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Flexible Pavement Distress Rating of Forestry Road In Oredo LGA, Edo State Using PCI

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***Abstract**: This study examines the flexible pavement distress rating of Forestry road in Oredo LGA, Edo State, using Pavement Condition Index (PCI). Pavement distress refers to the condition of a pavement surface in terms of its general appearance. Distress rating method was carried out based upon visual inspection of observable distresses on Forestry flexible road pavement and was computed based on the summation of the deduct points for each observable distress following the procedure for uniformly identifying distresses in terms of severity and extent according to the American Association Of State Highway and Transportation Officials (AASHTO) road test manual, the condition of the pavement was rated using the PCI scale. The PCI of Forestry road network was determined using the American Standard for Testing Material (ASTM) D6433 standard manual for assessing flexible road pavement condition manually. The distresses identified on forestry flexible pavement road are; raveling, bleeding, patching, potholes, debonding, settlement, wheel track cracking, longitudinal joint cracking and random cracking. Deduct Point for all distresses were obtained by multiplying distress weight times the distress severity weight and distress extent weights. Total deduct point was obtained to be 43.8, and the PCR-56.2% which was rated FAIR TO POOR condition from ASTM D6433 PCI rating scale. The results in this study showed that the distresses on Forestry flexible road pavement were rated and the condition of the pavement evaluated using PCI.*

Keywords: *Deduct Point, Flexible road pavement, Pavement Condition Index (PCI), Pavement Distress and Pavement Condition Rating (PCR)*

I. INTRODUCTION

The existence of road infrastructure is naturally threatened by several deteriorating factors ranging from traffic load, material properties, environmental factors, age of pavement original design of the structure, construction quality, road geometry and maintenance policy [1]. Flexible pavements are an integral part of transportation infrastructure, providing a durable and cost-effective solution for roadways. Over time, these pavements undergo distresses due to various factors such as traffic loads, environmental conditions, and material properties. To ensure the longevity and optimal performance of flexible pavements, it is crucial to assess and manage pavement distress effectively [2].

Pavement surface distresses are manifestations of defects that affect the serviceability, performance, and appearance of pavement. Evaluation and quantification of these distresses is an important aspect in any highway agency's pavement management system PMS. Usually, this is accomplished by rating the pavement surface condition. Surface condition rating has always been a subjective measure but the necessity to quantify this information is being realized by many agencies Ministry of Transportation and Communications [15] [16].

The Pavement Condition Index (PCI) is a widely recognized and standardized method for evaluating the condition of pavements. PCI provides a numerical rating that reflects the overall health of a pavement based on the severity and extent of distresses observed. This assessment method allows transportation agencies and engineers to prioritize maintenance and rehabilitation efforts, ensuring efficient allocation of resources [3].

Flexible pavement distresses encompass a range of issues, including but not limited to, cracking, rutting, potholes, and surface deterioration. The PCI methodology integrates these distresses into a comprehensive index, enabling a systematic and quantitative approach to pavement management [2].

The integration of PCI in the assessment of flexible pavement distress provides a systematic and quantitative approach to pavement management, facilitating informed decision-making and resource allocation for maintenance and rehabilitation activities. This methodology enhances the overall performance and longevity of flexible pavements, contributing to the sustainability of transportation infrastructure [4].

Flexible pavements serve as a critical component of transportation networks, facilitating the efficient movement of vehicles and goods. However, as these pavements are continually subjected to the dynamic forces of traffic loads, environmental conditions, and aging, it becomes imperative to assess and rate their condition systematically [3]. The Pavement Condition Index (PCI) emerges as a robust and widely accepted tool for evaluating the condition of flexible pavements, offering a comprehensive rating system that aids in informed decision-making for maintenance and rehabilitation strategies [5].

The Pavement Condition Index is a numerical scale that quantifies the overall health of a flexible pavement based on the severity and extent of various distress types. This index provides a standardized approach to assess and rate the condition of pavements, enabling transportation agencies and engineers to prioritize interventions and allocate resources efficiently [5].

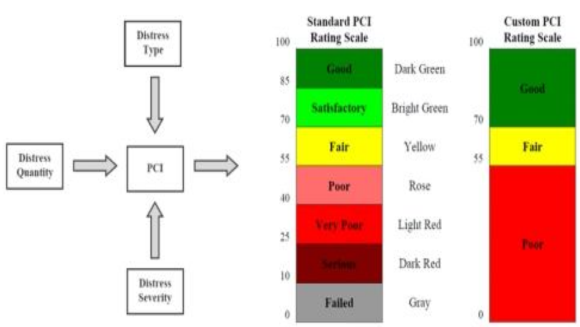

Fig.1: American Society for Testing and Materials (ASTM D6433) PCI Scale

The Pavement Condition Index serves as a vital tool in the rating of flexible pavements, offering a standardized and quantitative metric for assessing their overall condition [5]. This rating system enables transportation professionals to prioritize maintenance and rehabilitation efforts, ensuring the effective management of infrastructure assets [2]. By integrating PCI into pavement rating practices, agencies can enhance the durability and performance of flexible pavements, contributing to the sustainability and resilience of transportation networks [3].

[6] Opined that a pavement rating system tries to capture the observed distresses and deterioration of a pavement segment. The causes of pavement distresses and deterioration are environmental and structural. Environmental induced distresses are due to weathering, moisture, and aging. Loading causes structural induced distresses. Pavement deterioration usually occurs from both loading and weathering.

Pavement condition rating is the process of determining the serviceability of a pavement to the user in its existing condition [8] [13]. Pavement condition index (PCI) has been defined by [14] as a scoring system that measures the pavement’s structural integrity and surface operations condition. It is based on a scale of 0–100.measures the pavement’s structural integrity and surface operations condition. It is based on a scale of 0–100.

Present pavement condition is quantified in terms of either single parameter based index or composite indices. Composite indices or combined measure include the aggregation of individual measures. The most widely used indices by the highway agencies across the globe include Present Serviceability Index (PSI), International Roughness Index (IRI), Riding Comfort Index (RCI), Pavement Condition Index (PCI) and Pavement Quality Index (PQI) [7].

Apart from indices used by agencies there are others developed by researchers as per the requirement and observed deterioration pattern of flexible pavements, which in recent times includes Unified Pavement Distress Index (UPDI) [9], Overall Pavement Condition Index (OPCI) [10], Pavement Performance Index (PPI) for Indian Rural Roads [11]

The objective of this research work is to study and analyze by rating the condition of Forestry road flexible pavement in Oredo LGA, Edo State, Nigeria, using PCI as a rating scale. This study shows the effect of the prevalent climatic condition of Benin City Southern Nigeria on the lifecycle of flexible pavement and the traffic loading in the research study area on flexible pavement distress development.

A. Flexible Pavement Distresses with Severity and Extent Classification [12]

i. Raveling:

Disintegration of the pavement from the surface downward due to the loss of aggregate particles. Raveling may occur as a result of asphalt binder aging, poor mixture quality, segregation, or insufficient compaction [12]

Severity Level:
Low - Very little coarse aggregate has worn away. Loss of fine aggregate. Coarse aggregate exposed.

Medium - Surface has an open texture and is moderately rough with considerable loss of fine aggregate and some coarse aggregate removed.
High - Most of the surface aggregate has worn away or become dislodged. Surface is severely rough and pitted and may be completely removed in places.

Extent level:
Occasional - Less than 20 percent of the surface area is raveling.
Frequent - Between 20 and 50 percent of the surface area is raveling.
Extensive - More than 50 percent of the surface area is raveling**.**

Fig.2: Medium Severity of Raveling Distress in Flexible Pavement [12]

Fig.3: High Severity of Raveling Distress in Flexible Pavement [12]

ii. Bleeding:

Bleeding or flushing is the presence of free asphalt binder on the pavement surface. Bleeding is caused by an excess amount of bituminous binder in the mixture and/or low air void content [12].

Severity Level:
Only 2 severity levels are defined.

Medium - both coarse aggregate and free bitumen are noticeable at the pavement surface.
High - surface appears black with very little aggregate noticeable

Extent level:
Occasional - less than 10 percent of the length exhibits bleeding.
Frequent - between 10 and 30 percent of the length is bleeding
Extensive - bleeding occurs in more than 30 percent of the length.

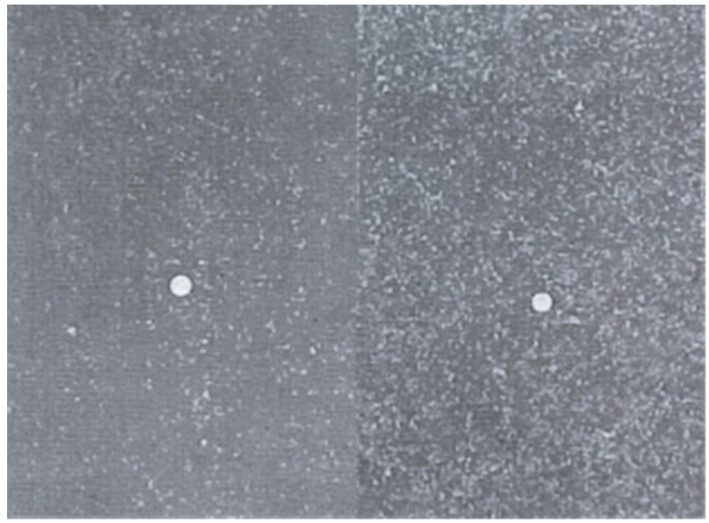

Fig. 4: High Severity of Bleeding Distress in Flexible Pavement [12]

Fig. 5: High and Medium Severity of Bleeding Distress in Flexible Pavement [12]

ii. Patching:
Patching is either the placing of asphalt concrete on the surface of the existing pavement or the replacement of the existing pavement in small isolated areas.

Deductions shall be made for all patches present in the pavement which are the result of deterioration and/or maintenance since the last construction project.
Large patched areas [greater than 15 sq. yd. (12.5 m2)], such as spot overlays or wedge courses, shall be rated for condition as a part of the existing pavement rather than as patches.
If more than one patch size is present, rate the severity of the size that exists in the largest quantity, and rate the extent of the total number of patches present [12].

Severity Level:
Low - patch size < 1 sq. ft. (0.1 m2).
Medium - patch size < 1 sq. yd. (0.8 m2).
High - patch size > 1 sq. yd. (0.8 m2).

Extent level:
Occasional - < 10 patches/mile (per 1.6 km).
Frequent - 10 - 20 patches/mile (per 1.6 km).
Extensive - > 20 patches/mile (per 1.6 km).

Fig.6: High Severity of Patching Distress in Flexible Pavement [12]

Fig.7: High Severity of Patching Distress in Flexible Pavement [12]

iii. Debonding:

Loss of surface by debonding is the removal of the asphaltic surface layer from the underlying layer. The problem is most common with thin asphalt surface layers [less than 2 inches (50 mm)] and is caused by freeze-thaw action or poor bonding of the two layers during construction [12].

Severity Level:

Depth of Debonded Area	**Debonded Area < 1 sq. yd. (0.8 m2)**	**Debonded Area > 1 sq. yd. (0.8 m2)**
< 1" (25 mm)	**Low**	**Medium**
> 1" (25 mm)	**Medium**	**High**

Extent level:
Occasional - < 5 debonded areas/mile (per 1.6 km).
Frequent - 5 - 10 debonded areas/mile (per 1.6 km).

Extensive - > 10 debonded areas/mile (per 1.6 km).

Fig. 8: Medium Severity of Debonding Distress in Flexible Pavement [12]

iv. Potholes:

Potholes are bowl-shaped voids or depressions in the pavement surface.
Potholes are localized failure areas which are usually caused by weak base or subgrade layers [12].

Severity Level:

Depth of Pothole	**Pothole** < 1 sq. yd. (0.8 m2)	**Pothole** > 1 sq. yd. (0.8 m2)
< 1" (25 mm)	**Low**	**Medium**
> 1" (25 mm)	**Medium**	**High**

Regardless of depth, potholes less than 6 inches (150 mm) in diameter shall be considered to be of low severity.

Extent level:

Occasional - < 5 potholes /mile (per 1.6 km).
Frequent - 5 - 10 potholes/mile (per 1.6 km).
Extensive - > 10 potholes/mile (per 1.6 km).

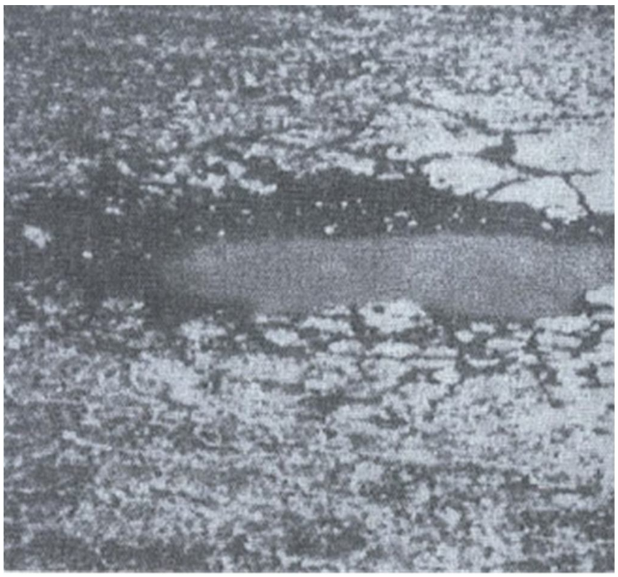

Fig. 9: Medium Severity of Pothole Distress in Flexible Pavement [12]

B. Pavement Condition Rating (PCR)

Pavement Condition Rating (PCR) is a valuable indicator for evaluating the integrity of road surfaces. It involves visual inspection of road sections to determine their condition. PCR serves as a quantifiable measure of road quality. The frequency of road inspections varies based on factors such as road type, for instance, whether it's a primary or secondary road, and traffic volume, measured by Average Annual Daily Traffic (AADT). Regularly conducted, PCR enables systematic monitoring of road deterioration.

The evaluation system depends on the physical assessment of the pavement's damaged state. While the relationship between pavement damage and its performance lacks a precise definition, there is a general consensus that the presence of noticeable distress negatively impacts a pavement's ability to support traffic loads safely and smoothly. This system provides a standardized method to identify and describe the severity and extent of pavement distress. The pavement condition rating (PCR) is a mathematical formula that reflects the combined consequences of various types, severity levels, and extent of distress on the pavement's overall condition. The PCR model is calculated by summing up the deducted points for each observable distress type. Deduct values are determined by the distress type, its severity, and its extent. The deduction for each distress type is calculated by multiplying the distress weight by the weightage assigned to the severity and extent of the distress. Distress weight represents the maximum number of deductible points for each distinct distress type.

The mathematical expression for PCR is shown in the equation below.

$$PCR = 100 - \sum_{i=1}^{n} Deduct$$

Where:
n = number of observable distresses, and
Deduct = (Weight for distress) (Weight for severity) (Weight for Extent).

II. MATERIALS AND METHOD

A. The Sample Location

The study area is located at Oredo local government area of Benin City, Edo State of Nigeria. The coordinates of the rectangular boundary of the study area based on a reference datum –WGS 1984, UTM Projection Coordinate System (zone 31) has the coordinates at the upper left corner to be 789600.000mE, 702350.000mN; upper right corner is 791600.000mE, 702350.000mN; lower left corner is defined by 789600.000m, 700350.000mN and lower right corner is 791600.000mE, 700350.000mN. The terrain is predominantly flat as it lacks significant variation in elevation. From Figure 2 below, the upper right figure shows the map of Edo State, figure at the lower right corner shows the map of Oredo Local Government Area in Edo State and figure at the left hand side shows the map of the study area in Oredo LGA.

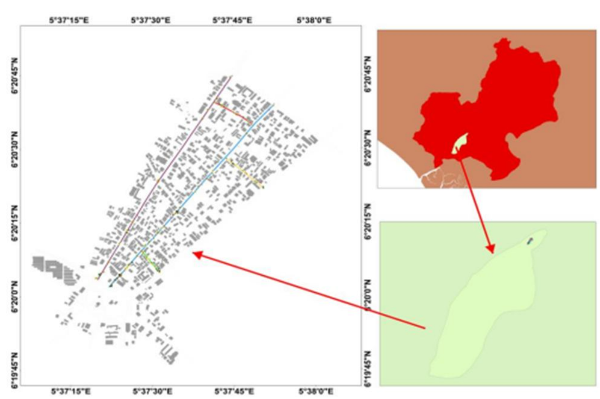

Fig.10: Maps and layout of study area

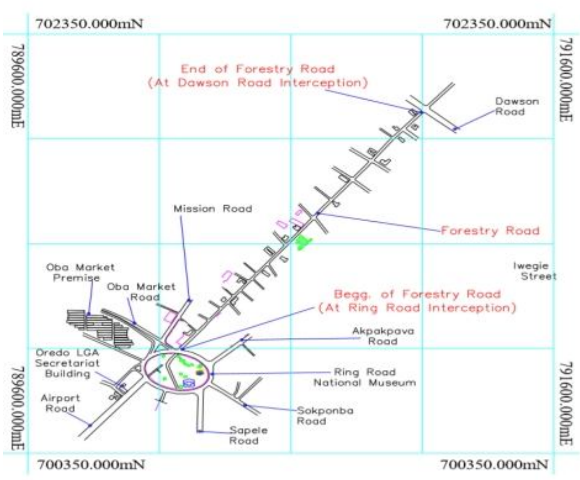

Fig.11: Layout of study area showing Forestry Road and its environs

B. Materials and Methods

The Pavement Distress Survey for the road in this study was performed in tandem with the AASHTO road test manual. A visual conditional survey was conducted by walking through the road length and the distress type and size were identified with their respective severity and extent weights from the AASHTO road test manual.

Distress Rating was performed on the road to obtain the PCR and PCI of the road. The PCR for the road was obtained by the summation of deduct points for each observable distress on the road. Deduct points for each distress was calculated by multiplying the distress weight and weights of the severity and extent of the distress. The total deduct points of all observable defects were summed and subtracted from 100 to obtain the PCR for the road.

The PCR of the road was computed using the equation:

$$PCR = 100 - \sum_{i=1}^{n} Deduct$$

n= number of observable distresses, and
Deduct= (Weight for distress) (Weight for severity) (Weight for Extent).

The numerical value of the PCR obtained for the road in the study was used together with the ASTM D6433 Standard Manual Rating Scale to determine the PCI of the road.

The scale ranges from 0 to 100, where 0 and 100 represent the worst and excellent pavement condition respectively. The PCI assessed the pavement performance and needed rehabilitation strategy for the road.

III. RESULTS AND DISCUSSION

A. Pavement Distress Evaluation Results

The length of Forestry road for this study is 1.46km.The distresses identified on the flexible pavement include: raveling, bleeding, patching, potholes, settlement, wheel track cracking, longitudinal joint cracking and random cracking. The pavement condition rating form for the road is shown in Table 1 below.

Table 1: Pavement Condition Rating of Forestry Road

DISTRESS	DISTRESS WEIGHT	SEVERITY WEIGHT			EXTENT WEIGHT			DEDUCT POINT
		L	M	H	O	F	E	
RAVELING	10	0.3	0.6	1	0.5	0.8	1	10×1×1= 10
BLEEDING	5	0.8	0.8	1	0.6	0.9	1	5×0.8×0.6= 2.4
PATCHING	5	0.3	0.6	1	0.6	0.8	1	5×1×1= 5
POTHOLES/ DEBOUNDING	10	0.4	0.7	1	0.5	0.8	1	10×1×1= 10
CRACK SEALING DEFICIENCY	5	1	1	1	0.5	0.8	1	0
RUTTING	10	0.3	0.7	1	0.6	0.8	1	0
SETTLEMENT	10	0.5	0.7	1	0.5	0.8	1	10×0.7×0.8= 5.6
CORRUGATION	5	0.4	0.8	1	0.5	0.8	1	0
WHEEL TRACK CRACKING	15	0.4	0.7	1	0.5	0.7	1	15×0.7×0.7= 7.35
BLOCK AND TRANSVERSE CRACKING	10	0.4	0.7	1	0.5	0.7	1	0
LONGITUDINAL JOINT CRACKING	5	0.4	0.7	1	0.5	0.7	1	5×0.4×0.5= 1
RANDOM CRACKING	5	0.4	0.7	1	0.5	0.7	1	5×0.7×0.7= 2.45
EDGE CRACKING	5	0.4	0.7	1	0.5	0.7	1	0
L= LOW O= OCCASIONAL TOTAL DEDUCT=	43.8							
M= MEDIUM F= FREQUENT H= HIGH E= EXTENSIVE PCR=100 – TOTAL DEDUCT=	56.2							
PCI =	FAIR TO POOR							
DISTRESS WT×(SEVERITY WT)×(EXTENT WT)= DEDUCT POINT								

From Table 1, the percentage of raveling on the road which is more than 50% of the surface gave 1 (EXTENT) from the PCR form which is used to multiply standard 1 (HIGH SEVERITY WEIGHT) and 10 (DISTRESS WEIGHT) to obtain 10 (DEDUCT POINT). The deduct point obtained for each distress were added together to get the TOTAL DEDUCT which is subtracted from 100 to give the percentage condition of the road. The TOTAL DEDUCT obtained was 43.8 and the percentage condition PCR- 56.2% which was rated FAIR TO POOR from the PCI Standard Scale.

This result from PCI rating scale shows the reduction in the total health and performance of Forestry flexible road pavement as a result of the distresses observed on the road. Overtime traffic loads on the pavement with these distresses leads to an increase in their severity and extent. Repetitive shear deformations of the pavement component layers weakens the subgrade soil, poor drainage system leading to penetration of water to the subgrade layer increases the moisture content of the layer which leads to premature pavement distresses on the road.

Fig.12: High Severity of Raveling distress on Forestry flexible road pavement

Fig.13: High Severity of Pothole distress on Forestry flexible road pavement

Fig.14: High Severity of Patching distress on Forestry flexible road pavement

Fig.15: Medium severity of Bleeding distress on Forestry road pavement

Fig. 16: **Low severity of longitudinal crack distress on Forestry road pavement**

Fig.17: Failed section on Forestry road pavement

IV. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

Based on the results from this study the distresses along forestry flexible road pavement were rated using the ASTM D6433 standard manual for assessing PCI of flexible road pavement, it can therefore be concluded that, forestry flexible road pavement is generally rated as being FAIR TO POOR using the PCI scale. Visual observations of distresses show the deterioration and reduction in the performance of the flexible road pavement.

B. Recommendations

From the study, it can be recommended that annual assessment of the road pavement condition of forestry road should be prioritized in order to ascertain the level of road pavement deterioration continually for the purpose of budgetary planning and timely rehabilitation strategies.

Maintenance culture should be imbibed and maintained by agencies responsible for Highway maintenance.

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