Skid Resistance Performance of Asphalt Pavements: A Study of Temperature and Weather Influence on Traffic Safety Risks

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Abstract. Skid resistance on asphalt surfaces is the most effective means to prevent vehicle skidding and improve traffic safety during driving. The principal problem identified is that, when wet, the tires lose traction on the road surface, heightening the risk of skidding and resulting in several accidents. To explore the effect of temperature and weather on skid resistance and the correlation between skid resistance and the number of accidents. The research was conducted on the Yomani-Guci road section in Tegal Regency, Indonesia, using the T2GO friction tester, and the data were statistically analyzed in RStudio. The research results indicate that weather has a strong negative correlation of -0.40 with skid resistance. The power model was identified as the best model for describing the correlation between the number of accidents and skid resistance values. When the skid resistance value is up to 0.5, the accident frequency remains relatively high, but it begins to decrease significantly once it reaches 1. When compared with the Indonesian technical standard, which sets a minimum threshold of 0.33, these findings indicate that this threshold does not yet fully reflect the actual level of safety under field conditions. The findings have important implications for civil engineering, underlining the need for regular assessment of road functional conditions, particularly in regions with high temperatures and high rainfall, to reduce accidents and improve traffic safety.

1 Introduction

Roads have two types of service, both structural and functional. One of the functional services of a road is the level of skid resistance. Skid resistance refers to the ability of the road surface to provide adequate friction, preventing vehicles from slipping or skidding under both wet and dry conditions, thereby ensuring road user safety. A decline in skid resistance performance on road pavements can lead to traffic accidents [1]. Skid resistance performance is influenced by several factors, including surface characteristics, tire performance, the number of vehicles per day, and environmental factors such as weather and temperature [2].

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Skid resistance on asphalt pavements is affected by surface texture aggregate characteristics, and environmental factors [3]. Among these factors, environmental conditions such as temperature and weather play a significant yet complex role in affecting skid resistance values. Several previous studies have shown that temperature affects road surface friction resistence, with higher temperatures generally resulting in lower friction resistance values [4]. Similar findings indicate that the statistical significance of this relationship remains a subject of debate.

In addition to temperature, the presence of water ponding on the road surface also significantly affects changes in skid resistance in the field. The risk of skidding is high even under very shallow water ponding conditions, a phenomenon known as aquaplaning [5]. This condition indicates that the interaction between weather factors and road surface characteristics requires a more in-depth understanding.

The correlation between skid resistance values and accident frequency does not show a significant correlation; however, locations with low skid resistance tend to experience a higher number of accidents. Other studies have shown that a significant decrease in skid resistance is correlated with an increase in accident rates [6]. This is further reinforced by findings indicating that the macrotexture and microtexture of road pavements should be designed to maximize skid resistance, thereby improving traffic safety [7].

A review of the existing literature reveals several significant research gaps, including inconsistencies in findings regarding the level of significance of temperature effects on skid resistance, a tendency to analyze temperature and weather variables separately, limited investigations focusing on flexible pavement structures, and a lack of exploration of the implications of changes in skid resistance for road safety. To address these gaps, this study adopts an integrated approach to analyze the simultaneous effects of temperature and weather conditions on skid resistance of flexible pavements, while also examining the correlation between skid resistance variations and traffic accident frequency.

2 Methods and materials

To achieve the objectives, a mixed methodology is used to build an integrated model from experimental, analytical, and numerical approaches. The experimental approach is conducted through field testing. Research data is analyzed using statistical methods, which are a numerical approach used to identify and evaluate the validity and significance of the results.

2.1 Research design

This research was divided into three stages: identifying the existing skid resistance conditions on roads with flexible pavement, analyzing the influence of temperature and weather on skid resistance, and exploring skid resistance in relation to accident frequency.

2.2 Samples and procedures

The method used in this research was a measurement survey with a T2GO friction tester and statistical regression analysis in RStudio. T2GO is a skid resistance measurement tool for road surfaces, and this tool has limitations that are highly dependent on calibration and wheel conditions. Data collection was conducted on the Yomani–Guci Road. On this road section, five segments were selected as samples and measured in both directions based on traffic accident frequency data. Data collection was conducted during the daytime and afternoon periods, and rainfall conditions were assessed by conducting experiments simulating skid resistance behavior on the asphalt pavement surface under dry and wet conditions.

2.3 Data analysis

An analysis of the effects of temperature and weather on skid resistance values in flexible pavements was conducted using statistical analysis in RStudio. The exploration of models relating skid resistance values to accident numbers was conducted using regression analysis, including linear, polynomial, exponential, logarithmic, quadratic, and power regressions. The best model was selected based on the Multiple R-squared indicator. The use of various regression models helps identify the most suitable form of relationship between independent and dependent variables.

3 Results and discussion

3.1 Results

The primary data consist of skid resistance values, which serve as the dataset forming the basis for data analysis. The total dataset comprised 50 observations divided into five road segments. Each segment underwent field testing to obtain the existing condition of actual skid resistance, with 10 observation data points collected for each segment. The data were statistically analyzed to examine the correlation between variables. **Fig 1** presents a comparison of existing skid resistance conditions under dry conditions during the daytime, dry conditions during the afternoon, and simulated wet conditions during rainfall.

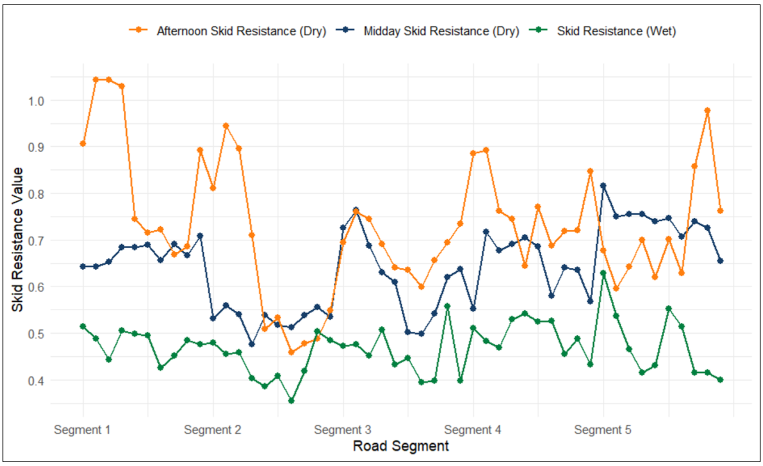

Fig. 1. Skid resistance values graph

The skid resistance test results in **Fig 1**, conducted under dry conditions during the daytime, dry conditions during the afternoon, and wet conditions, show substantial differences in the road surface's ability to resist skidding. The average skid resistance value during dry daytime conditions was 0.641. This value remained relatively constant, although Segments 4 and 5 showed a decrease due to high-temperature conditions. During the afternoon under dry conditions, the average skid resistance value increased to 0.730, and greater variation was observed, with a sharp decrease in the middle segments.

In contrast, under wet conditions, the skid resistance value decreased to 0.468, indicating that the road surface became more slippery and exhibited more uniform values across all segments. This decrease indicates that wet road conditions are more likely to cause vehicle skidding accidents. The skid resistance value decreased by 35.88% from dry afternoon conditions to wet conditions and by 13.81% from dry daytime conditions to dry afternoon conditions. These results highlight the importance of maintaining good functional road conditions by considering how weather variations affect driving safety [8], [9]. The correlation between temperature, weather conditions, and road skid resistance values is presented in **Fig 2**.

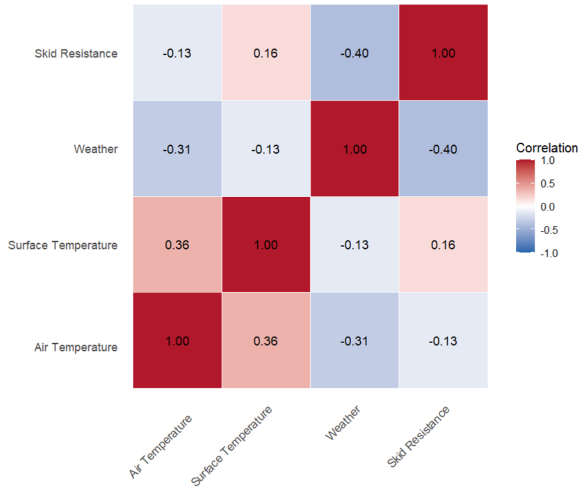

Fig. 2. Correlation of air temperature, surface temperature, and weather

Fig 2 explains the correlations showing that air temperature has a moderate positive correlation (0.36) with skid resistance, indicating that higher air temperatures increase the grip of the road surface. Surface temperature also shows a positive correlation with skid resistance (0.16), but the effect is weaker. On the other hand, weather shows a strong negative correlation (-0.40) with skid resistance, indicating that adverse weather conditions, such as rainfall or high humidity, reduce friction between the road surface and vehicle tires [8], [10].

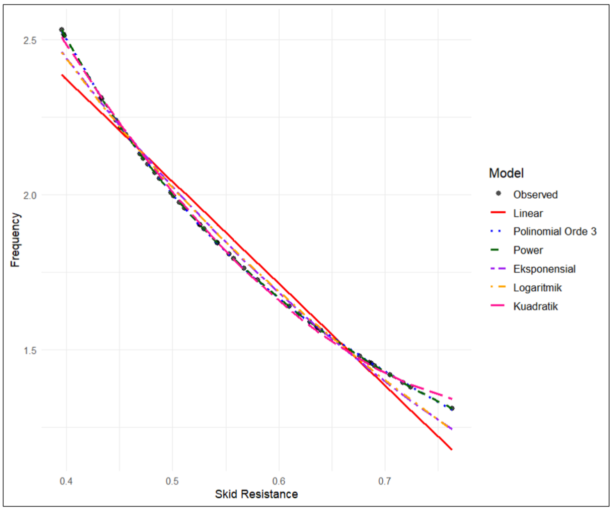

Fig. 3. Comparison of Skid Resistance Models

Fig 3 compares various models describing the correlation between skid resistance and accident frequency. The selection of the appropriate model depends on the complexity of the correlation and the characteristics of the data. Table 1, which compares regression models, provides important insights into each model's performance in explaining the correlation between the two variables.

Table 1. Comparison of Regression Models

Model	Equation	Multiple R-squared	Adjusted R-squared	df1	df2
Linear	$Y = 3.6852 - 3.2859.X$	0.968	0.968	1	38
Polynomial	$Y = 7.3785 - 20.0737.X + 23.873.X^2 - 10.4788.X^3$	0.999	0.999	3	36
Power	$Y = 1.X^{-1}$	1	1	1	38
Exponential	$Y = 5.1182.e^{-1.8535.X}$	0.992	0.991	1	38
Quadratic	$Y = 5.5802 - 10.1613.X + 6.038.X^2$	0.999	0.999	2	37
Logarithmic	$Y = 0.7438 - 1.847.logX$	0.992	0.991	1	38

Based on the Multiple R-squared criterion, the power model was identified as the best-performing model. Statistically, this model is the most appropriate among other regression models, such as linear, polynomial, exponential, quadratic, and logarithmic models, as it has the highest R-squared value. The power model can describe the correlation between road surface skid resistance values and accident numbers by producing an R-squared value of 1, indicating that skid resistance values fully explain the entire variation in accident frequency.

The resulting equation is $Y = 1.X^{-1}$. This equation indicates that a coefficient of 1 means that, as the skid resistance value approaches zero, the frequency of accidents increases. The negative X coefficient indicates that each increase in skid resistance value reduces accident frequency. This finding indicates that the correlation between skid resistance and accident frequency is nonlinear.

Based on the power model equation, the X value (skid resistance) was substituted at 0.25 intervals to explore the critical values of the correlation between skid resistance (X) and accident frequency (Y). The results of this substitution produced predicted accident frequency values (Y), which were then visualized in **Fig 4**.

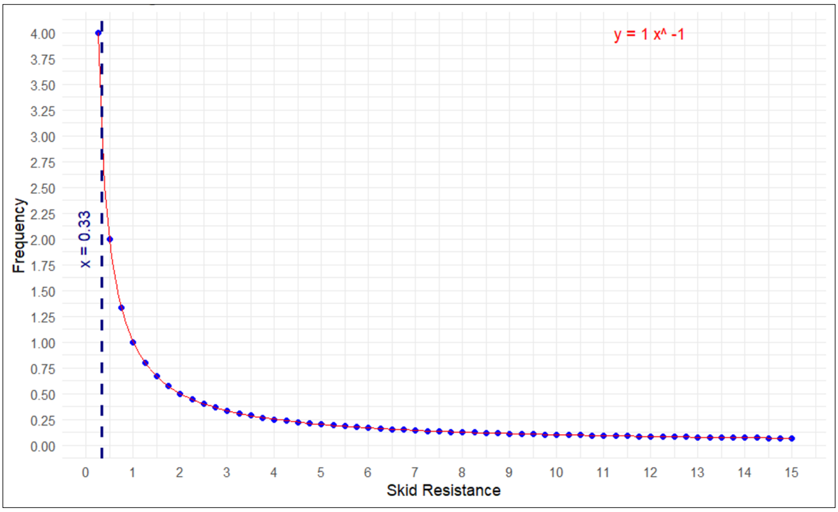

Fig. 4. Power Model Prediction

Fig 4 shows the analysis results, indicating that when skid resistance values are up to 0.5, accident frequency remains relatively high. However, it decreases significantly after skid resistance reaches 1. When compared with the Indonesian technical standard, which sets a minimum threshold of 0.33, these findings indicate that this threshold does not yet fully reflect the actual level of safety in field conditions. In other words, although skid resistance values are above the national minimum standard, the risk of accidents remains significant. This indicates that the threshold value of 0.33 can be too low and insufficient to ensure driver safety, particularly under operational conditions in hilly to mountainous regions.

3.2 Discussion

The analysis results show that road surface skid resistance values exceed the Indonesian technical standard's minimum threshold of 0.33. However, there is still a risk of vehicle accidents, particularly in hilly and mountainous areas. Skid resistance values of 0.641 during the daytime and 0.730 during the afternoon are still not sufficiently high to fully reduce accident risk. The sharp decrease in skid resistance values to 0.468 under wet road conditions indicates that wet road surfaces are consistently more slippery, thereby increasing the risk of vehicle skidding. The 35.88% decrease from dry to wet conditions indicates that the current skid resistance standard is not sufficiently adequate to ensure driver safety, particularly under more adverse road conditions. This is particularly relevant during wet weather when skid resistance can drop dramatically, exacerbating the risks of skidding and loss of vehicle control [11], [12]. This finding supports previous findings, which indicate that weather conditions, particularly wet road surfaces, consistently reduce skid resistance. Statistically, wet road surfaces have lower skid resistance, which increases the potential risk of vehicle accidents [13], [14].

Therefore, it is important to consider revising the skid resistance threshold currently applied in Indonesia. This threshold may be too low to protect road users adequately. These findings indicate that temperature, humidity, and weather influence changes in skid resistance values, which can serve as a basis for improving driver safety on roads [15]. These findings have important implications in civil engineering, underscoring the need for routine assessments of road functional conditions, particularly in regions with high temperatures and high rainfall, to reduce accidents and improve traffic safety. By using recent data and findings, it is possible to review the standard skid resistance threshold and gain a clearer understanding of the actual safety level of road infrastructure.

4 Conclusions

Flexible pavements showed a 35.88% decrease in skid resistance from dry afternoon to wet conditions, and a 13.81% decrease from dry daytime to dry afternoon conditions. These results indicate the importance of maintaining good functional road conditions by considering how changes in temperature and weather influence the dynamic variation of skid resistance on road surfaces. The exploration and regression modeling across various forms show that the power model most accurately describes the correlation between skid resistance and accident frequency. This model has a value that can explain the data perfectly. The model shows that when skid resistance is up to 0.5, accident frequency remains relatively high, but it decreases significantly once skid resistance reaches 1. These results indicate that the current threshold of 0.33 can not be sufficiently high to ensure safe road conditions.

For future research, it is recommended that skid resistance data collection be conducted more frequently, and testing under diverse weather conditions would enable the identification of dynamic changes in road surface characteristics. Technical integration with the materials used should also be considered. Testing the model in different regions or using larger datasets can enhance the external validity of the results. Further research is needed to identify a more appropriate skid resistance threshold that considers risk, cost, and benefits. Such studies will support the formulation of more adaptive and data-driven road safety policies.

Acknowledgement - This work was supported by the Politeknik Keselamatan Transportasi Jalan.

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