.00 (31.39°C) and the lowest at 01.00 (25.27°C). The decrease in nighttime temperature is due to natural cooling after sunset.

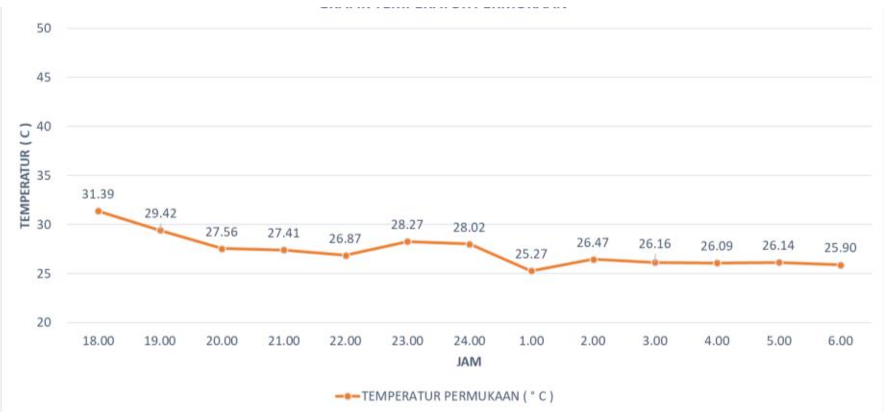

Figure 4. Graph of Nighttime Surface Temperature Measurement Results

The graph shows the decrease in air temperature throughout the night with time on the x-axis and temperature on the y-axis.
This pattern reflects natural nighttime cooling, as the Earth loses heat absorbed during the day.

Pavement Temperature Measurement Results
Pavement temperature measurements aim to understand the thermal characteristics of pavement materials. Temperature data was collected hourly for 24 hours to evaluate the impact of temperature on the strength, wear, and service life of the pavement. Analysing this data helps understand how temperature changes affect road performance.

The pavement temperature measurements, taken hourly from 06:00 to 18:00, showed temperature variations influenced by air temperature, sun exposure and traffic activity. Pavement temperatures tended to be high during the day when sunlight was maximum and dropped at night. The lowest temperature was recorded at 07:00 am (25.90°C), while the highest temperature reached 47.30°C at 09:00 am and 14:00 pm.

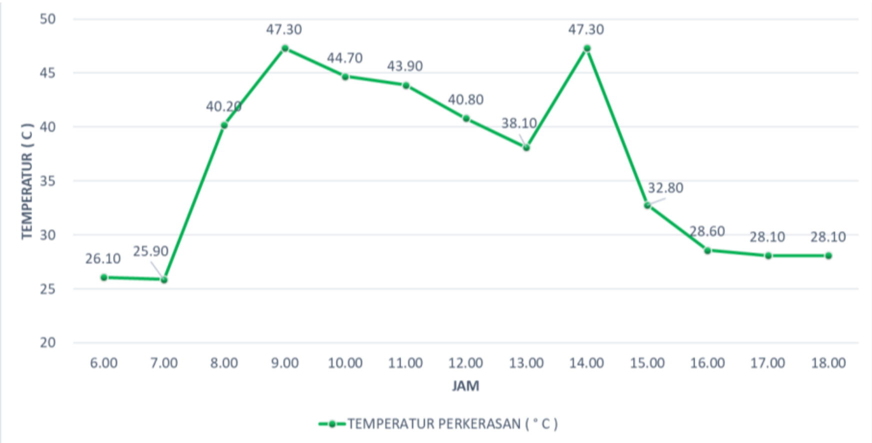

Figure 5. Graph of Daytime Pavement Temperature Measurement Results

This graph shows the variation of pavement temperature with x-axis for time and y-axis for temperature. Pavement temperature follows the pattern of air and surface temperature, peaking during the day and decreasing at night. Pavement temperature variations are influenced by traffic intensity, road geometry and pavement material type.

Nighttime pavement temperature data shows temperature variations influenced by air temperature, humidity, and environmental conditions. Measurements using the MPU 6050 accelerometer sensor were taken every hour from 06.00 to 18.00 WIB. The lowest temperature was recorded at 01.00 am (25.40°C) and the highest temperature at 18.00 pm (28.10°C).

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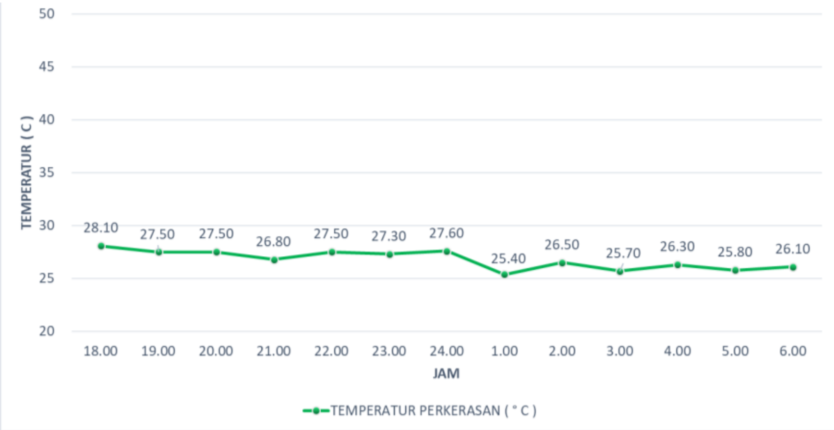

Figure 6. Graph of Nighttime Surface Temperature Measurement Results

The graph shows a decrease in air temperature throughout the night, reaching its lowest point in the late night or early morning. This pattern reflects the natural cooling at night, when the Earth loses heat absorbed from sunlight.

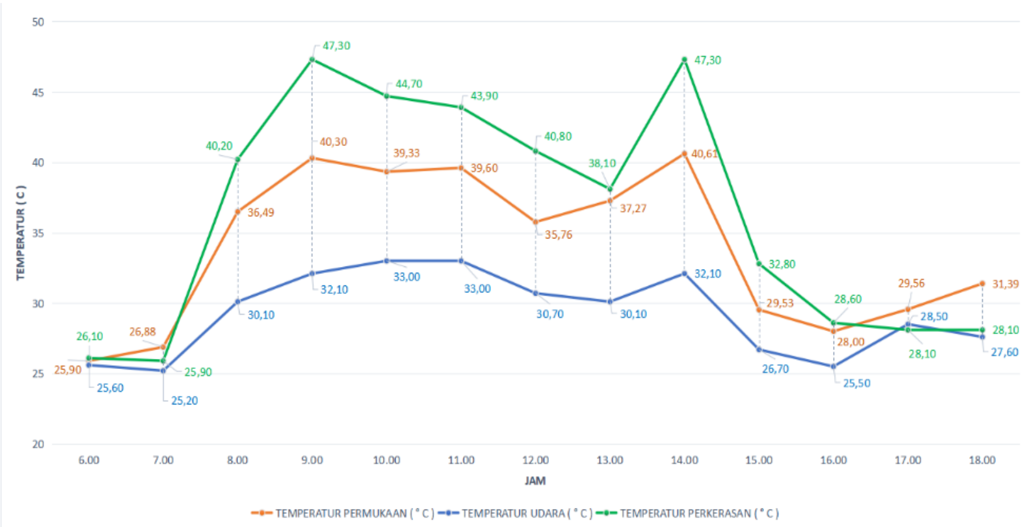

Figure 7. Graph of Temperature Data at Noon

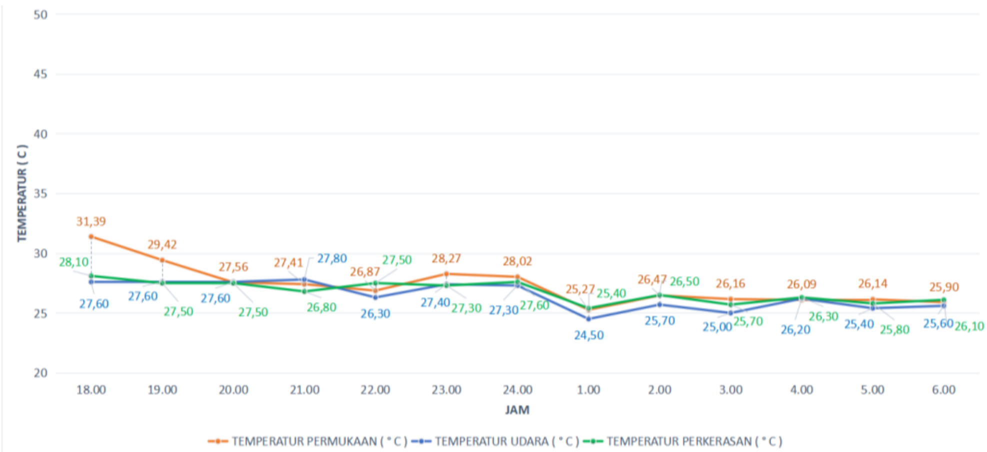

Figure 8. Graph of Temperature Data at Night

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Results of Correlation Analysis of Air and Surface Temperatures

The correlation analysis results show a strong positive relationship between air temperature and road surface temperature, with a correlation coefficient value of 0.966 at a significance level of $p<0.01$. This means that an increase in air temperature tends to be followed by an increase in road surface temperature. The correlation graph supports this finding with the points following an upward trend line. Air temperature is the main factor affecting road surface temperature, along with other factors such as solar radiation and traffic intensity.

The correlation graph visualises the relationship between road surface temperature and pavement temperature, with the x-axis for road surface temperature and the y-axis for pavement temperature. The analysis results show a strong positive correlation, with a Pearson coefficient close to 1, indicating that an increase in road surface temperature is followed by an increase in pavement temperature, and vice versa.

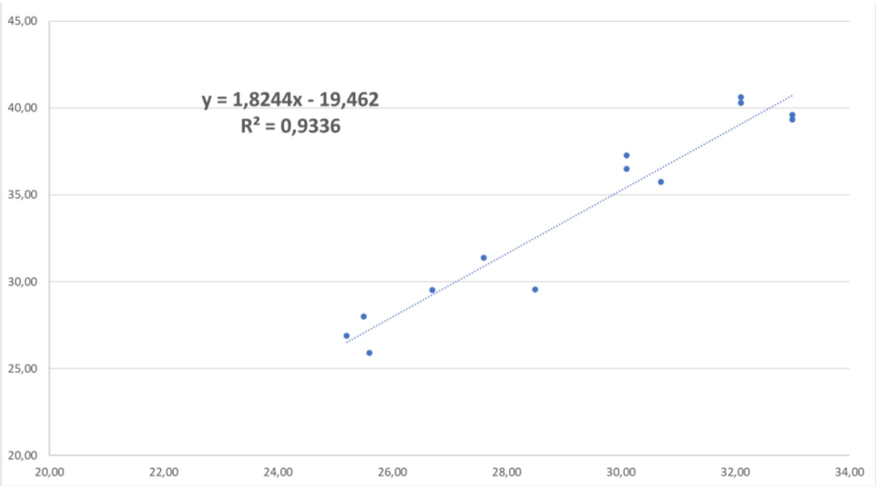

Figure 10. Equation Graph of Daytime Air and Pavement Surface Temperatures

The correlation result of temperature at night shows a correlation coefficient of 0.784 with a significance of $p<0.01$, indicating a strong positive relationship between road surface temperature and pavement temperature. The graph shows that as the road surface temperature increases, the pavement temperature also tends to increase, and vice versa.

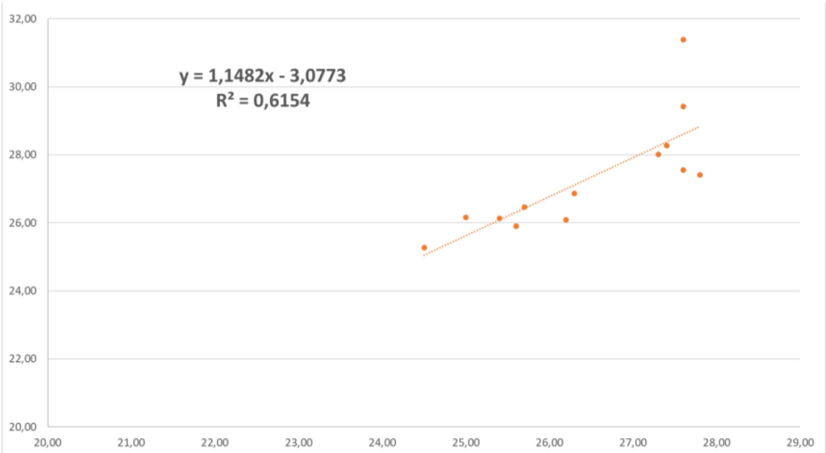

Figure 11. Equation Graph of Nighttime Air and Pavement Surface Temperatures

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Correlation Results of Road Surface and Pavement Temperatures

The daytime correlation results show a coefficient of 0.967, indicating a very strong positive relationship between road surface temperature and pavement temperature. The graph shows that as the road surface temperature increases, the pavement temperature also increases, with the trend line indicating the strength of the relationship.

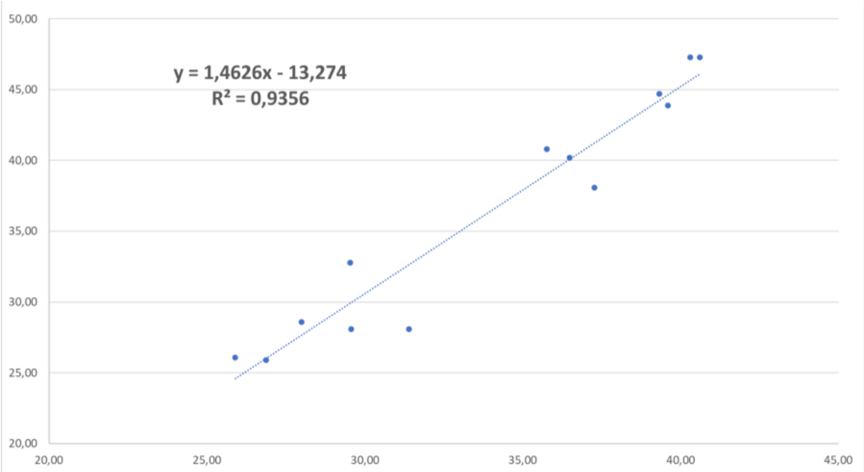

Figure 12. Equation Graph of Daytime Surface and Pavement Temperatures

The nighttime correlation results show a coefficient of 0.967, indicating a very strong positive relationship between road surface temperature and pavement temperature. The graph shows that the road surface temperature and pavement temperature increase over time, with the trend line clarifying the strength of the relationship between the two variables.

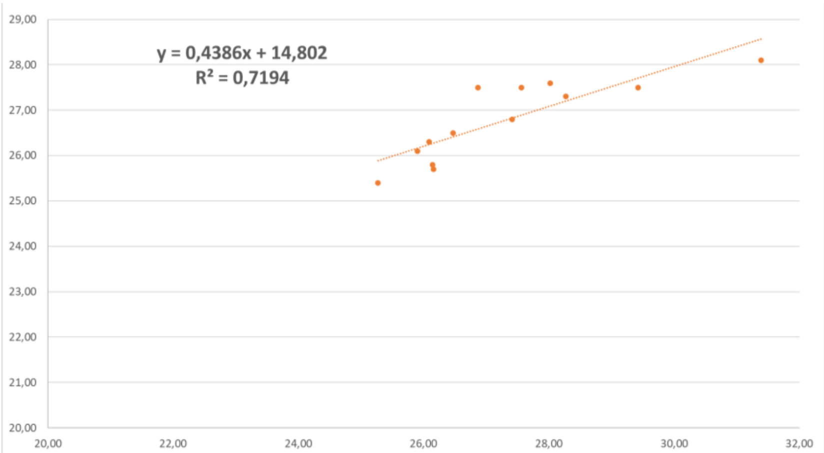

Figure 13. Equation Graph of Surface Temperature and Pavement at Night

Correlation Results of Air and Pavement Temperatures

The daytime correlation results show a coefficient of 0.935, indicating a very strong positive relationship between road surface temperature and pavement temperature. This value is close to 1, indicating that the surface temperature and pavement temperature increase simultaneously.

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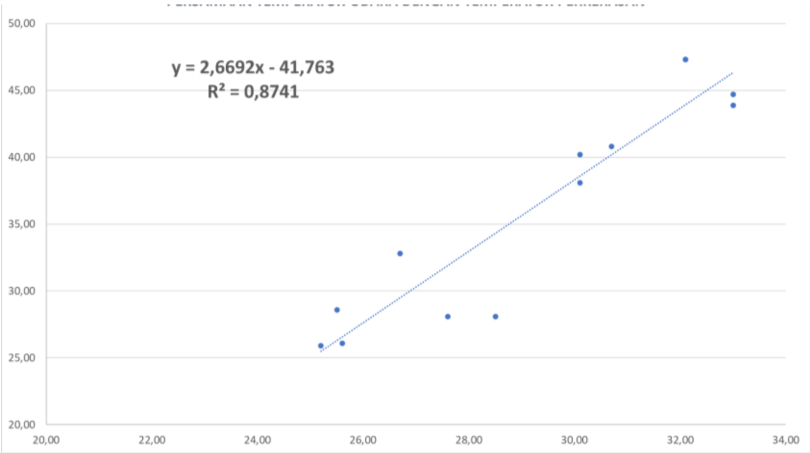

Figure 14: Equation Graph of Daytime Air and Pavement Temperatures

The nighttime correlation results show a coefficient of 0.877, indicating a strong positive relationship between road surface temperature and pavement temperature. This value is close to 1, indicating that surface temperature and pavement temperature tend to increase together.

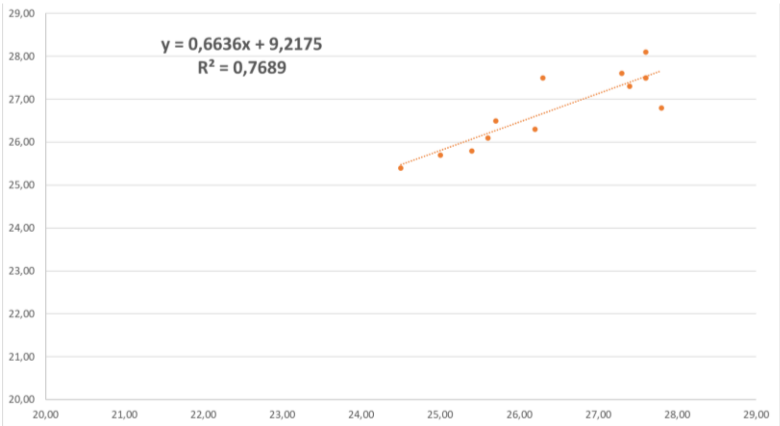

Figure 15. Equation Graph of Air Temperature and Nighttime Pavement Pavement

Coefficient of Variation Results

The coefficient of variation (CV) measures temperature fluctuations compared to the average temperature. High values indicate large fluctuations, while low values indicate small fluctuations. The results of the air, pavement, and surface temperature measurements are summarised in Table 4.17, which presents the mean and standard deviation for calculating the CV.

The Coefficient of Variation (CV) for air temperature is 9.50%, indicating small and stable fluctuations. The surface temperature has a CV of 17.34%, indicating moderate fluctuations. Pavement temperature had a CV of 24.20%, indicating large fluctuations that could be affected by changes in weather, clouds, or human activity.

This study aims to explore the relationship between air temperature, road surface temperature, and pavement temperature using the MPU 6050 accelerometer sensor. The analysis results provide a comprehensive picture of temperature variations at various time conditions and the influence of environmental factors on road surface and pavement temperatures.

The analysis showed a significant positive correlation between air temperature and road surface temperature, with the correlation coefficient reaching 0.967 during the day and 0.784 at night. This indicates that the road surface temperature tends to increase as the air temperature increases, and vice versa. This strong correlation underscores the importance of air temperature as a major factor affecting road surface temperature, in addition to solar radiation and weather conditions.

The correlation coefficient between air temperature and pavement temperature also shows a strong positive relationship, with values close to 0.934 during the day and 0.877 at night.This indicates that pavement temperature follows the pattern of air temperature, with pavement temperature increasing when air temperature rises and decreasing when air temperature falls. This correlation indicates that air temperature plays a significant role in influencing pavement temperature.

The correlation between road surface temperature and pavement temperature also shows a strong positive relationship, with the correlation coefficient reaching 0.967 during the day and 0.876 at night.This indicates that road surface temperature and pavement temperature move in tandem, with temperature fluctuations in both influenced by the same factors, such as sun exposure and ambient environmental conditions.

The coefficient of variation shows that the air temperature has small fluctuations (9.50%), indicating the stability of the air temperature during the measurement period. In contrast, road surface temperature and pavement temperature have higher coefficients of variation, 17.34% and 24.20% respectively, indicating more significant temperature fluctuations. The higher temperature fluctuations of the road surface and pavement may be influenced by factors such as weather changes, sunlight intensity, and traffic activity.

These findings have important implications for road infrastructure planning and maintenance.Understanding the relationship between air temperature, road surface temperature and pavement temperature can help in designing pavement materials that are more resistant to temperature fluctuations and extreme environmental conditions.In addition, this information can be used to design more effective drainage and protection systems to minimise the impact of extreme temperatures on road infrastructure.

Overall, this study showed a strong and significant relationship between air temperature, road surface and pavement temperature, with consistent results across different measurement times.High temperature fluctuations in road surface and pavement temperatures emphasise the need for special attention to environmental factors that influence these temperatures.

CONCLUSION

This study shows a very strong relationship between air temperature and road surface temperature, with a correlation coefficient of 0.9663 during the daytime.Road surface temperature also has a very strong relationship with pavement temperature, with a correlation coefficient of 0.9673 during the daytime.The regression equation shows that changes in air temperature significantly affect road surface temperature, and road surface temperature directly affects pavement temperature. These findings confirm the importance of considering temperature fluctuations in road design and maintenance.Therefore, it is recommended that road planners use this information to design better materials and maintenance strategies to improve the durability and performance of road infrastructure.

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