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Assessment of Flexible Pavements of the Road System of the Urucu Petroleum Province/Amazonas/ Brazil

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ABSTRACT

The study presents the functional and structural performance of a section of Tronco Main Road (TMR), which is related to the road system of the petroleum province of Petrobras located in the State of Amazonas/Brazil. The TMR was divided into seven subsections for better evaluation and control of data collection in the field. The functional analysis was based on the collection of pavement surface, using a characterization of the type and frequency of distresses, alongside the collection of the asphalt coating conditions and the macrotexture measurement. About the structural assessment, the study was based on the execution of a Nondestructive test, using the Benkelman beam. The maximum rebound deflection results and the radius of curvature of the vertical displacements (deflectometry survey) that occurred on the pavement surface were both determined. In general, the Pavement Condition Index (PCI) results registered a very poor concept. The macrotexture presented an average texture, except for spots with the presence of HMSA, which displayed a microtexture. As for the pavement's structural condition, we concluded that restoration is not necessary.

1. INTRODUCTION

Petrobras' natural gas and oil exploration center, located in Urucu, is largely responsible for the regional development of the Municipality of Coari in the State of Amazonas/BR [1]. Contrastingly, this gas pipeline is an alternative to the Amazonian energy matrix, as it has the potential to enable the gradual replacement of diesel oil and fuel from thermoelectric plants with natural gas for generating electricity [2].

The aforementioned gas and oil generation center is divided into three main production stations, Rio Urucu (RUC), East Rio Urucu (EUC), and Southwest Rio Urucu (SUC). The absence of access roads between the stations demanded the initial use of two transport modes - aerial (helicopter) and by the river (ferry). However, due to the high costs, which could impair the site exploration, Petrobras opted for creating small roads. Thus, it provided a road network for the access and operation of these production sites [3].

On the other hand, the geotechnical issues present in this region are significant. The soil from the Solimões sedimentary basin, in general, does not provide adequate technical conditions to compose the sub-layers of these pavements when subjected to the repeated load-induced by vehicles and equipment. This situation is notably aggravated by the high amount of rainfall in the region. The combination of these factors usually prevents adequate traffic conditions throughout the year [4].

That being said, the question that arises here is how to assist the fulfillment of these structures' life spans using a maintenance and restoration plan. Thus, we assessed the functional and structural performance of the pavement located on the Tronco Main Road (TMR), belonging to the road system of the Petroleum Province of Urucu/Coari/Amazonas/BR.

2. MATERIALS AND METHODS

2.1 Location characteristics

The stretch of the Tronco Main Road where the pavement's functional and structural performance was assessed is located at the EUC Production Station. The aforementioned

Petrobras base is located approximately 650 kilometers from Manaus/AM/BR, more specifically in the rural area of the Municipality of Coari/AM/BR (Figure 1).

Figure No.1: Location of the Municipality of Coari/AM/BR and the Petroleum Province of Urucu (PPU)

The study site, due to the lack of land access, is limited to water transport for materials, equipment, and cargo. Air transport is used to transport people and small loads. It is noteworthy that throughout the year, usually, the rivers located in the region offer certain restrictions to the passage of vessels in the fluvial cargo transport. Such a condition emerges from the particular climate of the Amazon Region, in which only two climatic seasons are well defined (summer and winter). During summer, the “phenomenon” known as the ebb of rivers is observed. Rain levels decrease drastically, causing the water level to drop, and consequently hindering river transport in the dry season, which occurs from July to early November [5].

In light of these adversities, and since the site is located in the Amazon rainforest, the research was carried out at the end of the Amazon summer period, so to avoid discontinuity in the field survey.

The studied TMR section is encompassed between the E2270 and E2615 piles (Figure 2), with an approximate length of 6,900m. In this section of the road, a general intervention was carried out in 2004. Subsequently, it received minor maintenance to regularize the condition of the pavement serviceability.

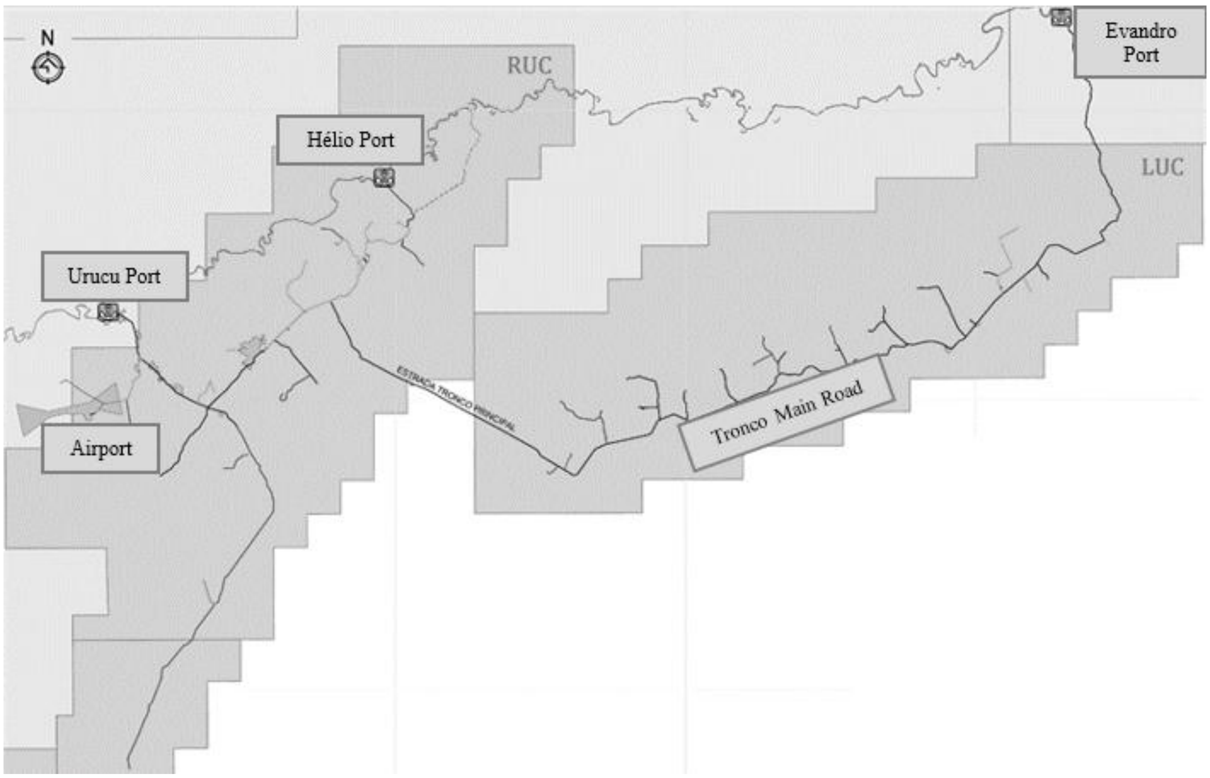

Figure No. 2: Section of the Tronco Main Road (TMR)

2.2 Pavement Structure

The examined cross-section can be seen in Figure No. 3. In the first layer, there is an asphalt coating made of asphalt concrete (AC), followed by the graded stabilized base and sub-base, overlaid with a subgrade reinforcement layer.

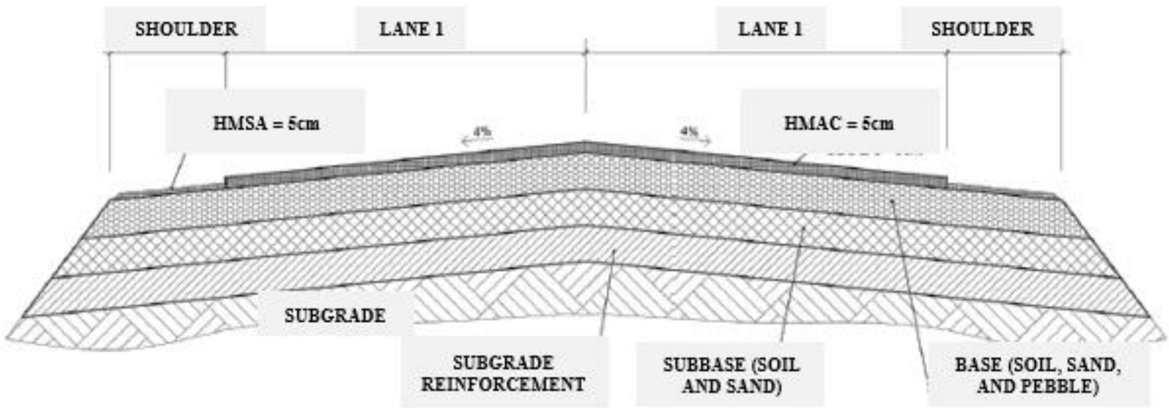

Figure No. 3: Pavement Section

2.3 Functional and Structural Assessment

The evaluation of the functional characteristics of the pavement is based on the survey of surface defects and profile deformations, which provide information on the condition of the surface. For its determination, we elaborated a survey of the superficial and geometric degradation by measuring the arrows on the inner and outer wheel tracks. Thus, based on the Brazilian standard DNIT 008 (2003) [5], the Pavement Condition Index (PCI) was obtained. Macrotexture testing (Sand Patch) [6] and visual investigation of surface defects [7] were also part of the study.

As for the structural evaluation, it can be carried out using a survey of field data. It can also be performed, as it was done in the present study, using the values of vertical displacements (deflectometry survey) that occurred on the pavement surface when subjected to a load measured by the Benkelman beam [8].

3. RESULTS

3.1 Functional analysis

The functional analysis was carried out on the Tronco Main Road (TMR), according to 7 subsections. They were identified by their initial and final pile (Table No. 1).

Table No. 1: Subsections

Subsection	Initial Pile	Final Pile	Quantity of Piles	The extension (m)
1	2270	2320	50	1000
2	2320	2370	50	1000
3	2370	2420	50	1000
4	2420	2470	50	1000
5	2470	2520	50	1000
6	2520	2570	50	1000
7	2570	2615	45	900
Σ	345	6900	-	-

3.1.1 Pavement Condition Index (PCI)

Several distresses were observed on the pavement surface of TMR subsections, some more frequently and others in a localized manner. We emphasize that cracks were disregarded in the general computation, mainly because of the pavement age, which was 15 years old at the time.

On the other hand, we tried to highlight the cracks (cracking), Low and High-Severity Transverse Cracking (LSTC and HSTC), Low and High-Severity Longitudinal Cracking (LSLC and HSLC), Shrinkage Cracking (SC), which can be more relevant for the assessment of the paved road. Still, regarding cracking, isolated cracks were not identified, which occurred because of the thermal shrinkage or dissection of the base or coating. Furthermore, interconnected cracks, Block Cracking (BC) and Interconnected Block Cracks with Erosion at the Edges (IBCE)were not found, whose particularity is the formation of rectangular blocks with well-defined sides, caused mainly by the contraction of asphalt coating resulting from the thermal variation. However, cracks classified as LSTC, HSTC, LSLC, and HSLC, as well as groove worn(rutting), registered a high frequency when compared to other types of defects (Figure No. 4).

We emphasize that the consolidated rutting was not identified in the surveyed stations. They are constituted of distresses characterized by permanent deformation, generating a depression in the pavement surface without generating lateral volumetric compensations (uplifting). It should also be mentioned that the depths of wheel tracks did not present values greater than 50mm, except for one station displaying this value exactly.

The PCI result is the sum of individual severity indices, composed of the defects found on the pavement surface [9]. In this particular case, the sum of all evaluated subsections resulted in a value greater than 160. Therefore, being considered as failed (Figure No.5) according to the concept that depicts the degree of superficial degradation [5]. This result indicates that the coating has a marked deterioration, with several points that demand immediate restoration.

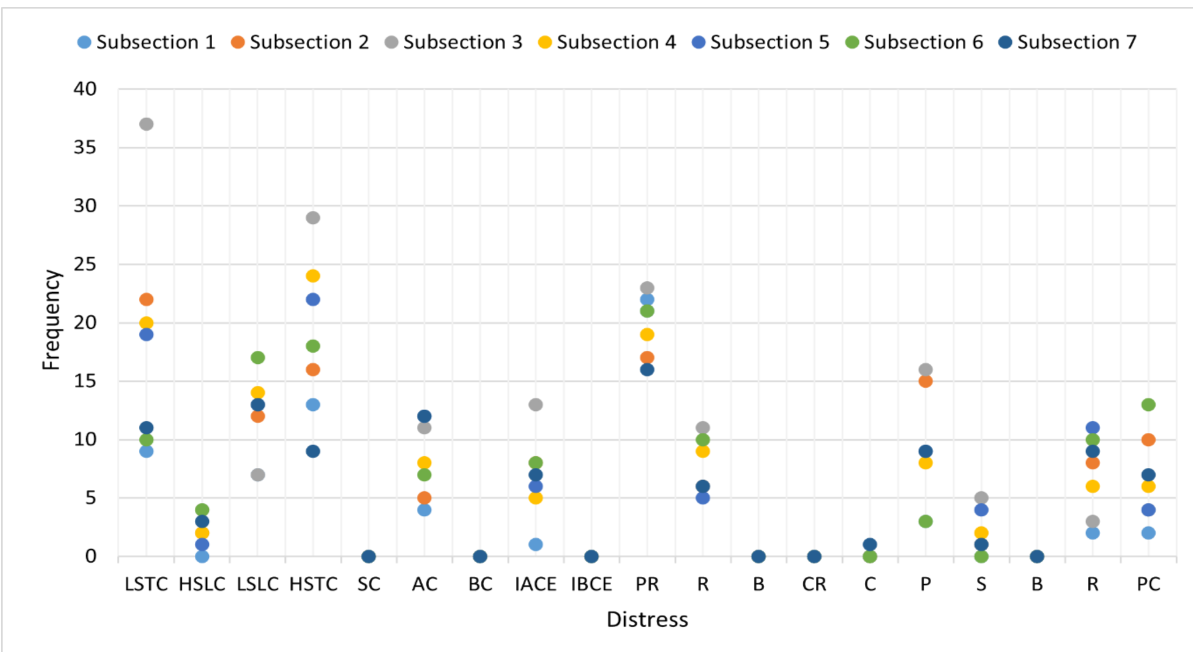

Figure No. 4: Frequency of distresses

Description: Low-Severity Transverse Cracking (LSTC), High-Severity Transverse Cracking (HSTC), Low-Severity Longitudinal Cracking (LSLC), High-Severity Longitudinal Cracking (HSLC), Shrinkage Cracking (SC), Alligator Cracking (AC), Block Cracking (BC), Interconnected Alligator Cracking with Erosion at the Edges (IACE), Interconnected Block Cracks with Erosion at the Edges (IBCE), Plastic Rutting (PR), Rutting (R), Bump (B), Consolidation Rutting (CR), Corrugation (C), Potholes (P), Shoving (S), Bleeding (B), Raveling (R), Patching (PC).

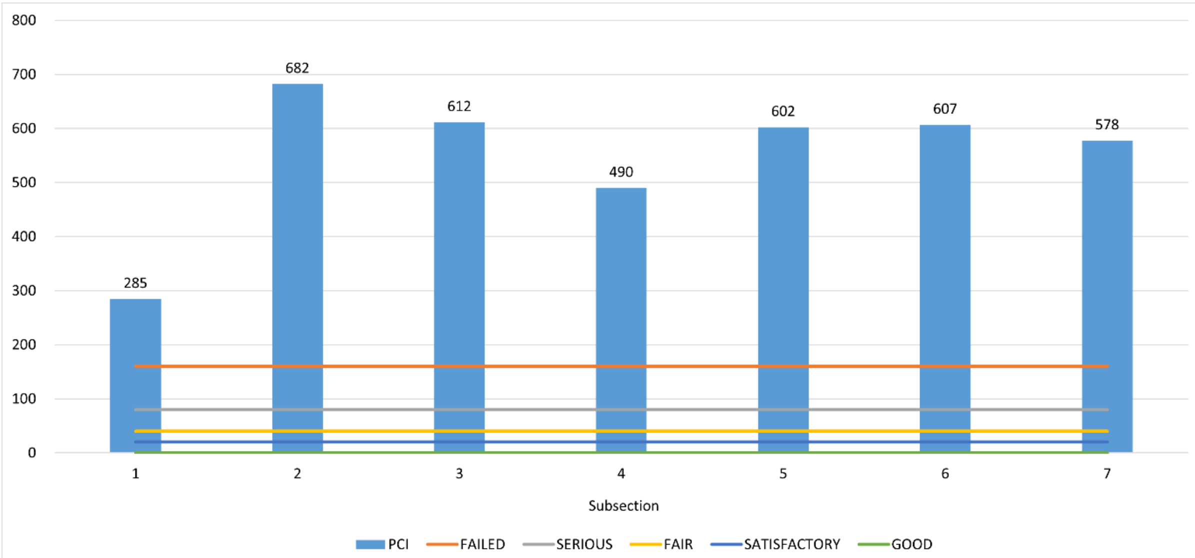

Figure No.5: Defects (pavement distress) along with the subsections

3.1.2 Sand Patch

A macrotexture survey was carried out for determining the condition of the pavement surface roughness (Figure No.6). This investigation was performed on surface spots not displaying any cracking or significant defects.

Figure No. 6: Measurement of the diameter of the scattered sand circle

During the experiment, we observed that the section revealed periodic maintenance. Hot Mixed Sand-Asphalt (HMSA) patches were made. Such a solution is identified as a formulation without the presence of coarse aggregates in its composition, which leads to a microtexture to Asphalt Concrete (AC). In determining the average depth of the macrotexture (Hs), we proceeded the same way. There was no separation by subsection, that is, all spots were considered. However, in the locations where the replacement of the AC coating with HMSA had been carried out, a reduction in the average of Hs values is noticed. These different spots are positioned below the line (0.40) (Figure No. 7).

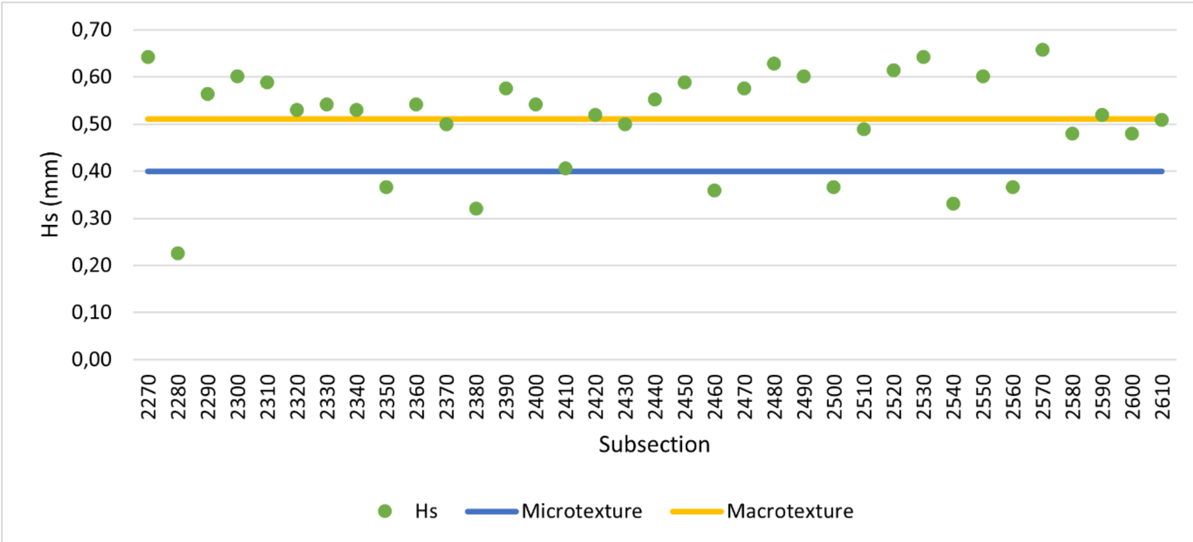

Figure No.7 - Macrotexture (Hs) along the stretch

In short, the complete surveyed stretch displayed Hs values ranging between 0.23 mm and 0.66 mm, with a standard deviation of 0.11. That is, within the range of values that corresponds to a texture ranging from thin to average. Using the arithmetic mean of these values (0.51mm), the representative section of an average texture can be measured [6]. Similar results are obtained by disregarding the HMSA-applied sites. Hs results varying between 0.41 mm and 0.66 mm, with a standard deviation of 0.06, and an average of 0.55 mm were identified (Figure No. 8).

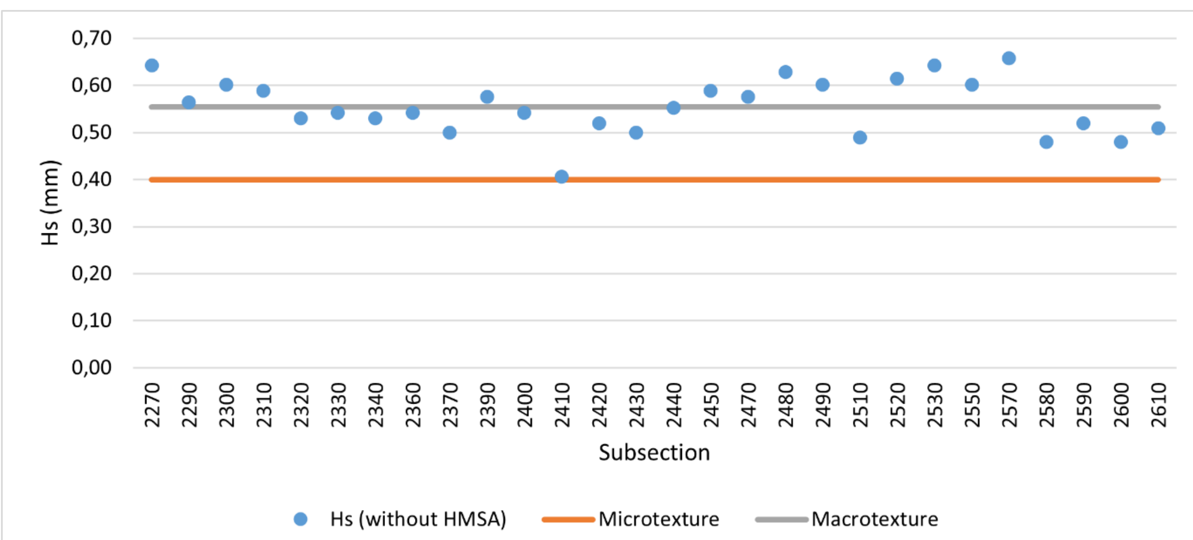

Figure No. 8 - Macrotexture (HS) along the stretch (without HMSA).

3.1.3 Visual Survey

The visual verification of defects in the TMR section [7], between piles 2270 and 2615, employed a pickup vehicle traveling at an average speed of 40km/h. The following defects were noted: potholes (P), cracking, and patching (PC), with a relatively high frequency. Depending on the deformations (AF), these defects made average frequencies clear. In the case of raveling (R) and shoving (S), they reached a low frequency. Notably, the defect corresponding to corrugation (C) was observed only in subsection 7, with a low frequency. Block cracking (BC) and bleeding (B) were not registered. In conclusion, despite displaying a small variation in the result value (2 and 3), the concept was classified as regular.

3.2 Structural analysis

This type of assessment aims to analyze a pavement's performance or ability to maintain its structural integrity. For this purpose, we decided to use the Benkelman beam (Figure No.9), mainly because it constitutes a nondestructive test. Thus, we can obtain a measurement of the actual response of the pavement to the applied load, without subjecting the materials to physical changes arising from sample collection.

Figure No. 9: Benkelman beam.

For the load applied during the testing, a single rear axle and a double wheel truck were used. To meet the specified load of 8.2 tf, 182 bags of cement (42.5 kg) were employed, distributed on wooden platforms for better positioning in the vehicle body.

The pavement deflection measures were distributed in an interposed way, that is, spaced apart every 5 piles (100m), to both sides. It should be mentioned, however, that the positioning on the left side was arranged between the measuring points on the right side (Figure No. 10). With this methodology it was possible to calculate the deflections every 50m, alternating between the right and left sides.

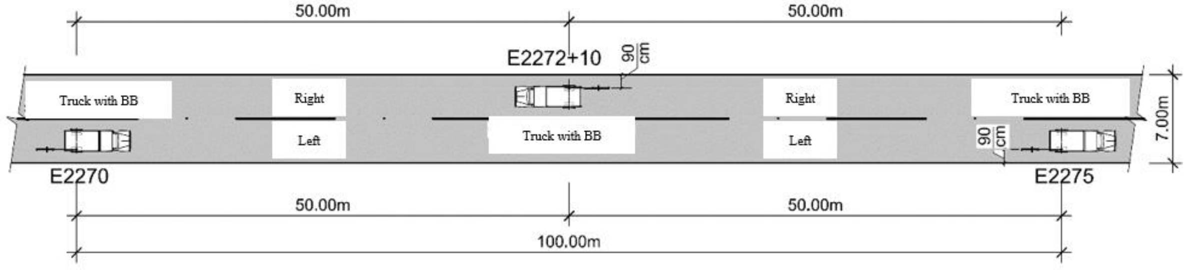

Figure No. 10: Diagram of the location of the deflection measurement points

At each evaluation point, 4 measurements were determined, one located exactly on the rear axle of the truck, the other 25 cm away from the first position, the others located at 50 cm, and 75 cm about the initial position. The first two measured deflection points (on the axis and at 25cm) are the most important ones since with them the values of the maximum recoverable deflection (D_0) and the Radius of curvature (R) are determined.

The values derived from the relationship between these two parameters registered the results observed in Figure No. 11.

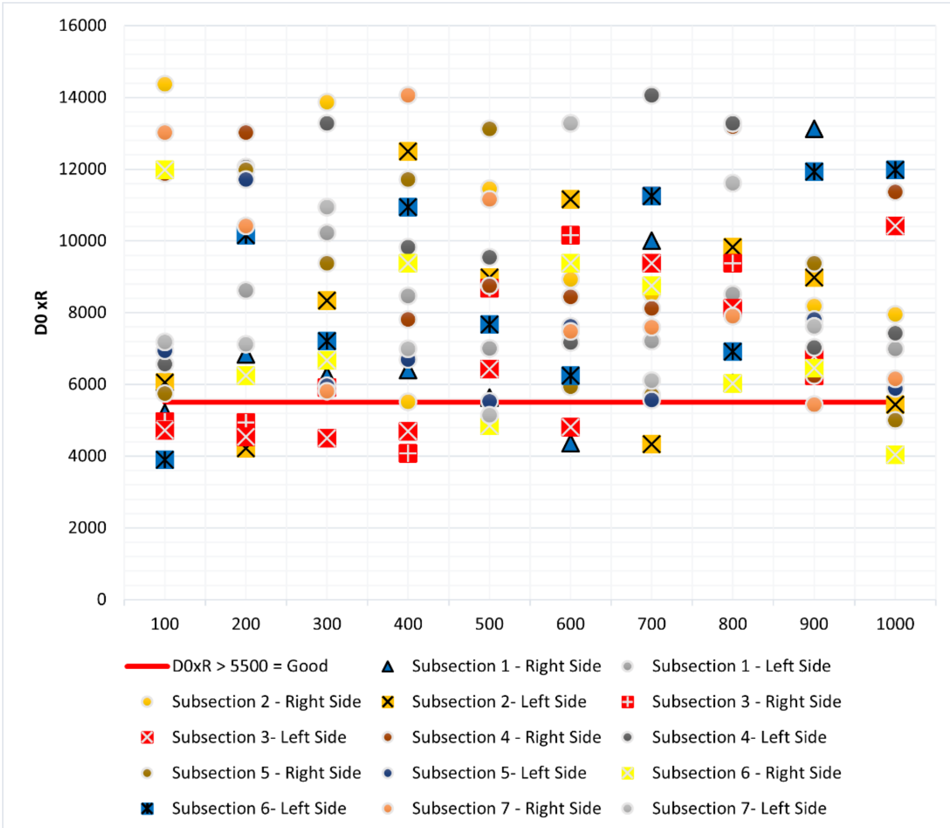

Figure No. 11: D_0 x R relationship along with the subsections.

As described by Lopes [10], the product of the RxD0 ratio is considered as one of the simplest parameters to analyze the structural performance of pavement, with the limit value being 5,500. That is, higher values show structurally acceptable pavements. The results found were satisfactory according to this criterion.

4. CONCLUSION

By analyzing the results, we found that the PCI presented a poor concept in all subsections. Complementing the functional evaluation, the assessment of the macrotexture resulted in an average texture. However, due to periodic maintenance, the spots with the application of HMSA were characterized as a microtexture. In short, the appearance of certain defects is associated with the age of the pavement's existence and the deficiency of periodic maintenance. As a suggestion, the asphalt coating should be replaced in its entirety in the verified subsections, with recommendations of using the milling methodology for the reuse of the removed material.

As for the structural condition of the pavement, although the values found in the RxD0 ratio did not prove to be incisive, we concluded that restoration is not necessary for the entire length of the stretch.

From the aforementioned, we highlight that the use of the methodology employed here, which assessed the TMR stretches functionally and structurally, may result in more precise indications for better subsidizing the use of resources in future interventions and restorations of the Petroleum Province of Urucu/Coari/Amazonas/BR.

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