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Effect of Channelization on the Performance of Flexible Pavements in Nigeria

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ABSTRACT

In traffic management and road design, channelization which is the act of directing traffic into designated lanes is a common approach. The impact of channelization on the performance of flexible pavements is a major concern in Nigeria, where road infrastructure is essential to connectivity and economic development. This research looks at the effects of channelization on flexible pavements in Nigeria, taking into account both present-day circumstances and potential future obstacles. The concentration of vehicle loads in Nigeria as a result of channelization is a significant factor that contributes to the early deterioration of flexible pavements. The nation's road network, which frequently sees high traffic loads from commercial vehicles, is prone to accelerated wear and tear in channelized lanes. Common problems include surface deformation, rutting, and cracking, especially in urban areas and along major highways where there is heavy traffic. Inadequate maintenance of the road exacerbates these issues, resulting in shorter pavement life and higher repair costs. There are other difficulties with Nigeria's road system that compound the consequences of channelization. Flexible pavements deteriorate quickly due to a variety of factors, including poor drainage systems, shoddy building techniques, and the use of inferior materials. In addition, the country's environment, which is marked by intense rains in some areas, hastens the deterioration of pavement, particularly when coupled with inadequate drainage and traffic patterns that are channelized. The demand on Nigeria's road network is anticipated to increase as the country's population continues to expand and urbanization rises. The consequences of channelization may be exacerbated by the possible arrival of autonomous cars and a greater dependence on data-driven traffic management systems, which might further concentrate traffic volumes in certain lanes. It will be crucial to use better materials, create more durable pavement designs, and put more efficient maintenance plans in place in order to lessen these upcoming difficulties. Channelization's impact on Nigeria's flexible pavements' performance is a serious problem that has to be addressed right now. Improving maintenance procedures, raising standards for road construction, and taking future traffic patterns into account when designing pavement are all necessary to meet this problem. Nigeria may better maintain its road system and encourage sustained economic growth by implementing these measures.

Keywords: Channelization, Pavement, Surface, Flexible, Performance

INTRODUCTION

Nigeria's road network is a vital component of the nation's infrastructure, supporting the movement of goods, services, and people across its vast and diverse landscape. As the country continues to experience rapid urbanization and economic growth, the demands placed on its roadways have increased significantly [1]. One critical aspect of road design and traffic management in Nigeria is channelization, the practice of directing vehicles into specific lanes to manage traffic flow, enhance safety, and reduce congestion [2]. While channelization serves important functions in improving road safety and efficiency, it also presents challenges, particularly concerning the performance and durability of flexible pavements [2-6]. Flexible pavements, which are predominantly used across Nigeria, consist of layers of asphalt and aggregates designed to distribute vehicular loads to the underlying soil [4]. However, when traffic is consistently channeled into specific lanes, the concentration of loads can lead to significant pavement distress [5]. In Nigeria, the effects of channelization on flexible pavements are particularly pronounced due to several contextual factors [2]. The country's roadways frequently experience heavy and concentrated traffic, especially from commercial vehicles that contribute to high levels of stress on the pavement surface. Additionally, the combination of inadequate road construction practices, substandard materials, and poor maintenance exacerbates the negative impacts of

channelization. These issues are further compounded by Nigeria's climatic conditions, with heavy rainfall leading to water accumulation and weakening of the pavement structure [5-10]. The resulting pavement distress, including rutting, cracking, and surface deformation, not only reduces the lifespan of the roads but also increases the cost and frequency of repairs [7]. As Nigeria continues to develop and its traffic volumes rise, addressing the impact of channelization on flexible pavements will be crucial to ensuring the sustainability and reliability of the country's road infrastructure [8]. This introduction sets the context for exploring the specific challenges associated with channelization in Nigeria, highlighting the need for improved pavement design, better construction practices, and more effective maintenance strategies to mitigate the adverse effects on the nation's road network.

Literature Review

Channelization, which involves directing vehicular traffic into specific lanes, is a crucial aspect of traffic management and road design [8-12]. However, this practice has been widely studied for its adverse effects on the performance and longevity of flexible pavements [10]. This literature review synthesizes the findings of various studies on how channelization influences pavement deterioration, highlighting key mechanisms, contributing factors, and potential mitigation strategies.

Pavement Distress Due to Channelization

Numerous investigations have examined the ways in which channelization intensifies the deterioration of flexible pavements. Channelization, according to [11-16], concentrates traffic loads on certain pavement portions, resulting in concentrated stress that hastens the onset of pavement deterioration, including rutting, cracking, and surface deformation. Ruts are longitudinal depressions created by cars passing over and over again. They are more common in channelized lanes and lead to water buildup and further damage [14-19]. Another major problem is fatigue cracking, which results from the asphalt binder becoming brittle from repetitive application of stresses. This can lead to surface cracking and structural failure [16-20]. Numerous investigations have examined the ways in which channelization intensifies the deterioration of flexible pavements. Channelization, according to [17], focuses traffic flows on particular portions.

Traffic Volume and Load Repetition Influence

Traffic volume and load repetition have a direct bearing on the effects of channelization on pavement performance. Research by [18] shows that high traffic volumes, especially from heavy vehicles, aggravate the effects of channelization because the application of heavy loads in concentrated lanes repeatedly accelerates pavement deterioration. Research by [20-24] also supports this idea, finding that pavements subjected to high traffic loads in channelized lanes had significantly shorter service lives than those with more evenly distributed traffic.

Environmental Conditions effects

Channelized lanes' flexible pavements deteriorate due in large part to environmental causes. The impacts of channelization are frequently amplified in areas like Nigeria that have excessive rainfall or extremely high temperatures. Water seeping via fractures and ruts undermines the pavement's underlying layers, causing more deformation and discomfort [21-25]. Furthermore, changes in temperature might lead to thermal cracking and softening of the asphalt, which would further jeopardize the structure of the pavement [24-30].

Mitigation Strategies

Due to the detrimental impacts of channelization on pavement performance, many techniques have been suggested by researchers to lessen these effects. High-performance asphalt mixes, like asphalt treated with polymers, have been proposed as a means of improving the longevity of pavements exposed to traffic channelization [25]. Sturdier foundation materials and thicker asphalt layers are two further improvements in pavement construction that can assist distribute loads more uniformly and lessen the chance of rutting and cracking [26-32]. Furthermore, to minimize excessive load concentration in certain lanes, dynamic traffic management systems that modify lane assignments based on pavement conditions have been proposed [28-35].

Future Considerations

Channelization's future effects on flexible pavements will probably depend on changing traffic patterns, especially as autonomous cars become more common. According to research by [29], loads may be concentrated even more on particular pavement portions by autonomous cars, which have a tendency to follow exact, established pathways. This might result in even more issues when it comes to regulating pavement performance [30-32]. In order to meet the changing needs of contemporary road networks, this emphasizes the significance of continual research and innovation in pavement materials, design, and traffic management.

Contextual Studies in Nigeria

Particular research on Nigeria has brought attention to the compounding impacts on channelized pavement performance of substandard road building methods, insufficient maintenance, and difficult environmental circumstances. [12][31-36] highlighted in their study the necessity for improved construction techniques and higher-quality materials to increase pavement resistance against channelization. In addition, [32-34] covered the significance of using cutting-edge pavement design techniques that take into account Nigeria's particular climatic and traffic circumstances in order to prolong pavement life and save maintenance costs [9][33-39]. The literature indicates that channelization significantly impacts the performance of flexible pavements, leading to accelerated deterioration and reduced service life. While various strategies have been proposed to mitigate these effects, the ongoing evolution of traffic patterns and environmental challenges, particularly in regions like Nigeria, necessitates continuous innovation in pavement design, materials, and traffic management

METHODOLOGY

The objective of this study is to investigate the effects of road geometries and features on pavement deterioration, with a particular focus on flexible pavements in Nigeria. Because of their viscoelastic properties, flexible pavements are more vulnerable to the effects of channelized traffic than rigid pavements; the research focuses on rutting as a common mode of deterioration on flexible pavements, suggesting a close relationship between rutting and traffic channelization. The study uses an observational data collection approach and a positivist research design, quantifying and measuring pavement performance. The case study location is Lagos, Nigeria, a densely populated metropolis. In contrast to hypothetical scenarios, the study's data was gathered through observations in the City of Lagos, Nigeria, because of the country's consistent climate and data availability. The pavement type was flexible, with homogenous characteristics along its length; visual inspections and core sample data from the Federal Road Maintenance Agency (FERMA) confirmed the pavement's homogeneity, indicating that it is a commonly used pavement structure in Nigeria. The calculation of sample size is essential for drawing valid conclusions from research and is dependent on the sampling technique chosen. Purposive sampling was chosen in this project in order to concentrate on essential features... Along the case study road, traffic flow was recorded at intervals of 15 meters and then again at 100 distinct sites. To find the minimum number of cars needed for traffic flow recording, a two-variances test was performed. The needed number of cars was calculated using the power value, sample size, ratio, and significance level. The necessary number of cars was determined using a 1.25 ratio, which had a 75% chance of identifying a 95% statistically significant difference in standard deviations. The findings showed that 110 cars from each road segment needed to be registered.

RESULTS AND ANALYSIS

The result obtained after the placement of vehicles laterally for each road section was entered into spreadsheets and standard deviations calculated. This serves as a measure of lateral wander of vehicle degree of channelization, the results were compared to those in the existing literature and then was analysed to investigate how road geometries relate to channelization. Since the degree of channelization varied, it was possible to record this fluctuation and do analysis to see if it was connected to the road sections' geometry. It was discovered that the vehicle placements at each of the observation sites roughly followed a normal distribution. The distributions at several places with varying geometric properties are displayed in Figures below. Every location is in relation to the nearside (right) road edge.

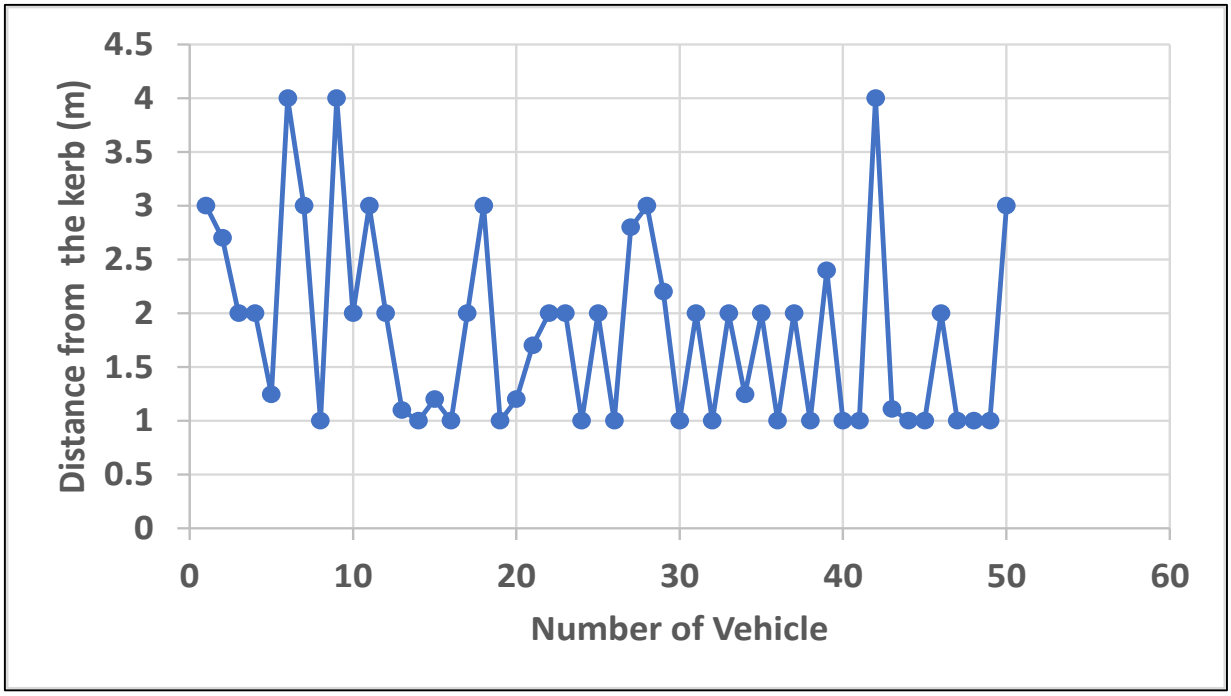

Figure 1: Frequency distributions of lateral placement of vehicles for different road widths

The normality of data was checked further to determine the significance difference. After plotting the frequency distributions for the road sections as shown in Figure above, further analysis was carried out to determine whether the distributions at each location was normal. The assessment of normality was completed by conducting the most well-known normality test. The test checks the difference between the distribution at each location and a perfectly normal one based on p-value. When the p-value is 0.05 or higher, there is no statistically significant difference from the normal distribution. In set of tests, the p-values were found to be greater than 0.05, which indicates that they were normally distributed in 110 of the road sections. There were 10 road sections (highlighted in Table 1) where p-values were lower than 0.05. In the tests, the *p*-values were found to be greater than 0.05, which indicates that they were normally distributed in the road sections.

Table 1: The Results of Normality test.

Vehicle number	P-Value	Vehicle number	P-Value	Vehicle number	P-Value
1	**0.076**	41	**0.575**	81	**0.542**
2	**0.12**	42	**0.055**	82	**0.076**
3	**0.524**	43	**0.936**	83	**0.657**
4	**0.059**	44	**0.242**	84	**0.124**
5	**0.001**	45	**0.773**	85	**0.243**
6	**0.825**	46	**0.81**	86	**0.345**
7	**0.254**	47	**0.009**	87	**0.365**
8	**0.397**	48	**0.345**	88	**0.632**
9	**0.586**	49	**0.384**	89	**0.34**
10	**0.186**	50	**0.142**	90	**0.2**
11	**0.794**	51	**0.381**	91	**0.054**
12	**0.517**	52	**0.517**	91	**0.029**
13	**0.617**	53	**0.34**	93	**0.237**
14	**0.674**	54	**0.1**	94	**0.733**
15	**0.007**	55	**0.923**	95	**0.242**
16	**0.629**	56	**0.502**	96	**0.055**
17	**0.831**	57	**0.094**	97	**0.474**
18	**0.329**	58	**0.085**	98	**0.329**
19	**0.008**	59	**0.518**	99	**0.408**
20	**0.026**	60	**0.139**	100	**0.629**
21	**0.009**	61	**0.041**	101	**0.674**
22	**0.242**	62	**0.119**	102	**0.617**
23	**0.744**	63	**0.143**	103	**0.196**
24	**0.065**	64	**0.304**	104	**0.517**
25	**0.532**	65	**0.996**	105	**0.794**
26	**0.087**	66	**0.2**	106	**0.186**
27	**0.116**	67	**0.2**	107	**0.366**
28	**0.113**	68	**0.24**	108	**0.013**
29	**0.2**	69	**0.519**	109	**0.2**
30	**0.152**	70	**0.746**	110	**0.007**
31	**0.094**	71	**0.1**		
32	**0.936**	72	**0.03**		
33	**0.81**	73	**0.77**		
34	**0.732**	74	**0.746**		
35	**0.2**	75	**0.123**		
36	**0.083**	76	**0.34**		
37	**0.065**	77	**0.204**		
38	**0.092**	78	**0.5**		
39	**0.162**	79	**0.923**		
40	**0.076**	80	**0.983**		

DISCUSSION

The influence of road dimensions and features on channelization, suggesting that varying rut depths on consistent asphalt pavements should be considered as a degree rather than a binary value. One prevalent and important type of pavement damage is rutting. More research was done, as detailed in the parts that follow, to account for the channelization (lateral wander) of traffic and how it affects pavement rutting. To reiterate, the degree of channelization/lateral wander of vehicle locations was measured using the standard deviation of vehicle positions. It would be predicted that rut depth on a vehicle's nearside wheel would be deeper than on its offside wheel due to repeated loads.

CONCLUSION

The study finds that the degree of channelization, which influences the lateral position of cars, is correlated with road and lane widths [13][25]. This implies that drivers only adjust their lateral position in response to things that are wider than their traffic lane. According to the findings, lane widths are narrowed relative to road width and that is the only influence of road characteristics. The results partly justify the adoption of lane width as a proxy for channelization degree in international standards, as opposed to the measurements currently employed in Nigeria. The Dutch design rules, for instance, state that the damage caused by traffic is directly correlated with lane width; nevertheless, it is unclear how the distribution of loads was assessed in relation to lane width. The research aimed to provide more advise on the detrimental impact of traffic wander and channelization on rutting on flexible pavements in the Nigeria. Based on the case study location and data, the results indicated a reasonably substantial magnitude of influence between the degree of channelization and rut depth. The findings corroborated research by [14] and [17], showing that rutting increases with degree of lateral wander of vehicle placements. These discoveries may make it possible to estimate pavement design lifetimes more precisely and aid in improving pavement maintenance and design to ensure that stipulated lifespans are met. When channelization is projected based on the standard deviation of vehicle placements, pavement engineers can adjust pavement thicknesses more effectively rather than just doubling the load and thickness.

RECOMMENDATIONS

Channelization can significantly impact the performance of flexible pavements in Nigeria, leading to pavement deterioration. To mitigate this, Nigeria should update design standards, use durable materials, strengthen supervision and quality control, implement routine and preventive maintenance, and use modern technologies like cold in-place recycling and hot in-place recycling. Traffic management strategies should be implemented to reduce heavy vehicle concentration on specific road sections and improve channelization design. Research on local materials and pilot projects can also enhance pavement performance. Capacity building and training should be provided for engineers, contractors, and road maintenance personnel. Public awareness campaigns should be conducted to educate road users on adhering to load limits and using designated routes to reduce stress on pavements. By implementing these recommendations, Nigeria can significantly reduce the negative effects of channelization on flexible pavements, leading to longer-lasting roadways and improved transportation infrastructure.

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