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Evaluating The Impacts of Speed Bumps on Pavement Condition

Annune Jighjigh Eric[1, *], Abimiku Yohanna Kigbu[1], Ahmed Yakubu Ahmed[2], Odetora Dauda Adesola[1], Umeobika Ndilichukwu Mendez[1] and Ogedoh Tule Innocent[3]

[1]*Department of Science Laboratory and Instrumentation Research, Nigerian Building and Road Research Institute (NBRRI), Nigeria.*

[2]*Department of Road Research, Nigerian Building and Road Research Institute (NBRRI), Nigeria.*

[3]*Department of Engineering Materials Research, Nigerian Building and Road Research Institute (NBRRI), Nigeria.*

**Corresponding author*: ericjighjigh@gmail.com, *ORCiD:* 0000-0002-6422-4834

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***Abstract*—Speed bumps are a common traffic calming measure used to reduce vehicle speeds and improve safety. However, installing speed bumps without adherence to recommended standards can lead to additional problems, such as increased wear and tear on both vehicles and the road surface. This study investigates the impacts of speed bumps on Pavement Condition Index (PCI), focusing on surface roughness, cracking, and rutting. For this purpose, five asphalt-paved roads in Benue State were selected, including Makurdi–Aliede, Gboko-Ugbema, Makurdi-Gboko, Vandeikya-Tsar, and SRS–JOSTUM Southcore. Each site was divided into sections, and PCI values were calculated based on various distress types such as longitudinal cracking, block cracking, and rutting. The results indicated significant pavement deterioration near the speed bumps, with PCI values dropping to 18 on the Makurdi–Aliede road and to 10 on the Gboko-Ugbema road in sections directly after the bumps. Rutting was found to be the dominant distress type, particularly in the sections closest to the bumps. However, the effect of speed bumps on PCI values was minimal on the SRS–JOSTUM Southcore road, where traffic is lighter and dominated by smaller vehicles. These findings suggest that careful consideration should be given to the design and installation of speed bumps, especially on roads with high traffic volumes, to prevent accelerated pavement deterioration.**

Keywords*—Speed bumps, Pavement Condition, Traffic Calming, Pavement deterioration, Surface roughness.

I. INTRODUCTION

Intercity roads in Nigeria are vital for economic growth, connecting regions and enabling the transportation of goods and people across the country. As these roads facilitate significant economic and social activities, ensuring their safety and longevity is critical. One common method of traffic calming used on these roads is the installation of speed bumps, primarily aimed at controlling vehicle speeds to reduce accidents and enhance safety. However, the widespread installation of speed bumps, particularly on intercity roads, has become a growing concern. Many of these speed bumps are installed indiscriminately and without proper engineering assessments, leading to a variety of unintended consequences [1, 2].

Speed bumps, when appropriately designed and installed, are meant to control vehicle speeds in residential and urban areas. However, in Nigeria, these speed control measures are often placed outside village and city limits without clear justification. Their placement on major intercity roads has raised several concerns regarding road infrastructure, vehicle performance, and pavement integrity. The absence of adequate signage, proper design, and appropriate materials has exacerbated issues such as increased travel time, vehicle damage, passenger discomfort, and, most significantly, pavement deterioration [3, 4].

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Pavement deterioration, characterized by surface cracking, rutting, and potholing, is a critical problem on Nigerian roads. The National Bureau of Statistics (NBS) highlights speed violations as a leading cause of road crashes and emphasizes that speed breakers should be used judiciously, specifically in areas where speeding contributes to accidents [5]. Despite guidelines from organizations like the Institute of Transportation Engineers [6] on proper speed bump installation, including considerations for high-speed roads, these guidelines are often neglected. As a result, many speed bumps on intercity roads are poorly constructed, which has contributed to accelerated pavement failure and increased maintenance costs.

This research focuses on evaluating the effects of speed bumps on pavement deterioration in Nigeria, particularly on intercity roads. By investigating the characteristics of speed bumps, their improper design, and the stresses they introduce to road surfaces, this study aims to identify how these factors contribute to the weakening and damage of road infrastructure. Additionally, this study will assess the impact of factors such as high-speed vehicle passage and substandard construction materials, which have further aggravated pavement deterioration in Benue State, Nigeria.

II. RESEARCH METHODOLOGY

This study evaluated the effects of speed bumps on pavement deterioration along five selected intercity roads in Benue State, Nigeria, as detailed in Table I. These roads were purposively selected based on their high traffic volumes and geographic diversity to ensure representative sampling. Speed bumps were identified using a random sampling technique from a comprehensive inventory of all speed bumps present on the selected roads, resulting in a total of fifteen (15) speed bumps inspected. Data collection involved systematic visual inspections complemented by precise measurements. Pavement distress types including cracking, potholes, rutting, and surface wear were identified and documented using standardized distress rating scales (see Fig. 2). Dimensional measurements of speed bumps and adjacent pavement sections were taken using a laser distance meter (Bosch GLM 50 C) and a digital caliper to ensure accuracy. Additionally, a GPS device (Garmin GPSMAP 64) was used to geolocate each speed bump for spatial analysis as presented in Fig. 3. All measurements were cross-validated through repeated trials and inter-observer reliability checks to minimize errors and enhance data validity. The collected data were then analyzed to assess the impact of speed bumps on pavement integrity quantitatively and qualitatively.

Key parameters, such as distress quantity, distress density, and severity, were evaluated for each speed bump site. The severity of the pavement distress was categorized, and key indices like Deduct Value (DV), Mean Condition Deduct Value (MCDV) were calculated using Eqs. (1) and (2)[7], and Pavement Condition Index (PCI) were computed following the ASTM D6433-20 [8] standard practice as presented in Fig. 1 to ensure internationally accepted consistency in condition rating. The deduct value represents the numerical impact of each observed pavement distress type, calculated based on severity and extent.

$$DV = \left(\frac{Distress\ Severity\ Rating}{100}\right) X\ Distress\ Quality \quad (1)$$

$$MCDV = \frac{\sum_{i=1}^{n} DV_i}{n} \quad (2)$$

, where

DV_i is the deduct value for each distress type.

n is the total number of distress types observed at the sit.

Table I. Summary of selected road.

Site No	*Location*	*No. of Speed bumps studied*	*No. of Sections*	*Length of Road (m)*	*Average Bump height (m)*	*Average Bump width (m)*
1	*Makurdi - Aliede*	*3*	*4*	*45700*	*0.06*	*0.29*
2	*Gboko-Ugbema*	*3*	*4*	*59200*	*0.17*	*0.31*
3	*Makurdi-Gboko*	*2*	*3*	*88100*	*0.08*	*0.25*
4	*Vandeikya- Tsar*	*2*	*3*	*16200*	*0.07*	*0.32*
5	*SRS – JOSTUM South-core*	*2*	*3*	*6600*	*0.06*	*0.20*

Table II. Surveying and PCI results for site 1.

Section No.	*Station*	*Distress Type*	*Distress Quantity*	*Distress Density*	*Severity*	*Deduct Value*	*MCDV*	*PCI*
1	*100-150m before bump*	*Longitudinal cracking*	*22 m*	*8.8*	*Low*		*20*	*80 Satisfactory*
		Block cracking	*100 m^2*	*40*	*Low*	*16*		
		Transverse cracking	*8 m*	*3.2*	*Medium*	*5*		
		Alligator cracking	*10 m^2*	*4*	*Medium*	*6*		
		Rutting	*0 m^2*	*0*	*Low*	*0*		
2	*50-100m before bump*	*Longitudinal cracking*	*20 m*	*8*	*Low*	*1*	*52*	*48 Poor*
		Block cracking	*76 m^2*	*15.25*	*Low*	*12*		
		Transverse cracking	*2 m*	*0.40*	*High*	*4*		
		Alligator cracking	*30 m^2*	*6*	*Medium*	*26*		
		Rutting	*44 m^2*	*12*	*Medium*	*48*		
3	*0-50m before bump*	*Longitudinal cracking*	*48 m*	*8.8*	*Medium*	*15*	*60*	*40 Very poor*
		Block cracking	*108 m^2*	*26*	*Low*	*11*		
		Transverse cracking	*6.5 m*	*2.6*	*High*	*9*		
		Rutting	*140 m^2*	*56*	*High*	*65*		
		Alligator cracking	*20 m^2*	*8*	*Medium*	*10*		
4	*0-50m after bump*	*Longitudinal cracking*	*60 m*	*24*	*Low*	*8*	*82*	*18 Serious*
		Block cracking	*0 m^2*	*0*	*Low*	*0*		
		Rutting	*164 m^2*	*65.6*	*High*	*88*		
		Transverse cracking	*4 m*	*1.6*	*High*	*7*		
		Alligator cracking	*23 m^2*	*9.2*	*Medium*	*28*		

Table III. Surveying and PCI results for site 2.

Section No.	*Station*	*Distress Type*	*Distress Quantity*	*Distress Density*	*Severity*	*Deduct Value*	*MCDV*	*PCI*
1	*100-150m before bump*	*Longitudinal cracking*	*24 m*	*9.6*	*Low*	*4*	*26*	*74 Satisfactory*
		Block cracking	*120 m^2*	*48*	*Low*	*16*		
		Transverse cracking	*10 m*	*4*	*Medium*	*5*		
		Alligator cracking	*6 m^2*	*2.4*	*Medium*	*6*		
		Rutting	*0 m^2*	*0*	*Low*	*0*		
2	*50-100m before bump*	*Longitudinal cracking*	*16 m*	*6.4*	*Low*	*1*	*58*	*42 Poor*
		Block cracking	*45 m^2*	*18*	*Low*	*12*		
		Transverse cracking	*5 m*	*2*	*High*	*4*		
		Alligator cracking	*25 m^2*	*10*	*Medium*	*26*		
		Rutting	*30 m^2*	*12*	*Medium*	*48*		
3	*0-50m before bump*	*Longitudinal cracking*	*26 m*	*10.4*	*Medium*	*15*	*63*	*25 Very poor*
		Block cracking	*102 m^2*	*40.8*	*Low*	*11*		
		Transverse cracking	*6.5 m*	*1.875*	*High*	*9*		
		Rutting	*170 m^2*	*68*	*High*	*65*		
		Alligator cracking	*16 m^2*	*6.4*	*Medium*	*10*		
4	*0-50m after bump*	*Longitudinal cracking*	*40 m*	*16*	*Low*	*8*	*90*	*10 Serious*
		Block cracking	*20 m^2*	*8*	*Low*	*10*		
		Rutting	*151 m^2*	*60.4*	*High*	*88*		
		Transverse cracking	*14 m*	*5.6*	*High*	*7*		
		Alligator cracking	*20 m^2*	*8*	*Medium*	*28*		

Table IV. Summary of PCI for site 3-5.

Site No.	***No. of Bumps Studied***	***Location Section with Respect to Speed Bump***		
		Faraway	***50 m before***	***50 m after***
3	*2*	*92.5*	*48*	*50*
4	*3*	*84*	*56*	*44*
5	*3*	*88*	*74*	*90*

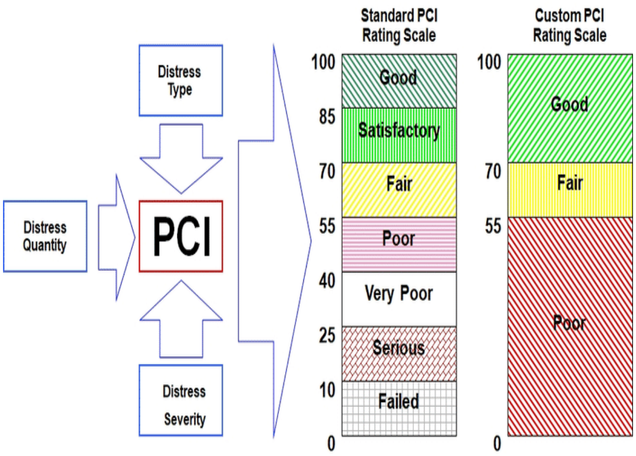

Fig. 1. Pavement condition (PCI) rating scale.

Fig. 2. A Typical speed bump on the studied road.

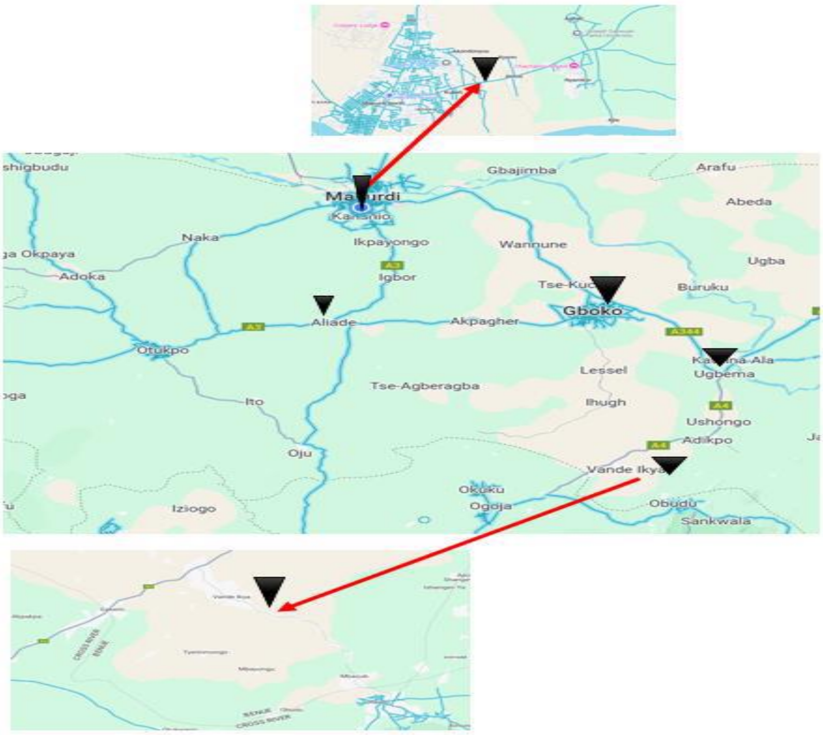

Fig. 3. A GPS map indicating the location of the studied roads.

II. RESULTS AND DISCUSSION

Table I presents a summary of the selected roads where the effects of speed bumps on pavement were studied. Five intercity roads in Benue State, Nigeria, were examined, with the number of speed bumps, road sections, and key speed bump characteristics (height and width) documented for each location.

The results from Site 1 as presented in Table II indicate significant pavement deterioration, particularly in the areas closest to the speed bumps. As observed, the pavement condition worsens as the distance to the speed bump decreases. In Section 1 (100-150 m before the bump), the Pavement Condition Index (PCI) is 80, indicating a satisfactory condition with low severity distress like longitudinal and block cracking. However, in Section 2 (50-100 m before the bump), the PCI drops to 48, signifying a poor pavement condition. This section shows increased quantities of distress, such as medium-severity rutting and alligator cracking, which heavily contribute to the lower PCI.

In Section 3 (0-50 m before the bump), the PCI declines further to 40, categorized as very poor, with severe rutting (140 m^2) and multiple distress types, including alligator and transverse cracking. The most damaged section is directly after the bump (Section 4), where the PCI is 18, indicating a serious condition. The high deduct values for rutting (164 m^2) and alligator cracking suggest that the repeated loading and abrupt forces exerted by vehicles going over the bump significantly degrade the pavement.

Site 2 as shown in Table III exhibits a similar pattern of pavement deterioration near the speed bumps. In Section 1 (100-150 m before the bump), the PCI is 74, indicating a satisfactory condition with relatively low severity distress like longitudinal cracking and block cracking. However, the PCI drops to 42 in Section 2 (50-100 m before the bump), where distress severity increases, particularly with medium rutting and alligator cracking. In Section 3 (0-50 m before the bump), the PCI further declines to 25, which is classified as “very poor”. The significant presence of high-severity rutting (170 m^2) and alligator cracking suggests considerable pavement distress due to vehicle load concentration near the bump.

In Section 4 (0-50 m after the bump), the PCI reaches its lowest value of 10, marking an extremely serious condition. Here, rutting (151 m^2) and alligator cracking dominate the pavement distress, reflecting the intense stress exerted on the road as vehicles pass over the bump.

The summary for Sites 3-5 as presented in Table IV shows a clear trend in pavement condition worsening as the distance to the speed bump decreases. For instance, in Site 3, the PCI drops from 92.5 in the faraway section to 50 in the section directly after the bump. This pattern is consistent across all sites, with the pavement in sections immediately before and after speed bumps experiencing the most deterioration. The repeated vehicle loading, especially at higher speeds, concentrates stress on the pavement near the speed bumps, leading to quicker deterioration in these areas.

The results from Site 1 and Site 2, which indicate significant pavement deterioration near speed bumps, align with findings from previous studies on the effects of speed bumps on road conditions. Literature validates the observed trend of increasing pavement distress near speed bumps, as several studies have highlighted the direct impact of speed control devices on pavement health.

References [1, 9, 10 – 12] noted that speed bumps are a significant cause of localized pavement deterioration, particularly when installed without proper engineering designs. Bekheet’s study highlighted that the constant braking and acceleration forces exerted by vehicles approaching speed bumps lead to the formation of distresses such as cracking, rutting, and potholes, especially in the sections closest to the bump. This aligns with the findings at Site 1, where the Pavement Condition Index (PCI) dropped from 80 in the area farthest from the bump to 18 in the section directly after the bump, where vehicle loading is most concentrated.

References [2, 4, 13] also highlighted the issue of pavement damage caused by speed bumps, particularly the formation of severe rutting and cracking in sections near speed bumps. The study emphasized that vehicles, particularly heavy ones, exert more pressure on the road surface when encountering speed bumps, leading to accelerated pavement deterioration. The results from Site 2, where the PCI dropped to 10 immediately after the bump, support Hallmark's observations of severe pavement damage concentrated near speed control devices. The study further stressed that poor drainage around speed bumps exacerbates the pavement's degradation, a factor that may also contribute to the significant rutting observed in this research.

Furthermore, studies by refs. [13 - 15] have shown that speed bumps significantly increase vertical pavement strain, especially in areas immediately adjacent to the bumps. These sections experience concentrated stress due to the repeated loading and unloading of vehicle weight. This observation aligns with the findings at Site 1 and Site 2, where pavement conditions deteriorated most severely near the speed bumps. The severity of this deterioration is influenced by both vehicle weight and approach speed. Heavier vehicles impose greater static and dynamic loads, particularly during deceleration and acceleration over the bumps. At higher speeds, the resulting impulse forces are amplified; leading to more pronounced rutting and fatigue cracking. This trend was notably observed on the Makurdi–Aliede and Gboko–Ugbema roads, which experience high volumes of heavy truck traffic.

Our findings align [2] where PCI values dropped sharply in the vicinity of poorly designed speed humps. However, unlike [1] study where light-duty vehicles dominated traffic, Benue's roads carry a significant volume of heavy vehicles, accelerating damage. Furthermore, the prevalence of inadequate drainage and substandard materials in Nigeria likely exacerbates these effects compared to well-regulated systems in developed countries.

IV. CONCLUSION

The PCI results across all sites indicate that pavement condition worsens as the distance to the speed bumps decreases, with the sections immediately before and after the bumps being the most affected. High-severity distresses such as rutting, alligator cracking, and transverse cracking are particularly prevalent near the speed bumps, where the repeated vehicle impact and braking forces lead to concentrated stress on the pavement. Indiscriminate installation of speed bumps, without proper engineering design, significantly accelerates pavement deterioration, as seen in the sharp decline in PCI scores around the bumps. The findings suggest that improper speed bump design and installation are major contributors to road failure on intercity roads in Nigeria, particularly in Benue State.

To mitigate pavement degradation caused by speed bumps, this study recommends the adoption of engineering interventions such as the use of high-performance asphalt mixtures (e.g., polymer-modified asphalt), reinforced pavement layers, and geosynthetic materials to enhance pavement durability. Additionally, speed bump designs should be improved by employing sinusoidal or parabolic profiles instead of abrupt trapezoidal forms, which can reduce dynamic loading and stress concentrations on the pavement. Incorporating effective drainage systems around speed bumps is also essential to minimize moisture-induced damage and rutting. Furthermore, international best practices such as rubberized speed cushions used in the UK and modular speed tables implemented in the US offer effective alternatives that combine traffic calming benefits with pavement preservation.

From a policy perspective, it is imperative that road authorities develop and enforce standardized guidelines for speed bump design, installation, and maintenance, integrating these engineering solutions to prolong pavement life and enhance road safety. Overall, implementing these recommendations will minimize pavement deterioration, improve road longevity, and contribute to more sustainable intercity road infrastructure in Nigeria.

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