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Structured Exploration of Factors Influencing Rutting

Lijie Ma, Zhao Ma

Architectural Engineering Institute, North China University of Science and Technology, Tangshan, Hebei, 063210, China

Abstract

The depth of rutting is one of the important indicators to measure the current condition of roads. Rutting can seriously affect the aesthetics of the road and reduce the safety of driving. With the rapid development of the domestic economy since the reform and opening-up, the number of cars and vehicle loads have continuously increased, leading to an increasing problem of rutting. This article aims to focus on studying the impact of external conditions such as traffic conditions on rutting depth. Through simulating real asphalt concrete pavement for testing and using multiple linear regression methods to summarize the impact of axle load and tire contact pressure on rutting depth, we aim to understand the influence of the external environment on rutting and the formation mechanism of rutting, thus providing new assistance for future road design and road disease repair, and enabling future roads to minimize the formation of rutting as much as possible. This article takes rutting depth as an important indicator to measure the current condition of roads and delves into the impact of traffic conditions on rutting formation.

Keywords

The Depth of Rutting; Axle Load; Contact Pressure of Tire on the Ground.

1. Analysis of Factors Influencing Rutting

The formation of rutting is not only related to the inherent properties of asphalt mixtures but also influenced by external environments and traffic conditions. Asphalt pavements, long-term exposed to the natural environment, are jointly constrained by multiple factors such as geographical conditions, geological conditions, climatic conditions, hydrological and hydrogeological conditions, soil types, and traffic loads. Among these factors, climatic conditions and traffic conditions have particularly significant impacts on the stability of the pavement surface.

Specifically, asphalt mixtures, as the main constituent material of the pavement, exhibit a comprehensive combination of elastic, viscous, and plastic properties. When exposed to the atmosphere for a long time, the dynamic elastic modulus of this material decreases sharply with increasing temperature. At the same time, asphalt pavements are also affected by solar radiation, convective heat exchange with the atmosphere, and effective radiation from the pavement surface. Solar radiation is closely related to effective sunshine hours, convective heat exchange with the atmosphere is significantly influenced by wind speed, and the effective radiation from the pavement surface is closely linked to temperature changes.

Moreover, the formation of rutting is significantly influenced by vehicle axle loads and driving speeds. Existing research has pointed out that the slower the vehicle speed, the more significant the impact on rutting in the pavement. This discovery further reveals the complexity of the rutting formation mechanism, indicating that multiple factors need to be considered comprehensively when analyzing rutting issues.

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In summary, the formation of rutting is a complex process influenced by multiple factors. To effectively prevent and treat rutting problems, it is necessary to conduct thorough research on the mechanisms of these factors and take corresponding measures to improve the stability and durability of the pavement.

2. Experimental Methods and Parameter Settings

In this simulation, quantitative control was conducted on three influencing factors: temperature, wind speed, and vehicle speed. The primary focus was on comparing and analyzing the relationship between vehicle axle load and tire contact pressure and their respective impacts on rutting in the pavement, as well as the order of their influence.

Selection of Temperature: According to the research conducted by He Jinlong{1}, when the temperature exceeds 25℃, the deformation of rutting in the pavement begins to intensify. Therefore, a temperature of 30℃ was selected to investigate its impact on rutting within a 10-hour period of effective daylight within a day.

Selection of Wind Speed: A wind speed of 4.4m/s, the median value of the third-level wind speed range (3.4~5.4m/s), was chosen as the model parameter.

Load Parameters: The tire load was converted into rectangular load based on the principle of equivalent load stress. The width of the tire load action was set to 18.6cm, and the length was 19.2cm. A vehicle speed of 40Km/h was selected.

For the study, the axle load and tire contact pressure were divided into two orthogonal groups for comparison. The axle loads were selected as 60KN, 80KN, 100KN, and 100KN, 110KN, 120KN, respectively. The tire contact pressures were selected as 0.42Mpa, 0.56Mpa, 0.7Mpa, and 0.7Mpa, 0.77Mpa, 0.84Mpa, respectively. Since the selection of axle loads falls within the category of light loads, the 8000-cycle loading method referenced in the APA experimental method was adopted in this experiment. Below are the values of the selected influencing factors:

Table 1. Analysis Table of External Influencing Factors for Asphalt Pavement1

	Temperature ℃ A	Wind Speed m/s B	Vehicle Speed Km/h C	Axle Load KN D	Tire Contact Pressure Mpa
1	30	4.4	40	60	0.42
2	30	4.4	40	80	0.56
3	30	4.4	40	100	0.7

Table 2. Analysis Table of External Influencing Factors for Asphalt Pavement2

	Temperature ℃ A	Wind Speed m/s B	Vehicle Speed Km/h C	Axle Load KN D	Tire Contact Pressure Mpa
1	30	4.4	40	100	0.7
2	30	4.4	40	110	0.77
3	30	4.4	40	120	0.84

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By analyzing the data obtained from this simulation, we aim to gain a deeper understanding of the relationship between the selected factors and their impact on rutting in asphalt pavements. This information will be crucial for optimizing road design and maintenance strategies to minimize rutting and enhance the overall performance and lifespan of roadways.

3. Experimental Results and Analysis

After integrating external influencing factors such as temperature, wind speed, vehicle speed, and axle load, the external influencing factors for asphalt pavement conform to Orthogonal Table 1. By varying the axle load and tire contact pressure while keeping other conditions constant, Table 3 is obtained. This table is used to compare the influence intensity of the independent variables (axle load and tire contact pressure) on rutting depth in the two experiments, aiming to establish a relationship model between axle load and tire contact pressure on rutting depth. Under different combinations, we obtain two sets of orthogonal tables.

Table 3. Composite Orthogonal Table of External Influencing Factors 1

	Axle load KN D	Contact pressure of tire on the ground Mpa	Cumulative Number of Axle Load Applications	The depth of rutting mm
1	60	0.42	8000	4.478
2	80	0.56	8000	3.67
3	100	0.7	8000	3.65
4	100	0.7	8000	11.9
5	60	0.42	8000	6.524
6	80	0.56	8000	7.895
7	80	0.56	8000	23.11
8	100	0.7	8000	32.12
9	60	0.42	8000	16.57

Table 3. Composite Orthogonal Table of External Influencing Factors 2

	Axle load KN	Contact pressure of tire on the ground Mpa	Cumulative Number of Axle Load Applications	The depth of rutting mm
1	100	0.7	8000	18.23
2	110	0.77	8000	11.06
3	120	0.84	8000	8.448
4	120	0.84	8000	41.08
5	100	0.7	8000	29.28
6	110	0.77	8000	29.96
7	110	0.77	8000	73.1
8	120	0.84	8000	84.49
9	100	0.7	8000	61.77

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Using the results from the two sets of composite orthogonal tables, a mathematical approach of multiple regression analysis was employed. The axle load and tire-to-ground contact pressure were set as characteristic variables (denoted as X_1 and X_2, respectively), while the rutting depth was designated Y as the dependent variable. In Python, libraries such as pandas, pyplot, and sklearn were utilized to visually represent the model relationship among these three variables in the form of a relational graph. The graph will take the following form:

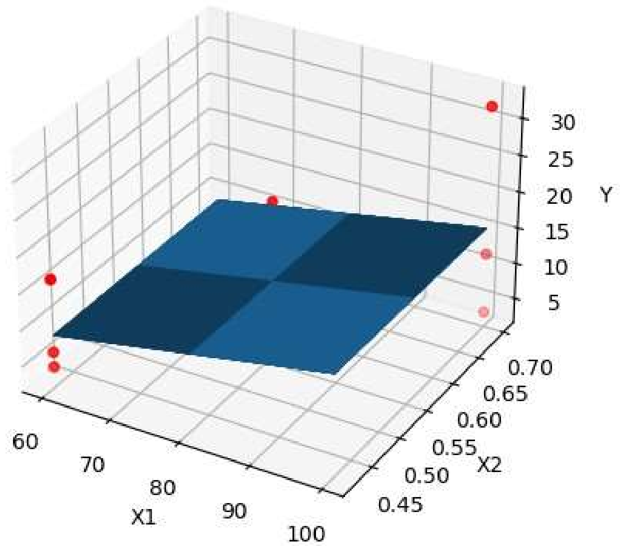

Fig. 1 Orthogonal Result 1

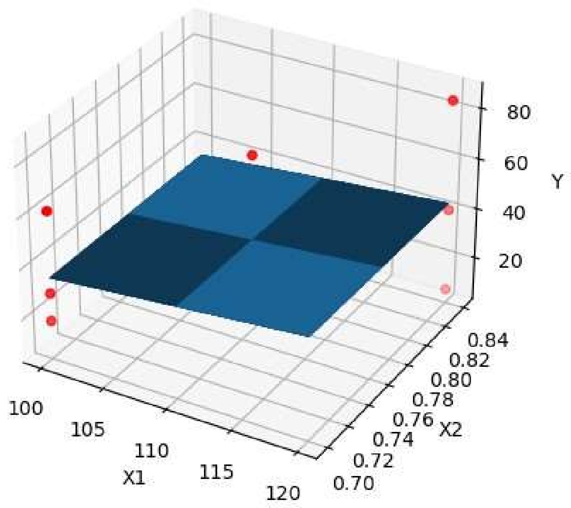

Fig. 2 Orthogonal Result 2

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Through multiple regression analysis, this study thoroughly explored the impact of the independent variables - axle load and tire contact pressure, on the dependent variable - rutting depth. The research found that tire contact pressure has a significant influence on rutting depth, while the influence of axle load is relatively weaker. This conclusion not only enhances our understanding of the relationship between the variables, but also provides a new perspective for research in related fields. Additionally, the results of this study have practical implications for policymakers, providing scientific evidence for policy adjustment and optimization. Simultaneously, the analytical methods used in this study offer valuable references for similar research. Therefore, this study holds significant importance both in theory and in practice.

By comparing the two orthogonal results, a joint impact relationship between axle load and tire contact pressure on rutting depth can be derived, deepening our understanding of road rutting damage in road construction and maintenance. The research conclusions can guide practical decision-making, enhance efficiency, or solve specific problems. However, this paper only explores the impact of axle load and tire contact pressure on rutting depth, and does not provide intuitive relationship diagrams for other external influencing factors such as temperature and wind speed. These aspects remain to be improved in future studies.

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