

The Effect of Rainfall, Humidity, and Temperature on Changes in the Surface Distress Index (SDI) on the Road Network in Gunungpati

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ABSTRACT

Roads are a vital infrastructure that connect people and places. Road resilience is non-negotiable. Many factors that affect roads' resilience are traffic loadings, traffic volume, quality, maintenance, and climate. This research aimed to investigate changes in the Surface Distress Index (SDI) from 2022 to 2024, as well as the effects of rainfall, humidity, and temperature on road damage in the Gunungpati, Semarang Barat, and Semarang Utara Districts in Semarang, Jawa Tengah. SDI is a tool for evaluating road surface conditions based on visual inspection. The SDI method has been used by Dinas Bina Marga Semarang, a road administration agency, as an evaluation tool since 2020. Aside from SDI data obtained from Dinas Bina Marga Semarang, this study also collected climate data from the Badan Meteorologi, Klimatologi dan Geofisika (BMKG) of the province of Jawa Tengah. The climate data were rainfall intensity, average temperature, and humidity. This study used regression analysis to process the data. In this study, road surface conditions are crack area, crack width, number of holes, and ruts. Regression analysis was used to investigate the effect of climate on each road surface condition. The SDI value change analysis showed no linear correlation between SDI value change and climate, indicating that other factors, such as pavement structure, traffic volume, or maintenance, also affect road surface condition. The regression analyses of the influence of climate on road surface distress showed R-squares ranging from 0.3536 to 0.677, indicating that other factors, such as traffic volume, maintenance, or road structure, explain the variation in the distress SDI.

Keywords: climate, SDI, road, surface, influence.

INTRODUCTION

As a vital infrastructure, roads have to always be in good condition, moreover, in terms of user safety. Dinas Bina Marga Kota Semarang has been using the Surface Distress Index (SDI) method to evaluate the condition of the Semarang road network since 2020 [1] [2] SDI evaluates road performance by the road crack area and width, potholes, and rutting depth. Factors affecting road performance are traffic volume, road quality, maintenance, and climate. [3], [4], [5][6][7]. This study aimed to examine changes in SDI and the influence of climate on road surface condition in the Gunungpati, Semarang Barat, and Semarang Utara Districts in Semarang.

The location of the climate stations was the reason these districts were chosen for the study. There are three climate stations in Semarang: Stasiun Klimatologi Jawa Tengah, located in Semarang Barat District; Stasiun Meteorologi Maritim Jawa Tengah, located in Semarang Utara District; and a rainfall observation station in Sumur Jurang, Gunungpati District.

[8]used ABAQUS software to model the response of the asphalt pavement structure to high temperatures in the summer. A propagation model was used to investigate the effects of temperature changes and humidity on rutting form. The result indicated that temperature accumulation increased pavement temperatures in the middle and lower layers by up to 10°C, leading to rutting. [9] did research on a modified asphalt called SBS asphalt, which adds Styrene-Butadiene-Styrene, a synthetic rubber polymer. The research aimed to assess the effects of temperature and humidity on the psychochemical properties of asphalt bonds. The result shows that a temperature increase

accelerates particle movement within the system. The increase in humidity also causes hydrogen bonding between the asphalt and water molecules, thereby increasing the oxygen concentration. The study was also conducted on an asphalt without SBS addition; the results show that the performance of an asphalt with SBS addition decreases with increasing humidity.

[10] did a study to investigate the effect of groundwater on road damage using SDI. The study was done using a geo-electric device on Jl. Keputih, Surabaya, a location containing groundwater, marked by surface cracks, rutting, and potholes. The result is the presence of water below the surface, which influences cracks in the road surface. The lowest resistivity value is $<6 \Omega\text{m}$ at a depth of 2-5 m, while at a depth of 0-2 m, the condition resistivity varies between $6 \Omega\text{m}$ and $18 \Omega\text{m}$. [11], studied asphalt pavement behaviour with different aggregate types, HMA (hot-mix asphalt) gradation, different temperatures, and the immersion time under extreme climate, using Indirect Tensile Test (ID) and Unconfined Compression Test (UC). The temperature conditioning ID test shows that HMA specimens with granite aggregates are more temperature-sensitive than those with marble or limestone aggregates. This study shows that temperature affects pavement material. Moreover, the study found that at 60°C (a standard temperature in tropical countries like Vietnam), HMA strength continues to decrease significantly. It is recommended to revise the temperature standard in the asphalt pavement design to allow the pavement to adapt to future non-stationary climate conditions. [12] investigated the mechanical behaviour of a granular pavement under environmental and humidity influences. Data was obtained from the Sunshine Coast, Australia. Observation was conducted for 3 years, analysing temperature variation, humidity, and strain values. The results indicate that as moisture increases and temperature decreases, the critical fatigue strain increases above the fatigue endurance limit. This occurs when the moisture is at or above the optimum moisture content, and the surface layer temperature is between 38°C and 31°C . The data indicated that changes in pore pressure resulting from moisture and temperature variations within the granular basecourse soil were causing pavement strains.

The Surface Distress Index (SDI) method is used to evaluate the surface condition of flexible road pavements and support decisions regarding road maintenance and rehabilitation. The assessment is based on visual surveys of pavement distress, including cracks, crack width, potholes, and surface deformation, with measurements recorded along defined road segments. SDI values are calculated using established assessment criteria, with higher scores generally indicating poorer pavement conditions. The results help determine appropriate treatments, such as routine maintenance, periodic maintenance, or rehabilitation, according to the applicable Indonesian road assessment guidelines [18].

The Pavement Condition Index (PCI) method also evaluates pavement condition through visual inspection but uses a more detailed procedure. It identifies distress types, severity levels, and quantities, then applies deduct values and a corrected deduct value to produce a score ranging from 0 to 100. In contrast, SDI is simpler and faster, making it suitable for screening extensive road networks and prioritizing routine maintenance. Typical SDI classifications are: below 50 (good), 50–100 (moderate), 100–150 (minor damage), and above 150 (severe damage). PCI provides a more comprehensive diagnosis for selecting specific rehabilitation treatments [19].

RESEARCH METHODS

Materials

The study used secondary SDI data obtained from Dinas Bina Marga Kota Semarang, as well as climate data from Badan Meteorologi Klimatologi dan Geofisika (BMKG) Propinsi Jawa Tengah. The SDI data were the SDI value data from 2022 to 2024 in three districts in Semarang, namely Gunungpati, Semarang Barat, and Semarang Utara. The climate data obtained from the BMKG website were rainfall intensity, average humidity, and temperature. Not all road sections from each district were analysed. The analyses were conducted on road sections with SDI and distress values. Seventeen road sections were examined in Gunungpati District, 14 in Semarang Barat District, and 2 in Semarang Utara District, with a total length of 48.98 km. Climate data were rainfall intensity, average humidity, and temperature.

Pavement type was not explicitly differentiated at the segment level, as individual road sections may consist of a mix of flexible and rigid pavements, requiring extensive manual segmentation across many road sections. Based on visual assessment and available records, the road network is predominantly composed of flexible pavement. Therefore, the analysis primarily reflects the response of asphalt-dominated urban roads to climatic factors.

This study used the average annual humidity, temperature, and total rainfall in the three districts in 2022, 2023, and 2024, as follows:

Table 1. Climate Data in 2022, 2023, and 2024.

District	Year	Total Rain (mm)	Avg. Tem. (°C)	Avg. Humid. (%)	Key
Semarang Barat	2022	2549.91	28.02	81.15	Semarang Barat 2022
	2023	1769.61	28.87	75.25	Semarang Barat 2023
	2024	2591.01	29.26	75.21	Semarang Barat 2024
Gunungpati	2022	2293.93	28.05	79.90	Gunungpati 2022
	2023	2237.30	28.81	74.21	Gunungpati 2023
	2024	2368.67	29.23	74.32	Gunungpati 2024
Semarang Utara	2022	2607.71	28.14	78.58	Semarang Utara 2022
	2023	1804.39	28.70	73.30	Semarang Utara 2023
	2024	2600.55	29.20	73.43	Semarang Utara 2024

Source: Badan Meteorologi, Klimatologi dan Kegempaan (2025).

Methods

The study followed a flowchart below:

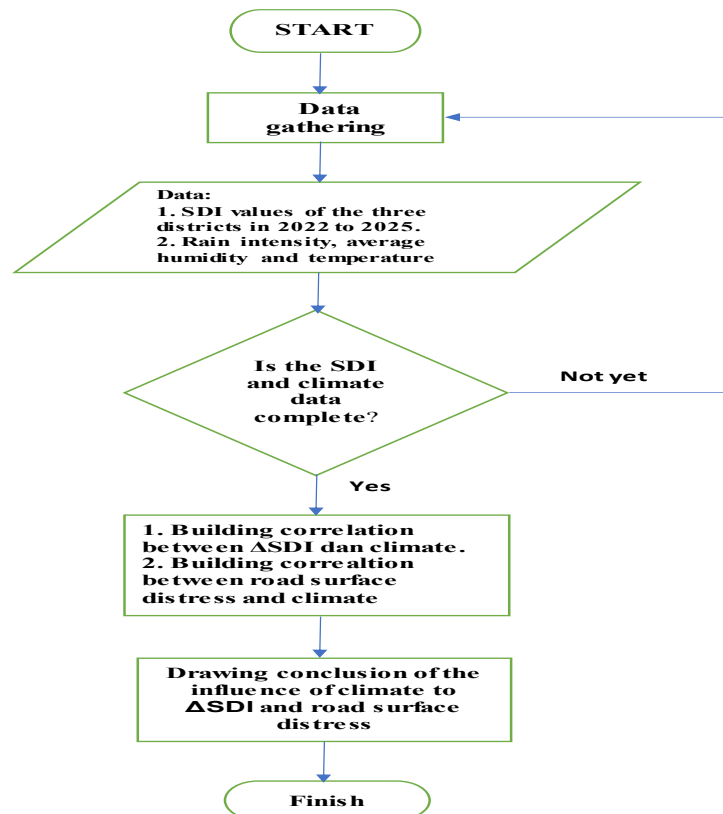


Figure 1. Study Flowchart

The study began with the observation of damaged roads within the city of Semarang's road network. Rainfall intensity, humidity, and temperature were our first concerns because, as rainfall intensity increases, so does road surface deterioration. According to

Data Analysis

Once all the SDI data were collected, the next step was to refine the road sections in each district with SDI values from 2022 to 2024. Microsoft Excel was used to record and identify SDI variations from 2022 to 2023 and from 2023 to 2024. Positive variation in SDI value means a road section degrades, while a negative or decreasing SDI value means a road section improves. SDI variation followed this formula:

$$\Delta \text{SDI}_{22-23} = \text{SDI}_{2023} - \text{SDI}_{2022} \quad (1)$$

$$\Delta \text{SDI}_{23-24} = \text{SDI}_{2024} - \text{SDI}_{2023} \quad (2)$$

The total calculated SDI was then averaged for each district for 2023 and 2024. As the SDI variation for each district in 2023 and 2024 was calculated, this variation was compared to the annual climate data, i.e., rainfall intensity, average humidity, and temperature:

Table 2. SDI Change and Climate Data in 2023 and 2024.

District	Year	Avg_ΔSDI	TotalRain_mm	AvgTemp_C	AvgRH_pct	Trend
Gunungpati	2023	-15.91	2237.3	28.80798033	74.21234608	Worse
Gunungpati	2024	3.4	2368.67	29.22964417	74.31904583	
Semarang Barat	2023	10.68	1769.61	28.87228815	75.2453533	Better
Semarang Barat	2024	-4.52	2591.01	29.26325022	75.20671425	
Semarang Utara	2023	-20	1804.39	28.69636395	73.29886958	Better
Semarang Utara	2024	-13	2600.55	29.19603819	73.43137746	

Source: Dinas Bina Marga Kota Semarang & Badan Meteorologi, Klimatologi, dan Geofisika Prop. Jawa Tengah.

The next step was to build a regression analysis of SDI surface distress versus annual climate data. Before we did the regression analysis, SDI variations in surface distress, i.e., crack width (RLe), crack area (RL), potholes (JL), and ruts (BR) in 2023 and 2024 were calculated following the same formula as the SDI variation. For example:

Crack width (RLe) variation:

$$\Delta \text{RLe}_{22-23} = \text{RLe}_{2023} - \text{RLe}_{2022} \quad (3)$$

$$\Delta \text{RLe}_{23-24} = \text{RLe}_{2024} - \text{RLe}_{2023} \quad (4)$$

The table below shows the results of the regression analysis of each surface distress variation in 2023 and 2024 versus climate data:

1. The influence of climate on crack area (RL) distress:
 - a. The regression analysis result on crack area (RL) distress versus climate in 2023:

Table 3. Regression Analysis Results For Crack Area versus Climate in 2023

- a. Regression Statistics of Crack Area versus Climate in 2023

Regression Statistics	
Multiple R	0.823362184
R Square	0.677925286
Adjusted R Squ	0.597406607
Standard Error	1.165475582
Observations	16

- b. ANOVA Table of Crack Area versus Climate in 2023

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	34.309375	11.43646	8.419479	0.002784107
Residual	12	16.3	1.358333		
Total	15	50.609375			

c. Coefficients and P-value of Crack Area versus Climate in 2023

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-4.26326E-14	3.906381573	-1.1E-14	1	-8.511274289	8.511274	-8.511274289	8.511274289
Rain_w	-0.06096	0.014381836	-4.23868	0.00115	-0.092295329	-0.02962	-0.092295329	-0.029624671
Temp_w	-20.40336729	12.50340835	-1.63182	0.128664	-47.64595382	6.839219	-47.64595382	6.83921925
RH_w	9.48852379	4.939419019	1.92098	0.078806	-1.273545739	20.25059	-1.273545739	20.25059332

An R-Square value of 0.598 indicates that 59.8% of the variability in SDI area cracking (RL) is explained by the model's climatic variables: rainfall intensity, average humidity, and average air temperature.

In 2023, rainfall intensity emerges as the most statistically influential climatic factor affecting SDI area cracking (p -value = 0.0011), and exhibiting a negative relationship (Coeff. = -0.06). In contrast, neither average humidity nor air temperature shows a statistically significant effect.

b. The regression analysis result on crack area (RL) distress versus climate in 2024:

Table 4. Regression Analysis Results for Crack Area versus Climate in 2024.

a. Regression Statistics of Crack Area versus Climate in 2024

<i>Regression Statistics</i>	
Multiple R	0.74162
R Square	0.55
Adjusted R Square	0.4375
Standard Error	0.774597
Observations	16

b. ANOVA Table of Crack Area versus Climate in 2024

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	8.8	2.933333	4.888889	0.019067378
Residual	12	7.2	0.6		
Total	15	16			

c. Coefficients and P-Values of Crack Area versus Climate in 2024.

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	2.8422E-14	2.596253582	1.09E-14	1	-5.656750613	5.656750613	-5.656750613	5.656750613
Rain_w	-0.0352252	0.018680995	-1.88562	0.083781	-0.075927617	0.005477166	-0.07592762	0.005477166
Temp_w	29.0466052	7.793908401	3.726834	0.002891	12.06513763	46.02807286	12.06513763	46.02807286
RH_w	-10.30133	3.045681483	-3.38227	0.005445	-16.93729969	-3.66535991	-16.9372997	-3.665359912

An R-Square value of 0.55 indicates that 55% of the variability in SDI area cracking (RL) is explained by the model's climatic variables: rainfall intensity, average humidity, and average air temperature.

In 2024, the average temperature is the most statistically influential climatic factor affecting SDI area cracking (p-value = 0.002), exhibiting a positive relationship (Coeff. = 29.04). In contrast, average humidity and rainfall intensity do not show statistically significant effects.

2. The influence of climate on crack width (RLe) distress:

a. The regression analysis result on crack width (RLe) distress versus climate in 2023:

Table 5. Regression Analysis Results For Crack Width versus Climate in 2023

a. Regression Statistics of Crack Width Versus Climate in 2023.

Regression Statistics	
Multiple R	0.77372092
R Square	0.59864407
Adjusted R Square	0.49830508
Standard Error	3.14112506
Observations	16

b. ANOVA Table of Crack Width Versus Climate in 2023.

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	176.6	58.86667	5.966216	0.009921577
Residual	12	118.4	9.866667		
Total	15	295			

c. Coefficients and P-Values of Crack Width Versus Climate in 2023.

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-1.54810653	10.52826267	-0.14704	0.88554	-24.48722031	21.391007	-24.4872203	21.39100725
Rain_w	-0.13138311	0.038761125	-3.38956	0.005372	-0.215836348	-0.04693	-0.21583635	-0.046929873
Temp_w	-56.0127413	33.6984918	-1.66217	0.122357	-129.4354476	17.409965	-129.435448	17.40996496
RH_w	25.3197554	13.31244782	1.901961	0.081447	-3.68557674	54.325087	-3.68557674	54.32508748

An R-Square value of 0.598 indicates that 59.8% of the variability in SDI wide cracking (RLe) is explained by the climatic variables included in the model: rainfall intensity, average humidity, and average air temperature.

In 2023, rainfall intensity emerges as the most statistically significant climatic factor affecting SDI-wide cracking (p-value = 0.005), with a negative relationship (Coeff. = -0.131). In contrast, neither average humidity nor air temperature shows a statistically significant effect.

b. The regression analysis result on crack width (RLe) distress versus climate in 2024:

Table 6. Regression Analysis Results For Crack Width versus Climate in 2024

a. Regression Statistics of Crack Width versus Climate in 2024

Regression Statistics	
Multiple R	0.59484969
R Square	0.353846154
Adjusted R Square	0.192307692
Standard Error	2.366431913
Observations	16

b. ANOVA Table for Crack Width versus Climate in 2024

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	36.8	12.26667	2.190476	0.142038827
Residual	12	67.2	5.6		
Total	15	104			

c. Coefficients and P-Values of Crack Width Versus Climate in 2024

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-1.54810653	7.931685708	-0.19518	0.848518	-18.82976511	15.733552	-18.8297651	15.73355205
Rain_w	-0.09686937	0.057071382	-1.69734	0.115393	-0.221217226	0.02747849	-0.22121723	0.027478494
Temp_w	55.26014635	23.81078347	2.320803	0.038711	3.380905835	107.139387	3.380905835	107.1393869
RH_w	-18.3842752	9.304710626	-1.9758	0.071627	-38.65749805	1.88894773	-38.6574981	1.888947726

An R-Square value of 0.3538 indicates that 35.38% of the variability in SDI wide cracking (RLe) can be explained by the climatic variables included in the model: rainfall intensity, average humidity, and average air temperature.

In 2024, the average temperature emerged as the most statistically significant climatic factor affecting SDI-wide cracking (p-value = 0.038), with a positive relationship (Coeff. = 55.26). In contrast, average humidity and rainfall intensity do not show statistically significant effects.

3. The influence of climate on pothole (JL) distress:

a. The regression analysis result on pothole (JL) distress versus climate in 2023:

Table 7. Regression Analysis Results For Pothole versus Climate in 2023

a. Regression Statistics of Pothole versus Climate in 2023

<i>Regression Statistics</i>	
Multiple R	0.602527873
R Square	0.363039838
Adjusted R Square	0.203799798
Standard Error	2.601081506
Observations	16

b. ANOVA Table for Pothole versus Climate in 2023

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	46.27337566	15.42446	2.279828	0.13151144
Residual	12	81.1875	6.765625		
Total	15	127.4608757			

c. Coefficients and P-Values for Pothole versus Climate in 2023

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	2.128646482	8.718172236	0.244162	0.81123	-16.86661904	21.123912	-16.86661904	21.123912
Rain_w	-0.06859421	0.03209705	-2.13709	0.05387	-0.138527671	0.0013393	-0.138527671	0.001339256
Temp_w	-27.2058284	27.90481819	-0.97495	0.348829	-88.00520424	33.593548	-88.00520424	33.59354751
RH_w	12.02191242	11.02368136	1.090553	0.296884	-11.99662597	36.040451	-11.99662597	36.0404508

An R-Square value of 0.363 indicates that 36.3% of the variability in SDI potholes (JL) is explained by the model's climatic variables: rainfall intensity, average humidity, and average air temperature.

In 2023, rainfall intensity was the most statistically significant climatic factor affecting SDI-wide cracking (p-value = 0.0538), with a positive relationship (Coeff. = -0.06). On the other hand, neither average humidity nor temperature shows a statistically significant effect.

- b. The regression analysis result on potholes (JL) distress versus climate in 2024:

Table 8. Regression Analysis Results For Pothole versus Climate in 2024.

- a. Regression Statistics of Pothole versus Climate in 2024

<i>Regression Statistics</i>	
Multiple R	0.68238008
R Square	0.46564258
Adjusted R Square	0.33205322
Standard Error	2.36048194
Observations	16

- b. ANOVA Table for Pothole versus Climate in 2024

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	58.26442321	19.42147	3.485626	0.05017398
Residual	12	66.8625	5.571875		
Total	15	125.1269232			

- c. Coefficients and P-Values for Pothole versus Climate in 2024

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	2.12864648	7.911742899	0.269049	0.792462	-15.10956045	19.36685342	-15.10956045	19.36685342
Rain_w	-0.06274494	0.056927887	-1.10218	0.291997	-0.186780145	0.061290274	-0.186780145	0.061290274
Temp_w	76.6932757	23.7509155	3.229066	0.007232	24.94447628	128.4420751	24.94447628	128.4420751
RH_w	-28.5879824	9.281315591	-3.08016	0.009535	-48.81023193	-8.36573296	-48.81023193	-8.36573296

An R-Square value of 0.4656 indicates that 46.56% of the variability in SDI potholes (JL) can be explained by the climatic variables included in the model: rainfall intensity, average humidity, and average air temperature.

In 2024, average temperature emerged as the most statistically influential climatic factor affecting SDI potholes (p-value = 0.00723), exhibiting a positive relationship (Coeff. = 76.69). In contrast, average humidity and rainfall intensity do not show statistically significant effects.

4. The influence of climate on ruts (BR) distress:

- a. The regression analysis result on ruts (BR) distress versus climate in 2023:

Table 9. Regression Analysis Results For Ruts versus Climate in 2023

- a. Regression Statistics of Ruts versus Climate in 2023

<i>Regression Statistics</i>	
Multiple R	0.603343
R Square	0.364022
Adjusted R Square	0.205028
Standard Error	2.659123
Observations	16

- b. ANOVA Table for Ruts versus Climate in 2023

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	48.56735	16.18912	2.28953	0.130422694
Residual	12	84.85123	7.070936		
Total	15	133.4186			

c. Coefficients and P-Values for Ruts versus Climate in 2023

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	2.380213793	8.912713198	0.267058	0.793959	-17.03892007	21.7993477	-17.0389201	21.79934766
Rain_w	-0.068266284	0.032813277	-2.08045	0.059576	-0.139760272	0.0032277	-0.13976027	0.003227704
Temp_w	-30.49297201	28.52749803	-1.0689	0.306147	-92.64905073	31.6631067	-92.6490507	31.6631067
RH_w	13.2752973	11.26966843	1.177967	0.261643	-11.27920085	37.8297955	-11.2792009	37.82979545

An R-Square value of 0.364 indicates that 36.4% of the variability in SDI in rutting (BR) is explained by the climatic variables included in the model: rainfall intensity, average humidity, and average air temperature.

In 2023, rainfall intensity emerged as the most statistically influential climatic factor affecting SDI in rutting (p-value = 0.0595), exhibiting a negative relationship (coefficient = -0.068). By contrast, average humidity and rainfall intensity do not show statistically significant effects.

b. The regression analysis result on ruts (BR) distress versus climate in 2024:

Table 10. Regression Analysis Results For Ruts versus Climate in 2024.

a. Regression Statistics of Ruts versus Climate in 2024

<i>Regression Statistics</i>	
Multiple R	0.673739
R Square	0.453924
Adjusted R Square	0.317405
Standard Error	2.421763
Observations	16

b. ANOVA Table for Ruts versus Climate in 2024

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	3	58.50258	19.50086	3.324991	0.056608332
Residual	12	70.37923	5.864936		
Total	15	128.8818			

c. Coefficients and P-Values for Ruts versus Climate in 2024

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	2.380213793	8.117141486	0.293233	0.774353	-15.30551822	20.0659458	-15.30551822	20.0659458
Rain_w	-0.05660254	0.058405805	-0.96913	0.351611	-0.183857854	0.07065278	-0.183857854	0.070652779
Temp_w	76.94396561	24.36751851	3.157645	0.008257	23.85170365	130.036228	23.85170365	130.0362276
RH_w	-28.930594	9.522269971	-3.0382	0.010308	-49.67783798	-8.18335	-49.67783798	-8.18335002

An R-Square value of 0.4539 indicates that 45.39% of the variability in SDI in rutting (BR) can be explained by the climatic variables included in the model: rainfall intensity, average humidity, and average air temperature.

In 2024, average temperature emerged as the most statistically significant climatic factor affecting SDI-wide cracking (p-value = 0.0082), with a positive relationship (Coeff. = 76.94). In contrast, average humidity and rainfall intensity did not show statistically significant effects.

RESULT AND DISCUSSION

Table 1 shows that there is no linear relationship between SDI variations and climate, as seen in the Semarang Barat and Utara Districts. Although rainfall intensity was higher in 2024 than in 2023, the road surface condition improved. A linear relationship between rainfall intensity and SDI variation occurred only in Gunungpati District.

This study focused on climatic variables and did not explicitly account for non-climatic factors, such as traffic volume, maintenance, and road structure; therefore, the unexplained variation in the regression results may reflect their influence.

The regression analysis results on the influence of climate on road surface distress show R-squares of 0.3538 to 0.677, indicating that other factors, such as traffic volume, road structure, and maintenance, can explain the variation in distress SDI beyond climate, as mentioned above.

This study did not account for pavement type, which may introduce uncertainty in interpreting climate effects, particularly for rigid pavements. However, given the dominance of flexible pavement in the study area, the findings remain relevant for understanding climate-related deterioration patterns in urban asphalt road networks.

CONCLUSION

This study demonstrates that climate plays a meaningful role in road surface distress, as indicated in the SDI value, although it does not act as a primary driver of the surface distress. The results suggest that climate acts as an environmental stressor that interacts with existing surface conditions to accelerate surface distress rather than as the main factor causing pavement deterioration. The findings emphasize the importance of accounting for climate-related stress in pavement condition assessments, particularly in urban road networks with flexible pavements. However, the deterioration of road surfaces remains a multi-factor process influenced by both climatic and non-climatic factors.

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