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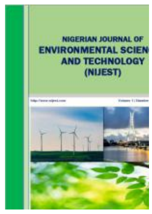

A Review of Decision Support Attributes for Selecting Road Pavement Type in Nigeria

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ABSTRACT

The impact of transportation infrastructure on the socio-economic development of any country cannot be over-emphasised. Among the multiple modes of transportation, roads are reported to be the most widely used. In Nigeria, there is a huge deficit in the provision of paved roads. Majority of these paved roads are flexible which frequently fail due to harsh climatic conditions and the phenomenon of overloading. To arrest this situation, the Federal Government of Nigeria is contemplating the adoption of concrete slab as the preferred option for road pavement as a national policy trust. It has been suggested that the choice of road pavement type is a critical long-term economic decision. The major performance requirements of road pavement is to provide resistance to environment and traffic. This paper hence reviewed the attributes of flexible and rigid pavements with a view to providing decision support guidelines for selecting a pavement type in Nigeria. Previous studies between 2015 and 2025 on road works were accessed via Google Scholar and ResearchGate databases using combinations of search terms like 'attributes', 'flexible pavement', 'performance', 'resilience', 'rigid pavement' and 'road'. Only peer-reviewed works in English-language were selected for this review. Based on the results synthesised from extant literature, it was found that rigid pavement is superior to flexible pavement in terms of both sustainability and resilience desired selection criteria. This review hence concluded that rigid pavement is a better solution to the harsh climatic conditions and overloading phenomenon which are the major agents of road pavement failure in Nigeria.

Keywords: Attributes, Flexible, Pavement, Resilience, Rigid, Road, Sustainability

1.0. Introduction

The impact of transportation on the overall development of any country cannot be over-emphasised. Adedotun *et al.* (2016) affirmed that transportation promotes the socio-economic development of any area. Mohod and Kadam (2016) claimed that the level of transportation infrastructure in any area is a measure of urbanisation and civilisation of the area. Ketema *et al*. (2016) described the development of road infrastructure as the backbone and blood artery of economic and social progress of any country. Isemede (2023) opined that a country's economic development is positively correlated with the quality of its road network. According to Rajput (2020), among the multiple modes of transportation (water, air, road and train), roads are the most widely used due to ability of remotest reach and liberty of speed. Mittal *et al*. (2020) concluded that transportation by road is the most flexible mode especially in rural areas not served by other modes. .Abija *et al*. (2024) observed that in Nigeria, over 90% of goods and commuters are moved via road pavement infrastructures. Similarly, Adewumi *et al*. (2024) posited that road is the most popular transport mode in Nigeria and 99% of the roads are flexible pavement. However, Khan and Imam (2021) found that flexible pavement is preferred to rigid due to lower initial cost rather than life cycle consideration.

Adedotun *et al*. (2016) observed that there is a huge road deficit in developing countries, generally and Nigeria in particular. The authors claimed that the demand for road transport is higher than the supply in Nigeria. Audu et al. (2016) reported that the demand for road transport infrastructure is high in developing countries due to ever growing population, industrialisation and urban growth. Thus, Nigeria as a developing country has a long way to go in the provision of road infrastructure in other to enhance socio-economic development. However, Adewumi *et al*. (2024) observed that the choice of a pavement type is critical to road construction because it is a long-term economic decision.

A road pavement is the surface used for travelling. Otti *et al*. (2016) defined pavement as the durable surfacing of a road, airfield or similar area whose primary function is to transfer loads to the sub-base and underlying soil. Onyebuchi *et al*. (2019) and Ugwuanyi and Onyelowe (2019) described road pavement to comprise structural elements that protect the natural sub-grade and carry traffic. The growth in traffic and traffic loads necessitated the construction of road pavement (Rajput, 2020). The major reasons for paving roads are to make them strong, durable and resist the environment and traffic (Taher *et al*., 2020).

There are two broad types of pavement based on their structural performance and materials used for construction. These are Rigid pavement (Portland cement concrete) and Flexible pavement (hot asphalt concrete). According to Taher *et al*. (2020), a flexible pavement consists of several layers of granular materials such as crushed stone or gravel and sand consolidated by a binder of bituminous materials. Rigid pavement, on the other hand, is so called due to the stiffness of its major constituent material (concrete).

Emmanuel *et al*. (2021) observed that it is difficult to travel a kilometre in Nigeria without encountering long cracks and potholes. A number of challenges confront road pavements in developing countries including Nigeria. These include frequent failures due to overloading, poor quality, harsh weather conditions, and budgetary constraints, among others. Several studies have documented veritable desired criteria for selecting road pavement type. These include cost, traffic, weather, soil characteristics, and safety (Taher *et al*., 2020); life cycle cost (Hamim et al., 2021); riding quality, friction, light reflecting features, noise absorbing features, and reduction of stress on sub-grade (Mohod & Kadam, 2016; Rajput, 2020); budgetary constraints and durability (Adewumi *et al*., 2024).

The Federal Government of Nigeria is contemplating the adoption of concrete as the preferred pavement type for road works as a national policy. Government choice of pavement type should however be based on a comparative analysis of the attributes of the various pavement types available for informed choice. However, studies which document the comparative attributes of flexible (asphalt) and rigid (concrete) pavements seem scanty in construction literature. This review is hence necessary to provide decision support guidelines for the selection of road pavement type in Nigeria. This is in line with the advice of Joo *et al*. (2023) that a shift from specification-based to performance-based design standards is necessary to ensure infrastructure resilience.

This research review hence explored the strengths and weaknesses of flexible and rigid road pavements under various desired criteria with a view to providing decision support guidelines for selecting a pavement type for Nigerian roads.

2.0. Methodology

This comparative review used literature search and data synthesis methods to identify studies that explored the attributes and performance of rigid and flexible road pavements. The selection criteria includes peer-reviewed articles published within the last 10 years (2015 and 2025) to ensure the inclusion of current opinions, findings and data. Reputable academic databases like Google Scholar, Scopus and Web of Science were used to access the studies used for the review. Out of the 21 studies selected for the review, 17 were indexed in Google Scholar, one in Scopus, and the remaining three in other databases like Scilit and Research Gate. The works used for the review were selected based on the relevance of their contents to the performance of rigid and flexible pavements under overloading and harsh tropical environmental conditions. To ensure credibility and technical robustness, only peered-reviewed papers which addressed the strengths and weaknesses of flexible and rigid road pavements under overloading and harsh tropical environmental conditions were considered. The findings were analysed and grouped in tabular format to enhance comparison. The search terms used include 'attributes', 'flexible pavement', 'performance', 'resilience', rigid pavement', 'roads' and 'Nigeria'. Only English-language studies were included. Works not published within the specified time frame and in peer-reviewed outlets were excluded from the review.

3.0 Results and Discussion

3.1 Climatic Conditions and soil Types of Nigeria

Nigeria presents different climatic conditions including rainfall, fluctuating temperatures and drought as one moves from the South to the North (Eze *et al*., 2024). The drier Northern part results in soil cracking unlike the Southern part which receives more rainfall, flooding and erosion and often leading to more frequent road dilapidation. The climatic conditions of Nigeria account for the major soil types in different parts of the country, namely peat, lateritic and expansive soils (Eze *et al.*, 2024). Peat soils are common in the coastal and delta regions of Nigeria. They are more compressive due to their high-water content. As a result, they are mostly unstable for infrastructure development. The Southern part of Nigeria mostly contains lateritic soils. This type of soil is difficult to work on and presents a hard mass when dried. They are susceptible to erosion during the rainy season. Prevalent in the Central and Northern parts of Nigeria are expansive soils like clay. These soils swell and shrink with moisture contents. They pose high risks to infrastructures because of the uneven pressure they exert on the ground due to irregular volume. Table 1 presents the impacts of the various soil types on construction infrastructures.

Table 1: Effects of common soils in Nigeria on Infrastructures

Soil Type	Phenomenon	Soil reaction	Result	Geo-technical Infrastructure affected
Expansive soils (Clay)	Heaving, shrink and swell	Soil undergoes significant volume changes due to moisture fluctuations	Damage to buildings and roads causing cracks and heaving	Building foundations, pavements, road surfaces and underground pipelines
	Cracking	Soil contracts when dry and expands when wet, creating tensile stress	Formation of large cracks on the ground surface and within structures leading to structural instability	Road pavements, walls, building foundations, and slabs
	Slope instability	Repeated expansion and contraction weaken soil structure and slope cohesion	Increased risk of landslides and slope failures, particularly during wet seasons	Slopes, embankments, retaining walls, and hillside roads
Lateritic soils	Cementitious	Soil particles bind together due to high iron and aluminium oxide content	Formation of hard, cemented layers difficult to work with during construction	Road sub-bases, embankments, and dam construction
	Erosion	Soil particles are easily detached and transported due to heavy rainfall	Road surface degradation and loss of soil material, compromise road stability and require frequent maintenance	Unpaved roads, slopes, embankments, and drainage channels
	Low load-bearing capacity	Soil strenght diminishes under load due to its porous nature	Structural failures or deformation of roadbeds and foundations lead to increased construction costs	Roadbeds, building foundations, and bridge abutments.
Peaty soils	High compressibility	Soil compresses significantly under load due to high organic matter and water retension.	Excessive settlement and sinking of structures, particularly for heavy buildings or roads	Building foundations, road embankment, and bridge foundations.
	Low shear strength	Due to its fibrous and saturated nature, soil offers minimal resistance to shear forces.	Instability in foundation construction and higher risk of landslides, especially in wet conditions	Foundations, slopes, embankments, and retaining structures.
	Organic decay	Organic matter in the soil decomposes over time, altering soil structure.	Long-term settlement and potential releases of greenhouse gases impact both structures and the environment.	Building foundations, roadways, and pipelines.

Source: *Eze et al.* (2024)

3.2 *Comparative attributes of flexible and rigid pavements*

A flexible pavement is one with element of adaptability (Rajput, 2020). It consists of several layers of bituminous materials. It is so called because its layers flexes under wheel loads. The design of flexible pavement is based on load distribution characteristics of component layers. Isemede (2023) affirmed that Nigerian roadways have high traffic volumes and mostly constitutes asphalt (flexible) pavement. A rigid pavement consists of cement concrete which acts as a rigid (stiff) plate transferring wheel loads to lower layer by flexural strength. It is so called due to the stiffness of the material when compared to asphalt pavement. Its design is based on flexural strength of the concrete layer. It distributes wheel loads over broader area beneath. The greatest advantage of using rigid pavement is its ability to hold its shape against traffic loads and difficult environmental conditions. Table 2 presents a summary of the performance of flexible and rigid road pavements based on the selection criteria synthesised from extant literature.

Table 2: Performance of Flexible and Rigid Road Pavements based on selection criteria

S/N	Performance of Pavements Based on Selection Criteria	Authors and Years of Publication
1	Flexible pavement has lower initial cost but higher maintenance cost and hence higher life cycle cost.	Mittal *et al*. (2020); Rajput (2020); Taher *et al*. (2020)
2	Rigid pavement has higher initial cost but lower maintenance cost and hence lower life cycle cost.	Taher *et a*l. (2020), Rajput (2020)
3	Flexible pavement has higher impact on all three pillars of sustainability (human health, ecosystem quality and cost of resources).	Hatmoko and Landra (2021)
4	Flexible pavement is less durable than rigid pavement.	Hamim *et al.* (2021); Adewumi *et al.* (2024)
5	Flexible pavement absorbs traffic noise better than rigid pavement.	Li *et a*l. (2015)
6	Flexible pavement provides better riding comfort than rigid pavement.	Li *et al*. (2015)
7	Flexible pavement has lower resistance to chemical spillage and extreme weather conditions than rigid pavement.	Li *et a*l. (2015); Mohod and Kadam (2016)
8	Flexible pavement has very lower load-carrying capacity than rigid pavement.	Mohod and Kadam (2016), Taher *et al.* (2020)
9	Flexible pavement transfers deformation to lower layer of pavement unlike rigid pavement which reduces pressure on sub-grade.	Mohod and Kadam (2016); Rajput (2020);
10	Flexible pavement is ready for use within 48hrs of construction but rigid pavement will need to properly cure before use.	
11	Flexible pavement has lower force of friction than rigid pavement.	Mohod and Kadam (2016)
12	Flexible pavement has lower light reflective characteristics than rigid pavement.	Mohod and Kadam (2016)
13	Flexible pavement requires surface to be rolledbut rigid pavement does not.	Mohod and Kadam (2016)
14	Surfacing of flexible pavement cannot be laid directly on sub-grade but on layers of materials unlike rigid pavement.	Mohod and Kadam (2016)
15	Major failuresof flexible pavement are cracking and rutting	Mohod and Kadam (2016)
16	Flexible pavement distributes wheel loads by layer to layer action	Mohod and Kadam 92016)
17	Rigid pavement is more resistant to harsh weather conditions and overloading than flexible pavement.	Taher *et al*. (2020)
18	Rigid pavement can be constructed without importing materials thus saving foreign exchange	Ketema *et al*. (2016)
19	Rigid pavement is stiffer than flexible pavement because it has higher modulus of elasticity	Adewumi *et al*. (2024); Mohod and Kadam (2016)
20	Rigid pavement is a better solution to budgetary constraints than flexible pavement because it saves foreign exchange.	Adewumi *et al.* (2024)
21	Rigid pavement does not depend on the strength of sub-grade unlike flexible pavement.	Mohod and Kadam (2016)

In selecting pavement type, several researchers have recommended veritable desired decision support criteria. These include life cycle cost, resistance to traffic loads and extreme weather conditions (Taher *et al*., 2020; Hamim et al., 2021); reduction of pressure on sub-grade (Rajput, 2020); durability and amenability to budgetary constraints (Mohod and Kadam, 2016). These selection criteria can be grouped under two broad categories: sustainability (life cycle cost, economic, social and environmental impacts of pavement, and ability of pavement to mitigate budgetary constraints); and resilience (durability of pavement and ability of pavement to withstand harsh weather conditions and overloading).

Regarding sustainability, Hatmoko and Lendra (2021) described sustainable development as an attempt to fulfill present basic needs and to create resources to satisfy human expectations for a better life. It involves meeting the needs of the present without jeopardising future needs. Hamim *et al*. (2021) noted that sustainability of transportation infrastructure aims at building roads with longer service life and reduced maintenance costs. It is important to note that the construction of road projects impacts the environment, and the impact will be more pronounced in developing countries with huge deficit in road infrastructure. Hatmoko & Lendra (2021) posited that there are three aspects of sustainability (social, environmental and economic). The authors assessed the impacts of the construction of flexible and rigid pavements in Indonesia and reported that flexible pavement has higher overall impact on human health, environmental quality and cost of resources. Thus, in terms of impact, rigid pavement performs better than flexible pavement and hence is more sustainable as indicated on Table 2. The Table also shows that in terms of life cycle cost, Mittal *et al*. (2020), Rajput (20200 and Taher *et al*. (2020) reported that although flexible pavement has a lower initial cost than rigid pavement, it has higher maintenance and rehabilitation costs than rigid pavement. This results in a higher life cycle cost of flexible pavement and so, rigid pavement is more economic in the long run and is hence more sustainable than flexible pavement. With regard to budgetary constraints, Table 2 shows that both Ketema *et al*. (2016) and Adewumi *et al*. (2024) concluded that the construction of rigid pavement will exert little or no pressure on scarce foreign exchange, unlike flexible pavement, since it requires little or no import components. This makes it to be a more sustainable option than flexible pavement.

Regarding resilience, Tables 2 indicates that Ketema *et al.* (2016), Taher et al. (2020), Hamim et al. (2021) and Hatmoko and Lendra (2021) reported that rigid pavement is more durable than flexible pavement. This makes it a preferred choice especially in developing countries like Nigeria which have limited financial strength. The problem of having to make frequent budgetary allocations for the maintenance and rehabilitation of failed flexible pavements will be avoided. Similarly, rigid pavement is reported to perform better than flexible pavement in terms of resistance to harsh tropical weather conditions and the unpleasant phenomenon of overloading (Taher *et al*., 2020; Mohod and Kadam, 2016; Rajput, 2020). These two issues are very common in developing countries like Nigeria. This is because, rigid pavement, due to its stiffness, is less susceptible to deformation and rutting (holds its shape better) than flexible pavement. Khan and Imam (2021) also concluded that rigid pavement is the optimal choice for developing countries with tropical climate conditions. The authors reported that the best way to ensure the sustainability of national highways is by reducing pavement life cycle cost to a minimum. Dong *et al*. (2023) reported that traffic and environmental effects result in the aging and premature failure of asphalt pavements leading to their early deterioration of performance.

4.0 Conclusions

The aim of this paper is to explore the strengths and weaknesses of flexible and rigid road pavements under overloading and harsh tropical environmental conditions with a view to providing decision support guidelines for selecting a pavement type for Nigerian roads. To achieve this, the socio-economic importance of transportation infrastructure in general, and road transport in particular, were identified. Peer-reviewed extant literature not more than 10 years related to the subject matter were accessed via Google Scholar, Scopus and Web of Science databases. Comparative attributes of flexible and rigid road pavements were analysed in tabular format using findings from the extant literature accessed. These attributes were used to discuss the suitability of the pavements for selection based on sustainability and resilience criteria. Based on the results synthesised from extant literature, this research review concludes that rigid road pavement performs better than flexible road pavement from the stand points of sustainability and resilience performance criteria.

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