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CHARACTERIZATION OF FLEXIBLE PAVEMENT FAILURE ON ILARO - IBESE ROAD IN YEWA SOUTH LOCAL GOVERNMENT AREA OF OGUN STATE

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ABSTRACT

Road transportation in Nigeria is widely used and the conduit of moving people, goods and services is the flexible pavement. Most of the Nigerian flexible pavement highways are in poor and deplorable state due to one failure pattern or the other. This study however investigated a portion of an international route passing through Yewa South Local Government Area of Ogun State in a bid to assess its condition, evaluate the observed failure patterns, score the overall surface rating and suggest appropriate treatment measure(s) of the portion of the flexible pavement studied. The visual assessments of the pavement revealed four distinct distress/failure namely cracking, pothole/patching, rutting and ravelling. Cracking has a weighed value of 0.76, potholes/patching has 31.64, rutting has 0.13 while ravelling has 0.013. With the total weighted percentage of distress as 32.563 equivalent to an overall surface rating of 1.0, a redesign of the road with adequate drainage system as well as full depth reconstruction is recommended.

Keywords: Flexible Pavement, Pavement Failure, Surface Rating, Treatment Measures.

1. INTRODUCTION

Effective transportation aids economic growth and ease movement of people, goods and services from one area onto another. Road transportation is the largest mode of transportation for the majority of people and goods the Sub-Saharan country of Nigeria (Alo and Oni, 2018). Road network serves as a very important component of transportation system. However, this mode of transportation is challenged by several issues in recent times causing delay in travel time, accidents and loss in the local, subnational and national economy.

There are two type of pavements namely rigid and flexible pavements. The commonly used in the Southern Nigeria is the flexible pavement. The flexible pavement has its attendant problems leading to different failure patterns. According to Chukweze (1988), road failure refers to the road's reduced serviceability due to the presence of surface distresses such as cracks, potholes and ruts. Several causes are attributed to the development of the distresses. The causes of road failures in Nigeria include lack of proper geotechnical studies, insufficient geological knowledge and or study, aging, poor maintenance, poor design and construction, lack of drainage, use of substandard construction materials, and heavy traffic (Dukiya J. J., Adeniyi G. and Adejumo T.W., 2023). Onyekachi V. N. and Ezichi K. (2022) averred that other factors contributing to road failures are lack of laboratory investigation of construction materials, poor quality of construction materials, poor soil condition, inadequate drainage systems, and overloading of road pavements. M. C. Nwachukwu et al (2022) held that the quality of subgrade materials, depicted by its moisture content, consistency limits, compaction, California bearing ratio, and shear strength, can influence pavement failure. Low road density, stress, functional disability, loss of cohesion, and lack of cambering tests are also contributing factors to road failures in Nigeria (Irokwe, J.O., Nwaogazie, I.L. and Sule, S. (2022); Yakubu J.A. et al (2023).

Yoder and Witczak (1975) identified two pavement distress / failure types, that is, structural and functional failures. Structural failure occurs when the pavement is unable to support the loads placed on its surface due to the collapse of the entire structure or the breakdown of one or more pavement components. On the other hand, functional failure happens when the pavement's roughness prevents it from performing its intended purpose without putting a severe strain on vehicles or causing pain to drivers or passengers. Pavement management system requires that sufficient data should collected for every road and adequate knowledge of causes of road failure be part of tools of personnel of maintenance agencies. The appropriate treatment measures therefore should be applied having carefully considered the impact of the observed failure on the overall surface of the pavement.

2. MATERIALS AND METHODS

The investigated road is located on the boundary of Ilaro -Ibese township in Yewa South Local Government Area of Ogun State, Southwestern Nigeria. The 5.8 - kilometer flexible road portion spans from the Yewa South Local Government (YSLG) Secretariat and terminates eastward on the rigid pavement built from Dangote Cement Factory, Ibese. The geographical coordinate of the road is latitude 6°53'4" N and longitude 2° 58' 51" E at the origin (YSLG) and latitude 5° 25' 36" E, longitude 8° 41' 56" E at the Ibese destination. The road forms part of Nigeria - Benin Republic international route network bearing both light passenger and heavy goods vehicular traffic.

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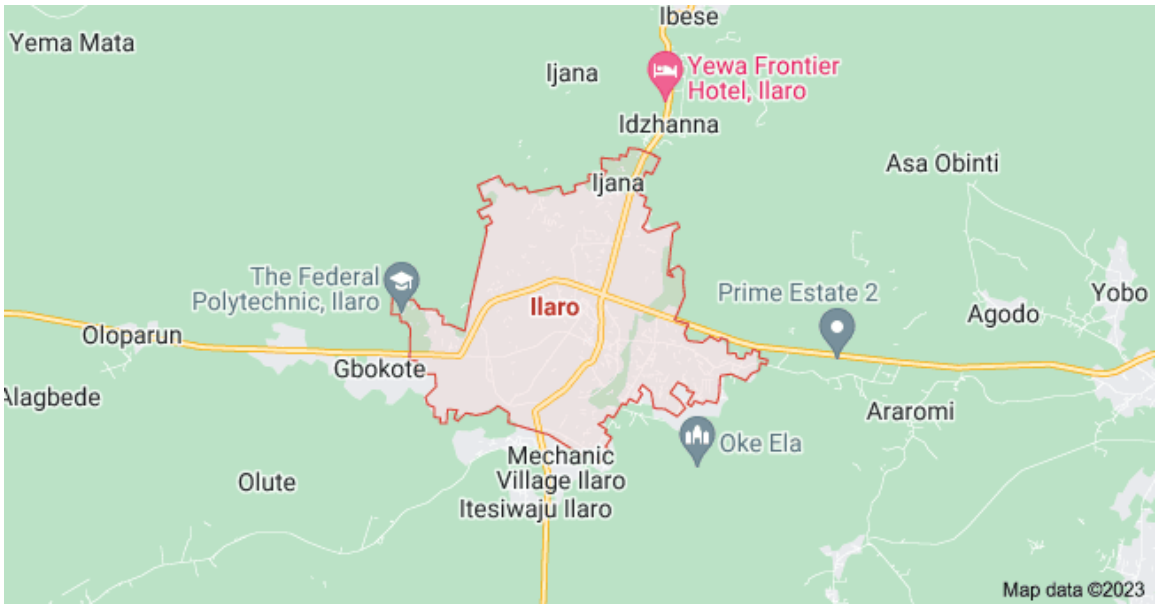

Fig. 1: Map of Ilaro Showing the Study Location

Reconnaissance survey was conducted to examine the extent of the road stretch to be studied and the type of developed failures on the road. Thereafter, pavement condition assessment was carried out by visually surveying the road to obtain pavement distress information at 100m interval along the road stretch. The inventories of the pavement distress/failure were carefully booked.

The following empirical equations as specified by the DOT Distress Identification Manual, 2003 are used to evaluate the overall surface rating of the asphalt concrete pavement:

$$\text{Cracking Percentage (\%)} = \frac{\text{Length of Observed Cracking}}{\text{Length of Surveyed Section}} \times 100\% \quad \text{.....(1)}$$

$$\text{Ravelling Percentage (\%)} = \frac{\text{Length of Observed Ravelling}}{\text{Length of Surveyed Section}} \times 100\% \quad \text{.....(2)}$$

$$\text{Pothole Percentage (\%)} = \text{Pothole Numbers} \times 2 \text{ (not to exceed 100\%)} \quad \text{.....(3)}$$

Weighted Failure = Percentage Distress x Weighting Factor .....(4)

(Source: Shehu et al, 2020)

The appropriate weighting factors in Table 1 were applied to the corresponding distress percentage to calculate resultant percentage pavement failure.

Table 1: Bituminous Pavement Failure Weighting Factors

Failure Type	Weighting Factor
Cracking (alligator, block and end cracking)	0.25
Rutting	0.15
Ravelling	0.02
Pothole / Patching	0.04

(Source: DOT Distress Identification Manual, 2003, Adapted from Shehu et al, 2020)

Having evaluated the resultant failure percentage for each failure type, the total percentage failure is related to the overall surface rating as indicated on Table 2. This surface rating is ranked on scale 0 – 4 depending on the total weighted percentage.

Table 2: Surface Rating of Asphaltic Concrete Pavement

Total Weighted Percentage	Surface Rating
0	4.0
1	3.8
2	3.6
3	3.4

4	3.2
5	3.0
6	2.9
7	2.8
8	2.7
9	2.6
10	2.5
11	2.4
12	2.3
13	2.2
14	2.1
15	2.0
16-17	1.9
18	1.8
19-20	1.7
21	1.6
22-23	1.5
24	1.4
25-26	1.3
27	1.2
28-29	1.1
30-33	1.0
34-40	0.9
41-47	0.8
48-54	0.7
55-61	0.6
62-68	0.5
69-75	0.4
76-82	0.3
83-89	0.2
90-96	0.1
97-100	0.0

(Source: DOT Distress Identification Manual, 2003, Adapted from Shehu et al, 2020)

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3. RESULTS AND DISCUSSION

Table 5: Cracking Weighted Failure of YSLG – Ibese Road for the Studied 6km Section

Chainage (m)	Crack length (m)	Crack percent	Weighted failure
`0+900 – 1+000	25	0.25	0.06
1+220 – 1+420	50	0.25	0.06
1+720 – 1+840	28	0. 23	0.06
1+960 – 2+160	85	0.43	0.11
2+240 - 2+280	12	0.30	0.08
2+280 – 2+720	100	0.23	0.06
3+340 – 3+360	8	0.40	0.10
3+840 – 3+860	6	0.30	0.08
4+310 – 4+400	8	0.09	0.02
4+660 – 5+140	39	0.08	0.02
5+140 – 5+320	25	0.14	0.04
5+330 – 5+360	10	0.313	0.08
5+860 – 6+000	7	0.05	0.01
Total			0.78

From Table 5, total weighted cracking is observed to be 0.78% of the entire road surveyed. Cracking lengths were found to be large at chainages 1+220 to 1+420, 1+960 to 2+160 and 2+280 – 2+720. This may be due to observed lack of drainage, inadequate asphalt thickness for the current heavy loads the road is being subjected, inadequate construction, and/or age of the pavement. Most of these cracks are either alligator cracks, reflective or block cracking adjacent to potholes or ravelling making sealing an improper decision.

Patching and potholes are predominant failure patterns on this road. It extensively covers the entire length except the newly rebuilt part around YSLG secretariat. The critical section of the road mostly affected is between chainage 3+000 and 5+200. This failure mode has the highest weighted failure percentage of 31.64 (Table 6)

Table 6: Patching/ Pothole Weighted Failure of YSLG – Ibese Road for the Studied 6km Section

Chainage (m)	No of Pothole	Pothole percent	Weighted failure
0+100 – 1+000	34	68	2.72
1+100 -1+500	37	74	2.96
1+600 – 2+000	30	60	2.40
2+200 – 2+300	25	50	2.00
2+400 – 2+900	31	62	2.48
3+000 – 3+200	41	82	3.28
3+300 – 3+600	47	97	3.88
3+700 – 4+000	46	92	3.68
4+100 – 4+500	33	66	2.64
4+600 – 5+200	43	86	3.44
5+300 - 6+000	27	54	2.16
Total			31.64

Rutting and ravelling were equally observed on the road but with insignificant weighted percentages of 0.13 and 0.013 respectively (Tables 7 and 8). These may be connected to high heavy goods traffic, moisture as well as the aging asphalt.

Table 7: Rutting Weighted Failure of YSLG – Ibese Road for the Studied 6km Section

Chainage (m)	Rutting Length	Rutting percent	Weighted failure
4+660 – 4+840	59	0.33	0.09
5+680 – 5+800	36	0.29	0.04
Total			0.13

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Table 8: Ravelling Weighted Failure of YSLG – Ibese Road for the Studied 6km Section

Chainage (m)	Ravelling Length	Ravelling percent	Weighted failure
0+400 - 0+800	72	0.18	0.004
1+600 – 2+100	105	0.21	0.004
5+200 – 5+500	73	0.24	0.005
Total			0.013

Table 9 shows that the overall pavement surface weighted percentage is 32.563 which implies that the surface rating is 1.0 on a scale of 0.0 to 4.0 (Table 2). This indicates the extent of damage to the road surface. The damage is severe with serious deterioration to the base and/or subgrade.

Table 9: Summary of Weighted Failure Percentage of the Investigated Road

Type of Failure	Weighted Percentage
Cracking	0.78
Pothole	31.64
Rutting	0.13
Ravelling	0.013
Total Weight (%)	32.563

Poor construction (such inadequate camber, insufficient pavement thickness, etc), absence of drainage, increase vehicular traffic above initial design and poor/inadequate were among observed causes of distress.

Table 10: Pavement Rating System and Corresponding Treatment Measures

	Rating System		Treatment Measures		
Overall Rating	Primary Rating Indicators	Secondary Rating Indicators	Treatment Measures	Surface Structures	
10	No visible defects	Road surface in perfect condition, like new.	Routine maintenance	Excellent	
9	Less than 10% of surface with surface defects.	Road surface in very good condition.		Very good	
8	10% to 30% of surface with surface defects	Little or no other defects	Resealing and restoration of skid resistance.	Fair	Good
7	Greater than 30% of surface with surface defects	Little or no other defects. Old surface with aged appearance		Poor	
6	Less than 20% cracking may be present. Patching generally in fair condition. May be out of shape requiring some reduction in driver speed.	Surface defects may be present. No structural Distress	Surface restoration-carry out localized repairs and treat with surface treatment or thin overlay	Fair	Good
5	Greater than 20% cracking present. Patching generally in fair condition.	Surface defects may be present.		Poor	

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	Out of shape requiring reduction in driver speed. Very localized structural distress (less than 5sq.m of surface) may be present.				
4	Rutting or alligator cracking for 5% to 25% of surface. Short lengths of edge break up/cracking. Small no of potholes.	Others defects may be present	Surface overlay-required to strengthened road. Localized patching and repairs required prior to overlay	Poor overall	
3	Significant areas of structural distress. Rutting or alligator cracking for 25% to 50% of surface. Significant continuous length with edge breakup/ cracking frequent potholes.	Others defects may be present			
2	Large areas of structural distress. Rutting or alligator cracking for over 50% of surface. Severe rutting (over 75mm deep). Extensive patching in very poor condition. Many potholes.	Very difficult to drive on.	Road construction-need full depth reconstruction with extensive base repair.	Very Poor overall	
1	Severe structural distress with extensive loss of pavement surface. Road disintegration of surface. Many large and deep potholes. Patching in failed condition.	Severe deterioration virtually un drivable		Failed overall	

(Source: DOT Distress Identification Manual, 2003, Adapted from Shehu et al, 2020

4. CONCLUSION

From vivid analysis of the results above, four major failure modes were prevalent namely cracking, patching/pothole, rutting, and raveling with weighted failure percentages of 0.76, 31.64, 0.13 and 0.013 respectively.

It is however noted that potholes and patching are predominant failure pattern on the road with a large percentage of 31.64.

The overall weighted failure percentage of 32.563 is equivalent to a surface rating of 1.0, this rating failure rating is in the last quarter making the road to be categorized as being in a deplorable state.

Unbiased comparison of the rating with Table 10 to establish adequate treatment measure indicates that too many potholes and extensive patching in poor condition leaves the road in very poor overall condition. Therefore, it is suggested that maintenance agency considers full depth reconstruction of the road.

Also, drain must be provided and adequate redesign of the road is suggested.

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