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Pathologies on Mozambique Roads, Assessment of Flexible Pavement Conditions

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Abstract: The primary purpose of a pavement is to create a resistant, regular and adherent surface that facilitates the circulation of vehicular traffic safely and with minimum operating costs for users. To maintain its useful life, floors require periodic diagnostics. Therefore, the assessment of the conservation conditions of a pavement is relevant for analyzing the causes of pathologies as well as a better design of highway recovery projects. This research aims to evaluate the functional condition of the flexible pavement of National Road Number Two (N2), Boane – Namaacha, over a length of 2 km, through the PCI method which was based on the survey, quantification and definition of the causes of pathologies, accompanied by photographic report with the aid of the metric wheel. The classifications were low, medium and high depending on their severity. The results revealed that crocodile skin and depression-type pathologies presented a high level of severity and hole-type pathologies presented three levels of severity (low, medium and high). Finally, it is concluded that there is a predominance of hole-type pathology in the flexible pavement of the N2 road.

Key words: flexible flooring, pathologies, PCI, National Road N2

1. Introduction

The pavement is a structure made up of several layers with the function of receiving and resisting traffic demands, and, at the same time, ensuring comfort, safety and savings for its users. Over time, floors experience problems with degradation or malfunctions resulting from various factors, such as environmental, climate and heavy traffic. The lack of follow-through on maintenance plans taking into account the need to preserve the life of highways in the face of the occurrence, over time, of deterioration of asphalt pavement has been identified as the main causes of road degradation [1]. According to Joia (2001) [2], the degradation of roads results from the excessive weight of trucks that travel on them. JICA (2021) [3] adds that the lack of appropriate maintenance of the drainage system and the poor performance of pavement rehabilitation contribute to the degradation of roads. Velásquez (2009) [1] mentioned that the ideal solution to avoid degradation is to detect and evaluate the pavements in a timely manner so that the resulting repairs correspond to conservation works or small repairs, and not necessarily construction, as this saves money and resources.

The total length of Mozambique's road network is 34,332 km, 5,324 km of which are paved roads, 6,878 km of gravel roads and the remaining roads are dirt roads [4]. Large parts of these roads are currently in poor condition, despite many efforts that the Mozambican road sector has made with a view to mitigating the problem of pathologies, which has affected the movement of people and goods. There is also a lack of systematized information on the condition of asphalt pavements on Mozambican roads.

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These problems justify the academic purpose of the need to develop the present work, which aims to investigate the conditions of the flexible pavement of National Road Number Two (N2), Boane-Namaacha section, over a length of 2 km, using the PCI method.

2. Material and Methods

2.1 Location and Description of the Study Area

National road number two (N2) was built in the 70s, before Mozambique's independence in 1975, and runs through the territories of the Districts of Matola, Boane and Namaacha in the Province of Maputo and is an international corridor that establishes the connection between Mozambique and the Kingdom of Eswatine. The N2 road is paved with a double surface asphalt coating. It is a classified road, of secondary category, designated as national number 2, and with a length of 39 km. Along its route, there are several communities and activities are carried out in the areas of agriculture, livestock, and the processing and sale of construction materials (stone and sand), which makes the route of extreme socio-economic importance. Geographically, the road is located south of the province of Maputo, as shown in Fig. 1.

Fig. 1 Location of the Boane Rotunda - Namaacha section.

2.2 Data Collection Procedures

The present work consisted of bibliographical research whose contents are similar to the topic, which allowed a better understanding of the pathologies on the road under study. For the study, data was collected on the conditions of the N2 road, which included photographic reporting and measurement of pathologies with the aid of a metric wheel. The survey was carried out in both directions of the highway, Boane-Namaacha and vice versa, over a length of 2 km. To this end, the section of road was subdivided into 4 sections, each with an area of 210 m^2. Based on the indicated data and with the help of the PCI method, it was possible to assess the level of severity of the pathologies. When defining intervention priorities, 3 levels of severity were considered: low (L), medium (M) and high (H). For crocodile skin type pathology, low severity levels (L) were considered, several thin

longitudinal fissures, parallel to each other, with no or little interconnection; Medium (M), well-defined cracks like “alligator skin”, with interconnection between each other, without disintegration of material; High (H), well-defined pattern, with interconnected cracks and high potential for material disintegration. Depression-type pathology, considered low level (L) when it slightly affects the circulation of vehicles (3 to 13mm); Medium (M), when the depression is easily visible and seriously affects traffic circulation (> 25 mm); High (H) correspond to a clearly visible depression, which seriously affects traffic circulation and poses a greater risk (> 25 mm). If the hole has a diameter greater than 750mm, the area must be determined in square meters and divided between 0.5 m2 to evaluate the equivalent number of holes. A depth less than or equal to 13 mm is considered the low level (L); the range of 13mm to 25 mm corresponds to medium level and; > 25 mm high (H) level of degradation.

2.3 Pathologies and Causes Along the Boane Section — Namaacha

During the inspection visit to the road under study, the existence of different pathologies was found, namely, crocodile skin, peeling, holes and an uncoated base as illustrated in Fig. 2. During the research, these were found to be causes of degradation on the N2 the poor preparation of the pavement surface, the intensity of traffic, and the lack of load control of heavy vehicles transporting inert materials. The N2 road has annually benefited from routine maintenance that consists of localized maintenance activities to fill potholes, however, it is noted that due to the lack of resources it has not been possible to carry out complete maintenance or rehabilitation, which is considered to be an appropriate option for this case.

Fig. 2 illustrates the pathologies found along the Boane section — Namaacha.

(a) Naked Skin (b) Holes

(c) Holes and crocodile (d) Uncoated base skin

Fig. 2 Road defects.

2.4 PCI Method (Paving Condition Index)

The PCI method provides information about road conditions under present pavement conditions, but cannot provide predictions for the future. The PCI rating scales as per Rosyidi citing the ASTM D 6433 standard are, Excellent (86-100), Very Good (71-85), Good (56-70), Fair (41-55), Poor (26- 40), Very Bad (11-25), and Terrible (0-10). According to Rosyid citing ASTMD 6433, Valésquez (2009) [1] citing ASTMD 6433-3 to obtain the PCI value of a sampling unit it is necessary to follow the steps below:

a) Deduction value (DV) — is the value obtained through the curve of the relationship between density and level of severity of the pathology. The deduction values (DV) are obtained for each type of degradation and severity level, depending on the density values obtained, by interpreting the deduction curves. If none or only one of the deduction values is greater than 5, the maximum corrected deduction value (Max CDV) to be used in calculating the PCI is equal to the sum of all DV.

b) Density (D) — is the percentage of incidence of degradation, calculated by severity level, in a given sampling unit, that is, it is the division of the total amount of area affected by degradation (m or m^2) by the total area of the unit sample, according to Eq. (1).

$$D(\%) = \frac{Amount\ of\ degradation\ (m\ ou\ m2)}{\text{Total area of U.A.(m2)}} x\ 100 \quad (1)$$

c) Maximum number of allowable defects (m) — The calculation of the maximum number of allowable defects (m) is carried out using Eq. (2).

$$m = 1 + \left(\frac{9}{98}\right)(100 - HDV) \leq 10 \quad (2)$$

Where:

m: Maximum number of permissible defects to be considered in calculating the PCI of the sampling unit; HDV: The largest deduction value (DV) of the sampling unit. To calculate the PCI, the maximum corrected deduction value (Max CDV) is subtracted from the maximum PCI value to obtain the PCI value of the sampling unit, as illustrated by Eq. (3).

$$PCI = 100 - CDV \quad (3)$$

3. Results and Discussion

Section 1 (0+400 to 0+800) of 210 m^2 presented hole-type pathologies, with low, medium and high severity. The deduction values obtained are 40.1, 46.3, 31.2, 32.1 and 27.1 and the maximum deducted value is 91, resulting in an index corresponding to a poor condition of the floor, therefore requiring rehabilitation. Table 1 presents the sample record from section 1 and Table 2 presents the PCI calculation.

Table 1 Sample registration in the section 1.

PCI Method									
Condition Index of Floors on Flexible Floor Roads							**Scheme**		
Registration Form									
Road name: N2-Rotunda de Boane/Namaacha Section: 1 Demonstration unit: U1 Executor_____ Date: 14/11/2023 Area: 210 m^2									
1. Cocodril skin 2. Exudation 3. Block cracks 4. Bulging and sinking 5. Corrugation 6. Depression 7. Edge cracking 8. Joint reflection crack 9. Dip in level of the shoulder 10. Longitudinal and transverse cracks 11. Patches and cuts 12. Polished aggregate 13. Holes 14. Settlement 15. Sliding 16. Parabolic fissure or slip17. Swelling 18. Weathering peeling and aggregate detachment									
Pathology							**Total**	**Density (%)**	**Value Deducted**
1H	6.84						6.84	3.3	40.1
6H	79.9						79.9	38.0	46.0
13L	0.528	0.564	0.97	1			3.062	1.4	31.2
13M	1.2	1.54	2.40	5.13	5.60		15.87	7.6	32.1
13H	11.22						11.22	5.3	27.1

Density = Total Quantity/Total Area
Density = 6.84/210 = 3.3%

Table 2 Section 1 sample PCB calculation.

#	Amount Deducted							Total	q	CDV
1	46	40.1	32.1	31.2	27.1			176.5	5	91.0
2	46	40.1	32.1	31.2	2			151.4	4	88.0
3	46	40.1	32.1	2	2			122.2	3	74.0
4	46	40.1	2	2	2			92.1	2	66.0
5	46	2	2	2	2			54	1	52.0

Max CDV = 91.0
PCI = 100-Max CDV = 100-91 = 9 (Terrible)

Section 2 (Km 1+100) presented hole-type pathologies, occupying 2 levels of severity, low and medium, with deducted values of 25 and 31.1, respectively. The maximum deducted value of 41 was obtained, resulting in an index corresponding to a good floor. According to Table 3, the sample record from section 2 is presented and Table 5 presents the PCI calculation.

Table 3 Sample registration in section 2.

Pathologies	Quantity						Total	Density (%)	Deducted Amount
13 L	0.264	0.7	0.81	0.945	0.96	0.96	92,129	4.4	25
13 M	1.045	1.89	2.34	2.55			7,825	3.7	31.1

Density = Total Quantity/Total Area
Density = 92.129/210 = 25%

Table 4 Section 2 sample PCB calculation.

#	Amount Deducted							Total	q	CDV
1	31.1	25						56.1	2	41
2	31.1	2						33.1	1	31

Max CDV = 41.0
PCI = 100-Max CDV =100-41 = 59 (Good)

Section 3 (Km 1+ 600), 210 m^2, exposes pathologies such as potholes with a low and medium degree of severity. The deducted values found are 20.1 and 35 and the maximum deducted value of 35.1, which leads to a good floor result. According to Table 5, the sample record from section 2 is presented and Table 6 presents the PCI calculation.

Table 5 Sample registration in section 3.

Pathologies	Quantity						Total	Density (%)	Value Deducted (VD)
13 L	2×0.46	3×0.63	0.6	2×0.8	0.88	0.96	5.62	2.7	20.1
13 M	1.05	1.5	2.21	2.5			7.26	3.5	35.1

Density = Total Quantity/Total Area
Density = 7,26/210 = 3.5%

Table 6 Section 3 sample PCI calculation.

#	Amount Deducted							Total	q	CDV
1	35.1	20.1						55.2	2	40.0
2	35.1	2						37.1	1	34.0

Max CDV = 40.0
PCI = 100-Max CDV = 100-40 = 60 (Good)

Section 4 (Km 1+900) with 210 m^2, presented pathologies such as holes with low, medium and high severity and crocodile skin and naked pathologies with a high severity level. The deducted values are 40.1, 22.1 and 5.2. and the maximum deducted and corrected value of 48, which led to a result of a regular floor. According to Table 7, presents the sample record from section 4 and Table 8, presents the PCI calculatio.

Table 7 Sample registration in section 4.

Pathologies	Quantity			Total	Density (%)	Value Deducted (VD)
7 L	0.75			0.75	0.38	5.2
7 M	1.25	2.08	2.25	3.33	1.6	22.1
7 H	4.44			4.44	2.1	40.1

Density = Total Quantity/Total Area
Density = 6.83/210 = 3.0%

Table 8 Section 4 sample PCI calculation.

#	Amount Deducted							Total	q	CDV
1	40.1	22.1	5.2					67.4	3	41.0
2	40.1	22.1	2					64.2	2	48.0
3	40.1	2	2					44.1	1	44.0

Max CDV = 48.0

PCI = 100-Max CDV = 100-48 = 52 (Regular)

4. Conclusion and Recommendations

4.1 Conclusions

The objective of this article aims to evaluate the functional conditions of the flexible pavement of National Road Number Two (N2), Boane – Namaacha, over a length of 2 km, using the PCI method. Therefore, in this work the following was concluded:

- The PCI method was important in identifying, defining and determining measures to be taken to mitigate pathologies;
- The PCI method proved to be a cheap method as it only requires a measuring wheel and tape measure and photographic reporting made on a cell phone in the absence of a camera;
- The PCI values obtained were different for different sections studied, being section 1, the PCI = 9 (Poor), section 2, the PCI = 59 (Good), section 3, the PCI = 60 (Good), section 4, the PCI = 52 (Regular);
- The results revealed the existence of predominant pathologies of the crocodile skin type, naked skin and holes, being of the crocodile and naked type with a high level of severity and holes presenting at three levels of severity (high, medium and low).

4.2 Recommendations

The following is recommended:

- The use of the PCI method in pavement condition research;
- Development of experimental studies that include more sections of roads with other types of defects not addressed in the present study;
- The use of PCI results to decide which type of maintenance activities to carry out;
- Consideration of PCI results for pavement design;
- In sections where the PCI is low, carry out rehabilitation and where the PCI is high, do nothing.

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