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ASSESSMENT OF PAVEMENT CONDITION INDEX: A CASE OF FLEXIBLE ROAD PAVEMENTS ON THE UNIVERSITY OF AGRICULTURE MAKURDI CAMPUS

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ABSTRACT

This study assessed the Pavement Condition Index (PCI) of flexible road pavements on the University of Agriculture Makurdi (UAM) Campus. The ASTM D6433 standard manual for assessing flexible road pavement condition manually was adopted. Analysis of results using descriptive statistics revealed that over 65% of the road pavement on the UAM campus were rated within the range of poor to failed state. Some segments at different routes were rated as fair and above (up to good) conditions, these routes and their corresponding percentages for fair and above conditions included; the Ring Road (RR) at 69.3%, University Entrance Gate - Clinic Junction (GCJ) route at 42.9%, Hostel Junction - Water Works (HJWW) at 33.3%, Clinic Junction - Ring Road Junction (CRRJ) at 26.7%, Staff Quarters Street (SQS) at 25%, South Core Bus Station – Entrance Gate Junction (SCG) at 9.1% and South Core Bus Station - Veterinary Auditorium (SCV) at 0%. The RR route had relatively high percentage of fair to good road pavement segments, while the SCV route had relatively high fraction of pavement with worse condition. Timely and total rehabilitation of flexible road pavement on the UAM campus were recommended since over 65% of the road network is at deplorable state, the prompt rehabilitation of the worse routes such as the SCV and SCG routes (having the least % for fair and above conditions) should be given priority. Also, the patching of potholes at this stage of deterioration is essential to prevent further damages and thereby reducing cost of rehabilitation in the future.

Keywords: *Flexible road pavement, Pavement Condition Index (PCI), maintenance strategies, pavement rehabilitation, surface distress and University of Agriculture Makurdi.*

1. 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]. Therefore, continuous road pavement monitoring and performance assessment are essential aspects of transport infrastructural development and management policies to curtail congested traffic flow, air and noise pollution, travel delay, accidents, etc. [2]. Also, since huge resources are required for highway construction and maintenance practices, frequent monitoring and maintenance strategies are essential for highway assets management [3 - 7]. It has been established by other researchers that, timely rehabilitation of road pavement saves about 50% of cost of rehabilitation [3].

Flexible road pavement is the commonest type of road pavement used for highway construction in Nigeria. This is due to its relatively cheap cost of construction [8]. A flexible road pavement is an elastic type of pavement whose structure is made of different unbound layers of soil materials which exhibit nonlinear behaviour under the influence of damaging factors. Its topmost layer is usually a thin Hot-Mixed Asphalt (HMA) known as the wearing course (other types include hot-laid, cold mix and cold laid) which is laid on the base layer. Both the

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base and its supporting sub-base layers consist of suitable soils with designed properties while the topmost layer called the surface or wearing course is usually an asphaltic concrete designed to carry traffic load directly and resist skidding [9].

The major disadvantages of flexible road pavement are its relatively short life cycle of 20 years and rapid deterioration and consequent failure with time due to significant impact of climate (temperature and precipitation), traffic load, material properties, pavement structure, design standard, etc. The periodic deterioration and consequent failure of road pavement has become a serious worry to concerned road management agencies hence assessing the level of damage or performance monitoring over time is essential for effective and sustainable road asset management in terms of improved performance (risk reduction) and budgetary planning [7, 10 - 12]. The solutions to pavement deterioration and consequent failure are timely rehabilitation and maintenance processes which require periodic monitoring and preplanning. A prior knowledge of when to carry out rehabilitation and maintenance process of existing deteriorated pavements is essential to pavement management agencies for the sake of budgetary planning and execution purposes [13].

Traditionally, assessment of pavement deterioration and consequent damage employs different engineering techniques which require field data generated on-site or obtained from database of pavement management agencies, or from experienced engineers working on pavement distresses which majorly include strains, stresses and deflection [14].

According to [15] and [16], the performance of pavements is usually measured using standard condition indices such as; Pavement Condition Index (PCI), Pavement Condition Rating (PCR) International Roughness Index (IRI), Present Serviceability Index (PSI), Present Serviceability Rating (PSR), Ride Number (RN) and Profile Index (PI) parameters. These indexes are affected by the severity of pavement distresses such as; cracks, potholes, rutting, shoving, ravelling, etc. per road section [17, 18]. The PCI is a numerical value established from a visual inspection and geometric measurement of surface distresses of pavements for condition rating per segment based on standards. It is a simple, convenient and inexpensive method of examining pavement condition which provides a numerical rating for the condition of road segments on a scale of 0 to 100, where 0 and 100 represent the worst and excellent pavement conditions respectively. According to [19], PCI is one of the most widely used indexes for assessing pavement performance. Survey for PCI assessment does not examine the structural status or adequacy of the pavement structure in serviceability, but rather its physical appearance in terms of quantity and severity of defects. Figure 1 shows a standard scale established by ASTM for the classification of PCI;

Figure 1: PCI Standard Scale [18]

This scale is used for defining the PCI of each road segment ranging from good to failed based on the quantity and severity of its defects as estimated by the preliminary procedure of pavement classification process. Pavement defects that influence the value of PCI include cracking, surface deformation, rutting, pothole, ravel, etc. The method of measuring PCI value uses a subjective approach of evaluation based on inspection and observation of the type, extent and severity of pavement surface distress. It is generally required that PCI inspection should be carried out annually on a road segment so as to ascertain periodic changes on pavement condition over time to check for the need for rehabilitation and maintenance as well as budgetary planning. PCI value is essential for assessing the serviceability, cost of rehabilitation and safety of road pavement for decision making and sustainable development [20]. PCI is assessed using standard engineering procedures stated in the American Society for Testing Materials (ASTM) manual D6433-07 published in 2007. The use of the

ASTM D6433 manual requires estimation of total surface area of pavement distress of particular kind per unit area of road segment for all defects, then the densities of various defects are estimated to be used for obtaining deduct values. The severity of the distress are categorise into low, medium and high based on the extent of occurrence as specified in the ASTM D6433 manual.

Though, mare observation shows that road corridors on the University of Agriculture Makurdi campus are said to be in a deplorable state, based on the level of deterioration of the flexible road pavements, this statement could not be justified using facts and figures since there is no technical and sectional assessment of the road sections which would have given an exact description of the pavement condition for optimum decision making and resource allocation.

This study therefore aims at assessing the present pavement condition of road corridors on the University of Agriculture Makurdi (UAM) campus using the ASTM D6433-07 standard manual. Objectives of the study include; to carryout site inspection of road pavement distresses along routes based on defined road segments on the UAM campus, to estimate PCI values of road segments using the ASTM D6433-07 standards and to propose a rehabilitation and maintenance strategy framework for flexible road pavements on the UAM campus.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The University of Agriculture Makurdi is one among the three (3) basic universities of agriculture in Nigeria. The institution is situated at the northern part of Makurdi town, at its suburb with an estimated population of 21,000 students and 1,746 staff. Total length of paved roadway on the campus measures about 5.9 km and unpaved road measures about 2.7 km to serve people living and working on the campus. The paved road network on the UAM campus are made of flexible pavements only. The routes of paved roads considered by this studies included; University Entrance Gate - Clinic Junction (GCJ), Clinic Junction - Ring Road Junction (CRRJ), Ring Road (RR), South Core Bus Station – Entrance Gate Junction (SCG), South Core Bus Station - Veterinary Auditorium (SCV), Hostel Junction - Water Works (HJWW) and Staff Quarters Street (SQS). These routes have undergone series of rehabilitations and maintenance in the past. The layout of paved road network on the UAM campus is as shown in Figure 2.

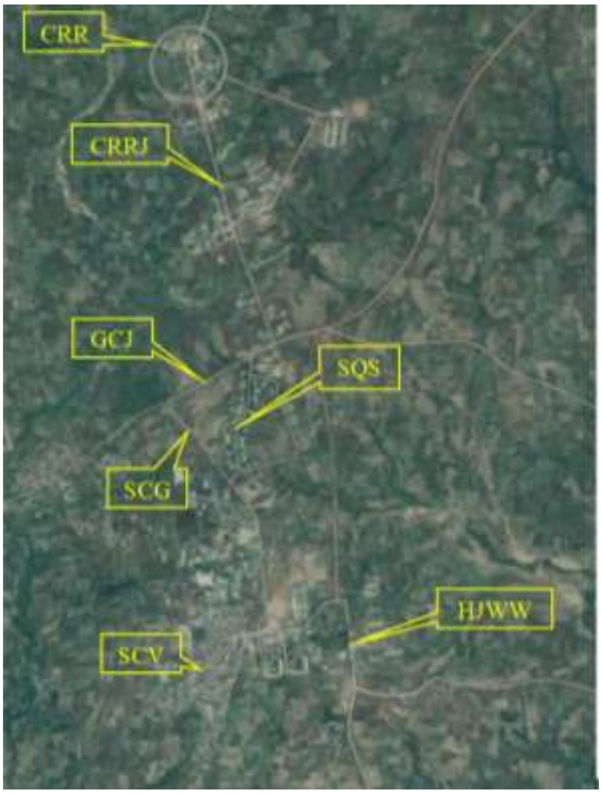

Figure 2: Layout of Road Network on the UAM Campus [21]

2.2 Data Collection and Analysis

The fieldwork involved visual inspection of pavement condition of road corridors on the UAM campus. The road corridors were divided into segments for examination and the geometry of defects in terms of widths and lengths per road segment were measured. The paved road corridors were subdivided into segments each measuring 100 meters long with varied widths for easy assessment. The quantity and severity of surface distresses were measured using linear measuring instruments such as measuring tape and metal rule in line with specifications of the ASTM D6433 manual. This was carried out during off office periods (mostly weekends) to enable enumerators work conveniently and under a secured condition without safety threats since very few number of vehicles travelled along the road corridors on weekends. Results were recorded and the analysis of collected data involved estimation of the density of distress and deduct values per road segment from charts in accordance with procedure in ASTM D6433 manual.

3. RESULTS AND DISCUSSION

Road corridors connecting locations were sub-divided into segments identified by codes. The distribution of PCI and rating for various road segments along routes are as shown in Table 1.

Table 1: Distribution of PCI and Ratings of various road segments along routes

Road Corridors	*ID Code of Segments*	*Total Deduct Values*	*Corrected Deduct Values*	*PCI*	*Rating*
University Entrance Gate - Clinic Junction	GCJ-1	63.9	40.0	60	Fair
	GCJ-2	76.0	43.0	57	Fair
	GCJ-3	98.9	62	38	Very poor
	GCJ-4	108.8	68	32	Very poor
	GCJ-5	144.2	59	41	Poor
	GCJ-6	107.0	67	33	Very poor
	GCJ-7	37.5	22.0	78	Satisfactory
Clinic Junction - Ring Road Junction	CRRJ-1	135.0	76	24	Serious
	CRRJ-2	125.1	77	23	Serious
	CRRJ-3	125.1	77	23	Serious
	CRRJ-4	75.3	38	62	Fair
	CRRJ-5	61.6	33	67	Fair
	CRRJ-6	71.9	36	64	Fair
	CRRJ-7	73.2	47	53	Poor
	CRRJ-8	110.9	58	42	Poor
	CRRJ-9	132.8	64	36	Very poor
	CRRJ-10	119.3	58	42	Poor
	CRRJ-11	127.1	62	38	Very poor
	CRRJ-12	147.6	76	24	Serious
	CRRJ-13	76.8	43	57	Fair
	CRRJ-14	158.3	91	9	Failed
	CRRJ-15	76.2	48	52	Poor
Ring Road	RR-1	55.0	41	59	Fair
	RR-2	48.0	30	70	Fair
	RR-3	32.0	32	68	Fair
	RR-4	29.1	17	83	Satisfactory
	RR-5	67.0	49	51	Poor
	RR-6	84.6	54	46	Poor
	RR-7	42.3	31	69	Fair
	RR-8	3.2	0	100	Good
	RR-9	0	0	100	Good
	RR-10	39.1	29	71	Satisfactory
	RR-11	90.8	64	36	Very poor
	RR-12	82.2	59	41	Poor
	RR-13	38.4	28	72	Satisfactory
South Core Bus Station – Entrance Gate Junction	SCG-1	156.2	79	21	Serious
	SCG-2	194.6	88	12	Serious
	SCG-3	119.5	68	32	Very poor
	SCG-4	194.4	88	12	Serious
	SCG-5	168.2	82	18	Serious
	SCG-6	146.5	75	25	Serious
	SCG-7	133.6	75	25	Serious
	SCG-8	78.8	40	60	Fair
	SCG-9	149.4	93	7	Failed
	SCG-10	175.0	82	18	Serious
	SCG-11	155.2	85	15	Serious
South Core Bus Station - Veterinary Auditorium	SCV-1	103.0	65	35	Very poor
	SCV-2	155.2	85	15	Serious
Hostel Junction-Water Works	HJWW-1	68.3	34	66	Fair

Road Corridors	*ID Code of Segments*	*Total Deduct Values*	*Corrected Deduct Values*	*PCI*	*Rating*
	HJWW-2	195.0	92	8	Failed
	HJWW-3	144.9	74	26	Very poor
Staff Quarters Street	SQS-1	154.7	85	15	Serious
	SQS-2	111.8	69	31	Very poor
	SQS-3	119.1	62	38	Very poor
	SQS-4	130.2	67	33	Very poor
	SQS-5	29.7	10	90	Good
	SQS-6	176.2	86	14	Serious
	SQS-7	72.1	41	59	Fair
	SQS-8	103.6	65	35	Very poor

Table 2: Descriptive Statistics of PCI Values

Parameters	PCI Values
Sample Size	59
Range	93
Mean	42.90
Variance	563.99
Standard deviation	23.75
Coefficient of variation	0.5536
Standard Error	3.0918
Skewness	0.51009
Excess Kurtosis	-0.44883
Minimum	7
Maximum	100
Percentiles	
5%	9
10%	14
25%	24
50%	38
75%	60
90%	72

Using a constant length of 100 meters for all segments with varied number of lanes and widths, Table 1 showed various rating of pavement conditions for different road segments within the road network on UAM campus. Statistical analysis of the data gave its descriptive statistics as shown in Table 2. It shows that the average PCI value for the entire road network is approximately 43, which shows that the average rating of pavement condition of road network on the UAM campus is poor based on the PCI scale.

In summary, the percentage frequency distribution of PCI and ratings for various routes of the entire road network of paved roads on the UAM campus are as shown in Table 3.

Table 3 revealed the percentages of route segments for fair to good pavement condition to include; the GCJ, CRRJ, RR, SCG, SCV, HJWW, SQS with 42.9%, 26.7%, 69.3%, 9.1%, 0%, 33.3% and 25% respectively. Road segments along the GCJ routes had majorly very poor or fair pavement conditions, while those along the CRRJ were very poor, serious and failed the rating. The rating of road segments on the RR route fell between fair and satisfactory. Road segments along the SCG routes are described or rated as being seriously damaged. The SCV route is rated as being very poor and seriously damaged. The combined HJWW and SQS routes are mostly rated as being at the very poor, serious, fair and good states. In spite of their significant bad condition, there are some good and satisfactory segments along the RR and SQS routes.

The combined distribution of PCI of various road segments along routes on the road network of UAM campus is as shown in Figure 3;

Table 3: Percentage Distribution of PCI and Ratings for various Road Segments

Rating of Pavement Condition	% Frequency Distribution of PCI of Road Segments						
	GCJ	CRRJ	RR	SCG	SCV	HJWW	SQS
Failed	0.0	6.7	0.0	9.1	0.0	33.3	0.0
Serious	0.0	26.7	0.0	72.7	50.0	0.0	25.0
Very Poor	42.9	13.3	7.7	9.1	50.0	33.3	50.0
Poor	14.3	26.7	23.1	0.0	0.0	0.0	0.0
Fair	28.6	26.7	30.8	9.1	0.0	33.3	12.5
Satisfactory	14.3	0.0	23.1	0.0	0.0	0.0	0.0
Good	0.0	0.0	15.4	0.0	0.0	0.0	12.5

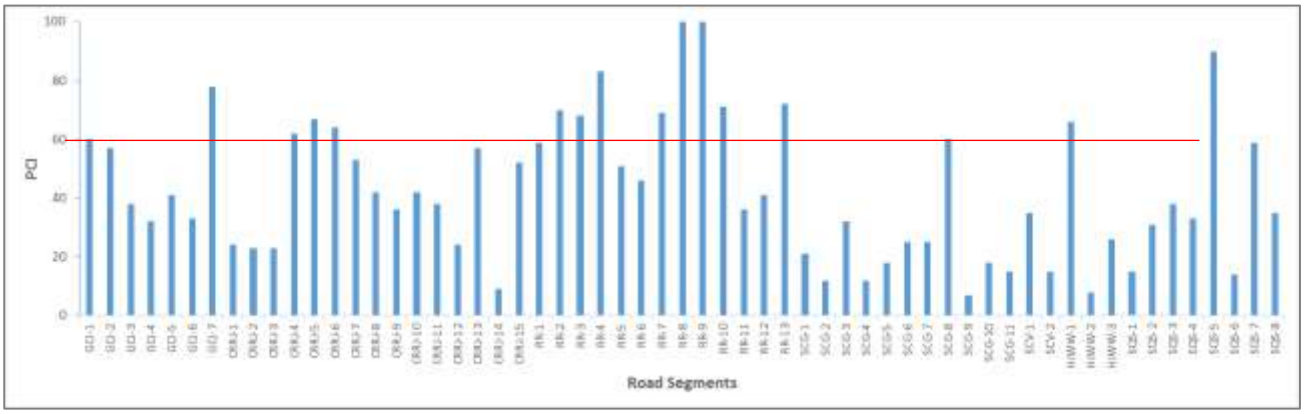

Figure 3: Combined Distribution of PCI along Routes

Figure 3 revealed that significant number of road segments have PCI values below the fair status (below 56) as shown by the line drawn across bars. Below the fair status, the road pavement segments are rated as poor, very poor, serious or failed depending on the corresponding PCI value which range between 0 - 55. This indicated poor state of significant number of road pavement segments.
In addition, summary of the entire rating of PCI of paved routes is as shown in Table 4;

Table 4: PCI rating of entire Road Network on the UAM Campus

Rating of Pavement Condition	Frequency	% Frequency
Failed	3	5.1
Serious	15	25.4
Very Poor	13	22.0
Poor	8	13.6
Fair	13	22.0
Satisfactory	4	6.8
Good	3	5.1

Table 4 revealed that significant number of road segments of the pave road network on UAM campus are rated between failed, serious, very poor and fair conditions in accordance with the standard PCI scale with percentage composition ranging between 20 – 25%. 5.1% of total paved roads have failed completely, only 6.8% and 5.1% of the road network is rated as being satisfactory and under good conditions respectively. This analysis showed that over 65% of the road network on the UAM campus is rated between poor and failed state. Only 12% of road segments on the UAM campus is classified as being satisfactory and under good condition.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Based on assessment carried out by this study using the ASTM D6433 standards manual for assessing PCI of flexible road pavement, it can therefore be concluded that, road pavement on the UAM campus is generally rated as being in a poor or failed state at the rate of over 65%, with only 12% classified as being satisfactory and under good condition. A fraction of segments at different routes were rated differently between fair to good conditions. These routes and their corresponding percentages of fair to good pavement conditions included; the GCJ, CRRJ, RR, SCG, SCV, HJWW and SQS having 42.9%, 26.7%, 69.3%, 9.1%, 0%, 33.3% and 25% respectively. The RR route had relatively high percentage of fair to good road pavement condition with SCV route having the worst pavement condition on the road network of UAM campus.

4.2 Recommendations

The following recommendations can be made;

1. Total rehabilitation of road network on the UAM campus is required since over 65% of the road pavement is in bad state with only 12% good segments.
2. Annual assessment of road pavement condition of the road network on UAM campus is recommended to ascertain the level of road pavement deterioration since it is a continuous process, and for purposes of budgetary planning and timely rehabilitation strategies in terms of prioritisation.
3. Rehabilitation of the SCV and SCG routes should be given a priority due to their present poor state to ease movement to and from the college of Veterinary medicine facilities and between the south core bus station and the entrance gate

junction of the University, so as to guarantee safe and efficient movement along the routes.

4. Generally, rehabilitation by cutting and patching of potholes at this present stage of road deterioration on the network is essential to prevent further damages, hence reducing the cost of future rehabilitation.

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