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Evaluation of Drainage Condition as a Cause of Pavement Deterioration on Selected Roads In Ilorin, Nigeria

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ABSTRACT

Poor drainage is an important factor associated with pavement deterioration in urban road networks. This study evaluated drainage condition and its relationship with pavement deterioration along five selected road corridors in Ilorin, Kwara State, Nigeria. Field assessment covered drainage geometry, slope, blockage, structural condition and flow behaviour, together with pavement distress, chainage and hydraulic performance. Drainage Condition Index (DCI) and Pavement Deterioration Index (PDI) were used for comparative assessment, while estimated runoff was compared with drainage conveyance capacity. DCI ranged from 25 to 78 and PDI from 25 to 85. Akerebiata-Sobi recorded the poorest drainage condition (DCI = 25), highest deterioration (PDI = 85) and about 60% affected pavement area. Fate Roundabout-Sango recorded the best drainage condition (DCI = 78), lowest deterioration (PDI = 25) and about 15% affected area. Potholes and cracking accounted for 25% and 20% of observed distress types, respectively, while poor maintenance and siltation/sediment deposition represented 25% and 20% of identified drainage deficiencies. Hydraulic comparison showed inadequate capacity on Sango-Kwara Polytechnic Gate, Royal Valley-Akerebiata, Akerebiata-Sobi and Maraba-Fate Roundabout roads; Fate Roundabout-Sango was adequate. The findings indicate an association between poorer drainage and greater pavement deterioration, but drainage is not the sole cause of failure. Integrated drainage rehabilitation, routine desilting, hydraulic upgrading, culvert/outfall maintenance and chainage-based monitoring are recommended.

Keywords: road drainage; pavement deterioration; Drainage Condition Index; Pavement Deterioration Index; hydraulic capacity; chainage; Ilorin.

I. INTRODUCTION

Road pavement performance is governed by the interaction of traffic loading, pavement materials, structural design, environmental exposure, construction quality and water management. Water entering or remaining within pavement systems can reduce the support provided by underlying materials and accelerate moisture-related distress; drainage is therefore an integral consideration in pavement design and performance assessment (AASHTO, 1993; Huang, 2004).

In urban corridors, inadequate side drainage, blocked inlets and outfalls, sediment accumulation and poor hydraulic continuity can increase the duration and extent of water contact with the pavement. The present study was motivated by recurring pavement deterioration observed on selected roads in Ilorin, Kwara State, and focused on whether the observed drainage condition was associated with the distribution and severity of pavement distress.

The objectives were to assess drainage condition on selected roads; identify pavement distress types and severity; identify major drainage deficiencies; examine the relationship between drainage condition and pavement deterioration; and propose engineering measures for improving drainage performance. The interpretation is deliberately cautious: drainage is treated as a contributing factor rather than the sole cause of pavement failure because traffic loading, pavement age, material quality, construction defects, subgrade characteristics and maintenance can also influence deterioration (AASHTO, 1993; Huang, 2004).

Drainage condition is a critical factor influencing the structural and functional performance of pavement systems because the presence and movement of water within pavement layers can substantially reduce their strength and durability. Inadequate drainage allows rainfall and surface runoff to accumulate or infiltrate through cracks, pavement edges, joints and other openings, resulting in prolonged moisture exposure of the base, subbase and subgrade. Excess moisture can reduce the stiffness and bearing capacity of unbound pavement materials, promote erosion and migration of fines, and contribute to deformation, rutting, cracking and pothole development. The Federal Highway Administration identifies adequate drainage and rapid removal of infiltrated water as essential measures for minimizing moisture-related pavement deterioration.

Recent studies further demonstrate the relationship between drainage, moisture and pavement deterioration. Bayou, Lemu and Fenta (2025), for example, reported that effective drainage is essential for rapidly removing moisture from pavement and protecting pavement integrity. Similarly, Apanpa, Adesope and Apanpa (2025), in a study of the Agbaje–Ijokodo residential road in southwestern Nigeria, identified poorly designed, undersized and blocked drainage systems as contributing factors to premature pavement distress alongside inadequate pavement thickness and weak subgrade conditions. A recent review by Albayati and Ismael (2025) also emphasizes that moisture damage is a major mechanism of asphalt pavement deterioration and that poor rainwater drainage can intensify water accumulation and associated damage.

Therefore, deterioration of drainage facilities—through blockage, inadequate dimensions, insufficient slope, discontinuity, poor hydraulic capacity or lack of maintenance—can accelerate pavement deterioration, particularly in areas exposed to intense or prolonged rainfall. In southwestern Nigeria, where seasonal flooding and high rainfall can interact with weak or moisture-sensitive pavement materials, effective drainage is consequently an important consideration in maintaining pavement serviceability and extending pavement life.

II. MATERIALS AND METHODS

2.1 Study Area and Selected Corridors

The study was conducted in Ilorin metropolis, Kwara State, Nigeria. Five road corridors were investigated: Sango–Kwara Polytechnic Gate Road, Royal Valley–Akerebiata Road, Akerebiata–Sobi Road, Fate Roundabout–Sango Road and Maraba–Fate Roundabout Road. The corridors were selected from the study assessment because of observed pavement deterioration and drainage-related problems.

Table 1. Study corridors and chainage coverage.

Road corridor	Evaluated extent / terminal chainage	Assessment basis
Sango–Kwara Polytechnic Gate	5.20 km; 0+000–5+200	Chainage-based field assessment
Royal Valley–Akerebiata	3.45 km; 0+000–3+450	Chainage-based field assessment
Akerebiata–Sobi	1.525 km evaluated chainage extent; 0+000–1+525	Terminal chainage reported; total GPS length requires confirmation
Fate Roundabout–Sango	1.05 km; 0+000–1+050	Chainage-based field assessment
Maraba–Fate Roundabout	1.15 km; 0+000–1+150	Chainage-based field assessment

2.2 Field Data Collection

Field investigations were conducted between May 2025 and August 2026 on five selected roads in Ilorin, Kwara State: Royal Valley–Akerebiata Road, Akerebiata–Sobi Road, Sango–Kwara Polytechnic Gate Road, Fate Roundabout–Sango Road, and Maraba–Fate Roundabout Road. The fieldwork comprised preliminary reconnaissance, selection of study locations, drainage-condition assessment, pavement-distress surveys, dimensional measurements, GPS referencing, photographic documentation, and repeated verification of critical locations.

Primary data were obtained through direct field inspection, engineering measurements, and photographic documentation. Initial reconnaissance and baseline observations were undertaken between May and August 2025 to identify drainage deficiencies and visible pavement failures. Detailed field assessments were subsequently conducted at 25 m chainage intervals, including measurements of drain width and depth using a measuring tape and determination of longitudinal gradient from level measurements. GPS and spatial referencing were used to establish road locations and chainages.

Drainage observations included drain type, dimensions, longitudinal slope, blockage and siltation, vegetation, structural condition, flow continuity, stagnant water, and evidence of overflow. Pavement-condition assessments focused on potholes, cracking, rutting, edge failure, depressions, shoulder failure, and settlement, with each distress classified according to its observed severity and approximate affected area. Photographs were taken to document representative drainage deficiencies and pavement distress, while critical locations were revisited for verification and consistency of measurements.

2.3 Drainage Condition Index (DCI)

The Drainage Condition Index (DCI) was developed to quantitatively assess the functional and physical condition of drainage facilities along the selected roads. Five parameters were evaluated: drainage continuity, blockage, structural condition, flow condition, and drainage adequacy/design. Each parameter was assigned a score from 1 to 5, where 1



represented failed/very poor condition and 5 represented excellent condition. Equal weighting was applied to all parameters, and the overall DCI was calculated as:

$$DCI = \frac{\sum Si}{\sum 5n} \times 100$$

where S_i is the score assigned to each parameter and $5n$ is the number of parameters assessed. The resulting index ranges from 20% to 100% and was classified as excellent (80–100%), good (60–79%), moderate (40–59%), poor (20–39%), and failed/very poor ($\leq 19\%$). The calculated DCI values were 32% for Sango–Kwara Polytechnic Gate, 45% for Royal Valley–Akerebiata, 25% for Akerebiata–Sobi, 78% for Fate–Sango, and 56% for Maraba–Fate. These results demonstrate considerable variation in drainage condition, with lower DCI values generally associated with blockage, structural deterioration, restricted flow, sediment accumulation, and stagnation.

2.4 Pavement Deterioration Index (PDI)

The Pavement Deterioration Index (PDI) was used to quantify the extent and severity of pavement distress along the selected road sections. Major distress types, including potholes, cracking, rutting, surface deformation, settlement, and edge failure, were identified through field inspection. Each distress was assigned a severity score from 1 (very low) to 5 (very high), while the affected pavement area was determined from measured or estimated distress dimensions. The percentage affected area was calculated as $P_a = (A_d/A_t) \times 100$, where A_d is the distressed area and A_t is the total surveyed pavement area. The PDI was then obtained by combining distress severity and affected area, with equal weighting applied to the distress categories:

$$PDI = \frac{\sum W_i S_i P_i}{\sum W_i}$$

where W_i , S_i , and P_i represent the weighting factor, severity score, and affected-area proportion, respectively. PDI values were interpreted as excellent (0–20%), good (21–40%), moderate (41–60%), poor (61–80%), and very poor/critical (81–100%), with higher values indicating greater pavement deterioration. The calculated PDI values ranged from 25% to 85%, with Akerebiata–Sobi recording the highest deterioration (85%) and Fate–Sango the lowest (25%).

2.5 Hydraulic Assessment

Runoff and Drainage Capacity Estimation

Peak surface runoff was estimated using the Rational Method:

$$Q_r = 0.278 C I A$$

where Q_r is peak runoff (m^3/s), C is the runoff coefficient, I is rainfall intensity (mm/h), and A is the contributing catchment area (km^2). The hydraulic capacity of the existing drains was estimated using Manning's equation:

$$Q_c = \frac{1}{n} A R h^{2/3} S^{1/2}$$

where Q_c is drainage capacity (m^3/s), n is Manning's roughness coefficient, A is flow area, $R_h = A/P$ is the hydraulic radius, and SS is the longitudinal drain slope. For rectangular drains, $A = by$ and $P = b + 2y$, while slope was calculated as $S = \Delta h / LS$. The analysis assumed steady, uniform flow, representative channel dimensions and slope, appropriate roughness coefficients, and spatially uniform rainfall over relatively small catchments.

Drainage adequacy was evaluated using the capacity ratio: $R = \frac{Q_c}{Q_r}$. A section was classified as adequate when $R \geq 1.00$, inadequate when $0.50 \leq R < 1.00$, and highly inadequate when $R < 0.50$. The estimated runoff/capacity values were 2.8/1.9, 2.1/1.5, 2.4/1.2, 1.7/2.5, and 2.0/1.8 m^3/s for Sango–Kwara Polytechnic Gate, Royal Valley–Akerebiata, Akerebiata–Sobi, Fate–Sango, and Maraba–Fate, respectively. These results indicate inadequate hydraulic capacity on the first three sections and Maraba–Fate, while Fate–Sango had sufficient capacity.

2.6 Statistical Analysis and Correlation

Descriptive statistics, percentages and comparative analysis were used to summarise the field observations. The thesis reports an inverse DCI–PDI correlation of $r = -0.89$. This coefficient is not retained as a verified inferential result in this journal version because the original calculation sheet was not supplied and the five displayed DCI/PDI pairs reproduce a different Pearson coefficient (approximately -0.997). The revised manuscript therefore describes the observed inverse pattern without reporting an unverified correlation coefficient. If the original dataset confirms a coefficient, the author should insert the verified value together with the sample size (n), Pearson procedure and exact variables used.



III. RESULTS

3.1 Drainage Characteristics

Table 2. Observed drainage characteristics of the selected road sections.

Road section	Drain type	Mean depth (cm)	Mean width (cm)	Slope (%)	Major blockage	Flow	Structural condition
Sango–Kwara Polytechnic Gate	Open concrete	110	85	1.2	Sediment/refuse	Restricted/stagnant	Poor
Royal Valley–Akerebiata	Earth drain	80	87.5	1.0	Vegetation/siltation	Restricted	Fair
Akerebiata–Sobi	Blocked/collapsed	72.5	90	0.8	Debris/collapse	Stagnant	Poor
Fate Roundabout–Sango	Open concrete	75	80	1.5	Minor sand	Free flow	Good
Maraba–Fate Roundabout	Lined open drain	65	130	1.4	Waste/siltation	Restricted	Fair

Drainage performance varied substantially. Akerebiata–Sobi had the lowest recorded slope (0.8%), stagnant flow and blocked/collapsed sections. Sango–Kwara Polytechnic Gate had relatively deep drains but high blockage from sediment and refuse. Fate Roundabout–Sango recorded the highest slope (1.5%), low blockage, free flow and good structural condition.

3.2 Drainage and Pavement Indices

Table 3. Drainage Condition Index and Pavement Deterioration Index results.

Road section	DCI	Drainage rating	PDI	Affected pavement area (%)
Sango–Kwara Polytechnic Gate	32	Poor	78	48
Royal Valley–Akerebiata	45	Fair	62	35
Akerebiata–Sobi	25	Very poor	85	60
Fate Roundabout–Sango	78	Good	25	15
Maraba–Fate Roundabout	56	Moderate	54	38

Akerebiata–Sobi recorded the poorest drainage condition and the highest pavement deterioration, whereas Fate Roundabout–Sango recorded the best drainage condition and the lowest deterioration. The comparison indicates an inverse field pattern between drainage condition and pavement deterioration, but the small number of corridors limits statistical generalisation.

3.3 Pavement Distress Characteristics

Table 4. Dominant pavement distress and affected area.

Road section	Dominant distress	Severity	Affected area (%)
Sango–Kwara Polytechnic Gate	Rutting and severe cracking	High	48
Royal Valley–Akerebiata	Longitudinal cracks and potholes	Moderate	35
Akerebiata–Sobi	Potholes and settlement	Very high	60
Fate Roundabout–Sango	Minor surface cracks	Low	15
Maraba–Fate Roundabout	Edge failure and depression	Moderate	38

Across the observed distress categories, potholes accounted for 25%, cracking 20%, rutting 15%, edge failure 15%, depression 10%, shoulder failure 10% and settlement 5%.



Table 5. Relative frequency of identified drainage deficiencies.

Observed drainage deficiency	Percentage (%)
Poor maintenance	25
Siltation and sediment deposition	20
Refuse dumping	15
Inadequate drain capacity	15
Vegetation growth	10
Structural collapse of drains	10
Improper drain alignment	5

3.4 Hydraulic Performance

Table 6. Hydraulic performance of the existing drainage systems.

Road section	Estimated runoff (m ³ /s)	Drain capacity (m ³ /s)	Source assessment
Sango–Kwara Polytechnic Gate	2.8	1.9	Inadequate
Royal Valley–Akerebiata	2.1	1.5	Inadequate
Akerebiata–Sobi	2.4	1.2	Highly inadequate
Fate Roundabout–Sango	1.7	2.5	Adequate
Maraba–Fate Roundabout	2.0	1.8	Slightly inadequate

Akerebiata–Sobi had the largest reported capacity deficit (2.4 m³/s runoff against 1.2 m³/s capacity), while Fate Roundabout–Sango was the only section with capacity exceeding estimated runoff. The hydraulic results are consistent with field observations of stagnation, overflow and restricted flow, but the underlying hydrological input parameters require verification from the original calculation sheet before publication.

3.5 Critical Chainage Sections

Table 7. Critical chainage sections and principal observed drainage problems.

Road corridor	Critical chainage	Principal observed problem
Sango–Kwara Polytechnic Gate	0+800–1+800; 3+000–4+200; 4+200–5+200	Blocked drains, low slope, damaged/collapsed drains, silted culverts and obstructed outfalls
Royal Valley–Akerebiata	2+925–3+150; 3+150–3+450	Choked culvert inlets, waste blockage, damaged lining and concentrated junction runoff
Akerebiata–Sobi	0+325–0+400; 0+400–0+620; 0+620–0+900; 0+900–1+250; 1+250–1+525	Blocked culverts, poor slope, siltation/refuse, collapsed drains and multidirectional runoff
Fate Roundabout–Sango	0+500–0+800; 0+800–1+050	Silted drains, blocked outfalls and multidirectional inflow
Maraba–Fate Roundabout	0+100–0+250; 0+450–0+550; 0+700–0+850; 1+000–1+150	Severe blockage, inadequate capacity, failed cross-culvert and multidirectional runoff

IV. FIELD PHOTOGRAPHIC EVIDENCE





Figure 1. Field assessment of a roadside drainage channel..



Figure 2. Surface water accumulation and drainage-related pavement distress.

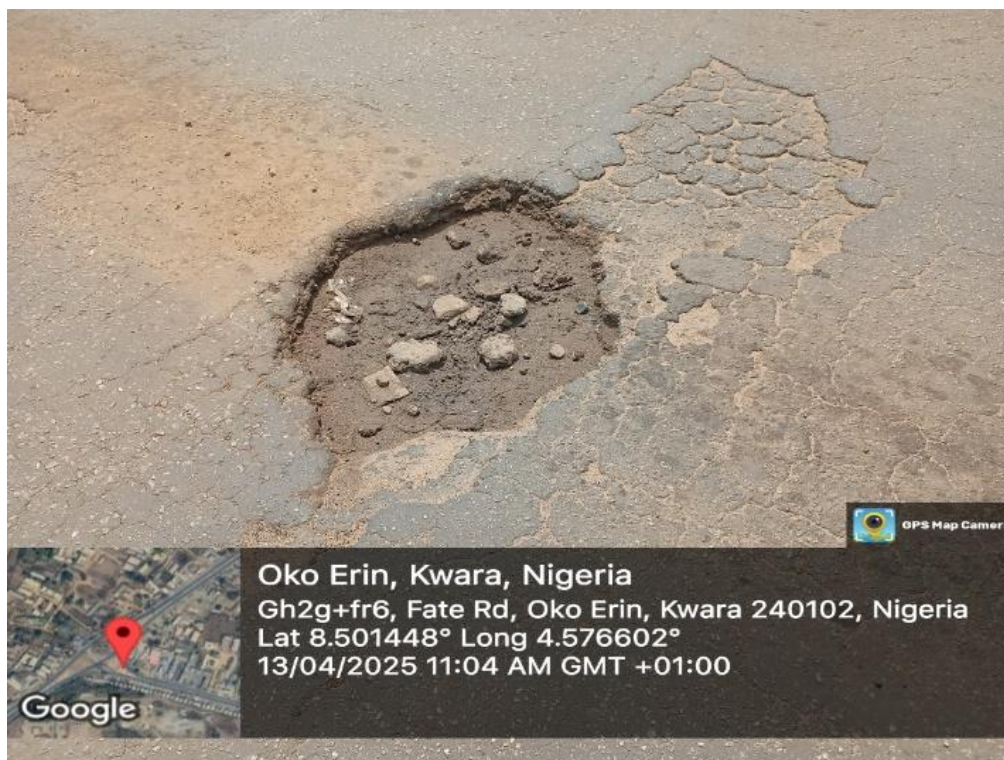


Figure 3. Localised pavement pothole/distress documented during the field survey.

V. DISCUSSION

The findings indicate an inverse relationship between drainage condition and pavement deterioration. Road sections with lower Drainage Condition Index (DCI) values generally recorded higher Pavement Deterioration Index (PDI) values. Akerebiata–Sobi recorded the lowest DCI (25%) and highest PDI (85%), while Fate–Sango recorded the highest DCI (78%) and a relatively low PDI (25%). This pattern suggests that poor drainage was associated with increased pavement distress, although other factors such as traffic loading, pavement materials, construction quality, pavement age and subgrade conditions may also contribute. The hydraulic assessment supports this relationship, as estimated runoff exceeded drainage capacity on Sango–Kwara Polytechnic Gate (2.8/1.9 m³/s), Royal Valley–Akerebiata (2.1/1.5 m³/s), Akerebiata–Sobi (2.4/1.2 m³/s) and Maraba–Fate (2.0/1.8 m³/s). Such hydraulic deficits can promote ponding, overtopping and infiltration of water into pavement layers. Previous studies have established that prolonged moisture exposure can reduce the strength and stiffness of pavement base, subbase and subgrade materials, thereby accelerating cracking, rutting, potholing and structural deterioration (Day, 1995; FHWA, 2005). Conversely, Fate–Sango, where drainage capacity exceeded estimated runoff (2.5/1.7 m³/s), exhibited better drainage and comparatively lower pavement deterioration. Field observations further showed that blockage, sediment accumulation, vegetation, discontinuity and structural deterioration of drains contributed to restricted water flow and surface ponding. Accumulated water can enter pavement through cracks and edges, weaken supporting layers and increase susceptibility to traffic-induced deformation. The combined DCI, PDI and hydraulic results therefore demonstrate that inadequate drainage is an important contributing mechanism in pavement deterioration on the selected roads, while recognizing that pavement failure is influenced by multiple interacting factors.

VI. CONCLUSIONS

- Drainage condition varied considerably among the five selected Ilorin road corridors, with DCI values ranging from 25 to 78.
- Akerebiata–Sobi had the poorest drainage condition (DCI = 25), the highest PDI (85), approximately 60% affected pavement area and the largest hydraulic capacity deficit.
- Fate Roundabout–Sango had the highest DCI (78), lowest PDI (25), approximately 15% affected area and adequate reported drainage capacity.
- Poor maintenance (25%), siltation/sediment deposition (20%), refuse dumping (15%) and inadequate capacity (15%) were the leading identified drainage deficiencies.
- Potholes (25%) and cracking (20%) were the most frequent pavement distress categories in the observed failure distribution.
- The combined field, index, hydraulic and chainage evidence indicates that ineffective drainage is an important contributing factor associated with greater pavement deterioration on the selected corridors, but the study does not establish drainage as the sole cause of pavement failure.

VII. ENGINEERING RECOMMENDATIONS

1. Undertake routine desilting and cleaning of roadside drains, particularly before and during the rainy season.
2. Rehabilitate or reconstruct blocked, collapsed and structurally defective drainage sections at the identified critical chainages.
3. Upgrade drainage capacity where verified peak runoff exceeds the existing conveyance capacity.
4. Clear and maintain culvert inlets, cross-drainage structures and outfalls to prevent water retention and backwater effects.
5. Maintain adequate longitudinal drainage slope and continuity to reduce stagnant flow and ponding.
6. Line unprotected or erosion-prone drains where engineering assessment shows a need for channel and shoulder protection.
7. Control vegetation growth and sediment accumulation through scheduled maintenance inspections.
8. Strengthen solid-waste management around drainage corridors to reduce refuse accumulation in channels.
9. Provide properly designed inlets and outfalls at junctions receiving concentrated or multidirectional runoff.
10. Integrate drainage rehabilitation with pavement repair and establish periodic DCI/PDI-based condition monitoring, prioritising the critical chainage sections identified in the study.

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