DIAGNOSIS OF THE STRUCTURAL AND FUNCTIONAL EVALUATION OF BR-116 HIGHWAY, IN THE STATE OF CEARÁ

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ABSTRACT

This paper performs a structural and a functional evaluation of flexible road pavements, both executed along 137 km of BR-116 highway, in the State of Ceará. The structural evaluation was performed through the simulation of different traffic volumes. This evaluation's research methodology is the analysis of deflections and radius of curvature of the pavement's structure. As a result, it was observed that the surface did not show an appropriate structural behavior to moderate, high and very high traffic, in which the evaluation indicated reinforcement in more than half of the stretch under study. The functional evaluation was performed through a comparative analysis between two indexes which assign degradation concepts to the pavement. This evaluation's research methodology is the execution of a distress inventory for the highway surface, in order to calculate the Global Severity Index (GSI) and the Surface State Index (SSI) When comparing the results of both indexes, divergent classifications were found in several sections. The difference may be due to the influence of the observer's opinion on the state of the pavement's surface on the Continuous Visual Survey (CVS) method. Therefore, SSI gave a worse degradation condition to the pavement when compared to the GSI.

Keywords: Structural evaluation. Functional Evaluation. Pavements

1. INTRODUCTION

The road pavement consists of a set of finite layers that aim to ensure continuous traffic, provide comfort to the bearing and safety to the user, regardless of the climatic conjuncture. Thus, in order to achieve its purpose, as well as its useful life, it is indispensable to perform regular evaluations of its functional and structural conditions, among others [1].

The structural evaluation verifies the load capacity of the pavement through the analysis of the elastic or recoverable deformations. When the highway presents a structural condition unsatisfactory for the operant traffic, one can verify the increase of the appearance of distresses, as well as the decrease of the level of use over time. Therefore, the analysis of its structural behavior indicates a situation of degradation consequent to a deterioration process.

In this way, the appearance of distresses causes the reduction of the functionality of the pavement and, consequently, the reduction of the level of comfort and safety of the user. Therefore, it is essential to carry out evaluations to indicate the maintenance and verify the behavior in front of the traffic. Through them are obtained indicatives that classify the general condition of the pavement.

Considering the above, this paper aims to analyze the structural evaluation of a 137 km section of the BR-116 highway, in the State of Ceará, through the simulation of low, moderate, high and very high traffic volumes. In addition, a functional comparative analysis between the Global Severity Index (GSI) and the Surface State Index (SSI) is carried out.

2. THEORETICAL FOUNDATION

The structural evaluation of the flexible pavements analyzes the recoverable deflection measurements as well as the equivalent radius of curvature. According to [2], the procedures performed show that there is a relationship between the amplitude of deflections and the appearance of structural distresses. Through the analysis of the parameters of characteristic deflection, allowable deflection and radius of curvature, it is possible to define the structural quality of the pavement, if there is a need for complementary studies, the criterion for calculation of reinforcement and corrective measure.

Also, according to [2], the diagnosis of the pavement structure may indicate the need for reinforcement to make the conditions admissible to traffic. The thickness of the reinforcement is given in centimeters and is calculated by design deflection, allowable deflection and deflection reduction factor (depending on the material used).

The deflection measurements may be of the recoverable (elastic) or permanent (plastic) type. The behavior of the structure under normal conditions of use is represented by the elastic deformations, which cause cracks in the coating, which can cause pavement fatigue. On the other hand, the plastic deformations are consequent of an effort beyond the capacity of support of the pavement and accumulate throughout the period of use, being able to cause more severe distresses [1].

[3] states that the structure of the pavement has three phases: traffic consolidation, elastic phase and fatigue. The elastic phase is characterized by the recoverable deflections and represents the shelf life. The pavement begins the fatigue phase when the deflections become permanent, increasing the incidence of structural distresses and deterioration of the pavement.

The functional evaluation, in turn, provides a diagnosis of the surface condition of the pavement, which is constructed to offer comfort and safety to the user. In this way, the pavement is conceptualized according to its level of degradation and can present distresses in its structure or its operation. Thus, maintenance services must be sized according to the origin of these changes or distresses [4].

According to [1], the distress is classified as structural when it reaches the bearing capacity of the pavement. While the functional distress affects comfort to the bearing of the track. The distresses presented on the surface of the highway are more perceptible to users, as they directly affect their trafficability.

The distresses of the flexible pavements are identified by [5], which conceptualizes and classifies the distresses according to their particularities. The nature and causes of distresses are valuable information for the elaboration of a technical solution. Thus, a specific maintenance plan can be created to solve the problems of a particular highway.

3. METHOD OF RESEARCH

The research methodology for structural evaluation is initially to define the limits of the homogeneous segments (HS) of the section under analysis, which extends from km 286.48 to km 423.24, totalling 137 km in length. The deflectometric data, collected and made available by a specialized road engineering company, were organized in a spreadsheet. Then, using the data of the deflection measurements, we performed simulations with different traffic volumes, as well as the calculations of deflections (characteristic, design and permissible) and radius of curvature.

Through the results obtained from the calculations, the HS of the stretch were evaluated structurally according to the parameters presented in [2], resulting in the structural quality and the corresponding corrective measure. The structural evaluation results may indicate reinforcement sizing or just surface corrections.

Finally, a spreadsheet was developed with the purpose of improving the visualization of the results of the structural evaluation described above, as well as facilitating the calculations of deflections (characteristic, design and admissible).

The research methodology for the functional evaluation used in this work is initially to define the HS boundaries of the section to calculate GSI and SSI parameters, according to [6] and [7]. The data was provided by a specialized road engineering company through specific reports of the stretch.

Finally, a comparative analysis was performed between the results of the functional evaluation by the two indexes mentioned in the previous paragraph.

4. CASE STUDY

The analysis will be done through the simulation in different volumes of traffic, using the deflectometric data of the pavement obtained by means of the equipment Benkelman Beam. As well as performing the evaluation of the surface condition, using two different methodologies, with the objective of performing a comparative analysis.

4.1 Structural evaluation

The 137 km extension of the highway under study was fractionated in 62 HS with approximately 2.2 km each. The stations were distributed with a spacing of 40 m and the deflectometric data obtained were the values of "d_0" and "d_{25}" which represent, respectively, the real deflection and the deflection at 25 cm from the test point. Initially, for each HS, the mean deflection, the standard deviation and the mean radius of curvature were calculated.

The structural evaluation was performed according to the parameters of design deflection, allowable deflection and radius of curvature. To obtain the values of the analyzed criteria, it is necessary to have the mean deflection, standard deviation (relative to deflections) and average radius of curvature, according to [2]. An automated spreadsheet was then created to optimize the calculations required for the assessment and its corrective measures. Through the spreadsheet, simulations of different traffic volumes were carried out. For each type of request, a value of Number N was assigned according to [8]. The variation of this data has the consequence of altering the permissible deflection which is one of the parameters of the structural evaluation.

For the field of the seasonal correction factor, the value of 1.00 was used, according to [2]. In this case, the evaluation was performed considering the rainy season. Then, the structural evaluation was performed on each HS in the low, moderate, high and very high traffic volumes. Results were obtained considering the following factors: structural quality, need for complementary studies, calculation criteria for reinforcement, corrective measure and reinforcement thickness in Asphalt Concrete (AC).

The HS showed a significant change in structural quality as the volume of traffic increased. This evidenced a migration of 61% of HS from Good to Regular classification, between Low and

Very high traffic volumes. The increase of the passage of vehicles causes, for calculation purposes, the increase of the Number N and, consequently, the reduction of the permissible deflection. Thus, the HS classified as Good structural quality was considered Regular quality, as shown in Table 1.

TABLE 1 Percentage of HS in relation to structural assessment criteria

PERCENTAGE OF HS				
CRITERIA	**TYPE OF TRAFFIC**			
	LOW	**MODERATE**	**HIGH**	**VERY HIGH**
STRUCTURAL QUALITY				
Good	63%	18%	3%	2%
Regular	8%	53%	68%	69%
Regular to bad	3%	0%	0%	0%
Bad	26%	29%	29%	29%
NEED FOR COMPLEMENTARY STUDIES				
Yes	29%	29%	29%	29%
No	71%	71%	71%	71%
CORRECTIVE MEASURE				
Only surface corrections	63%	18%	3%	2%
Reinforcement	8%	53%	68%	69%
Reinforcement or reconstruction	29%	29%	29%	29%
REINFORCEMENT				
Average Thickness (Cm)	5,0	8,0	11,0	13,0

From the data in Table 1, it can be seen that HS whose structural quality was classified as Regular to bad were considered to be of Bad quality due to the increase in the volume of traffic Low to Moderate.

The percentage of HS with structural qualities classified as Regular to bad and Bad remained constant (29%) in any type of traffic due to the fact that the radius of curvature of these HS did not vary during the simulations. In this way, it can be seen from Table 1 that the corrective measure of reinforcement or reconstruction has remained constant in the different types of traffic, since it is indicated for these structural quality ratings (Regular to bad and Bad), according to [2]. The average reinforcement thickness in AC of the HS showed a growth directly proportional to the traffic, according to Table 1. This occurred due to the reduction of the permissible deflection throughout the simulations.

4.2 Functional evaluation

4.2.1 Global Severity Index (GSI)

According to [6], the enumeration and classification of apparent distresses and the measurement of permanent deformations in wheel tracks were performed to calculate GSI. The study extension was fractionated in 64 HS with 10 evaluation surfaces each, totalling 640 sample units, in which all distresses were recognized and recorded. In addition, the arrows were measured in the inner and outer wheel tracks, in which the highest values corresponding to each track were recorded.

The distresses were as follows: cracks type 1, cracks type 2, cracks type 3, sinking, undulation, wear, exudation, patch and pan. It was verified that the greatest occurrence was the wear distress, which was identified in all the stations, followed by distresses such as fissure (99.84%), short transversal crack (62.19%) and short longitudinal crack (55,31%). On the other hand, the lowest occurrence was type 3: alligator leather cracks with marked erosion at the edges (0.94%) and block type cracks with marked erosion at the edges (1.09%).

The Individual Severity Index (ISI) was then calculated based on the relative frequencies, the weighting factors and the groups of distresses. While the calculations of the tracks of wheels were realized according to the average of the measures and the variance. Finally, through the ISI summation, the GSI was calculated for each HS. Through this index, it was possible to assign a concept of pavement status for each section.

From the results, an average GSI of 86.94 (standard deviation of 37.81) was obtained, which represents a Bad condition of degradation. Through these values, a coefficient of variation of 43% was obtained. This represents a large dispersion of values from the mean.

4.2.2 Surface State Index (SSI)

The study extension was fractionated in 692 HS with 200 m of length each, in which an inventory of distresses according to [7] was performed. This recognition was performed through Continuous Visual Survey (CVS). It was found that the most representative distresses were isolated cracks and corrugations, present in all HS. The smaller occurrences were: cracks type 3 (0.72%), panela (1,16%) and exudation (0,43%).

The indexes and their respective weights were defined according to the frequency of the groups of distresses (cracks, deformations, pans and patches). Then, the Expedited Global Gravity Index (EGGI) values were obtained by multiplying the frequencies and respective weights of each group. While the Flexible Pavement Condition Index (FPCI) was estimated for each HS. With this, the value of the SSI for each HS was obtained. Thus, it was possible to determine the concept of surface condition, as well as to define a restoration measure applicable to the pavement.

The section under study presented a Bad or Terrible state ($SSI \geq 5$.) Also, the survey showed an average EGGI of 57.94 and an average FPCI of 1.39.

4.2.3 Analysis of results

From the calculated parameters, a comparative analysis was carried out between the evaluations by the GSI and the SSI. Through the graph of Figure 1, it can be seen that in relation to GSI the stretch presented a Regular condition in its majority. Regarding the SSI, the section presented a Bad condition in the majority.

According to the graph of Figure 1, it can be verified that the SSI presented a Bad concept for 51.6% of the stretch, while the remaining 48.3% presented a Terrible concept. Still, only 1 HS (0.1%) presented a Regular concept. The concepts Good and Great were not found in any HS of the section discussed in this paper.

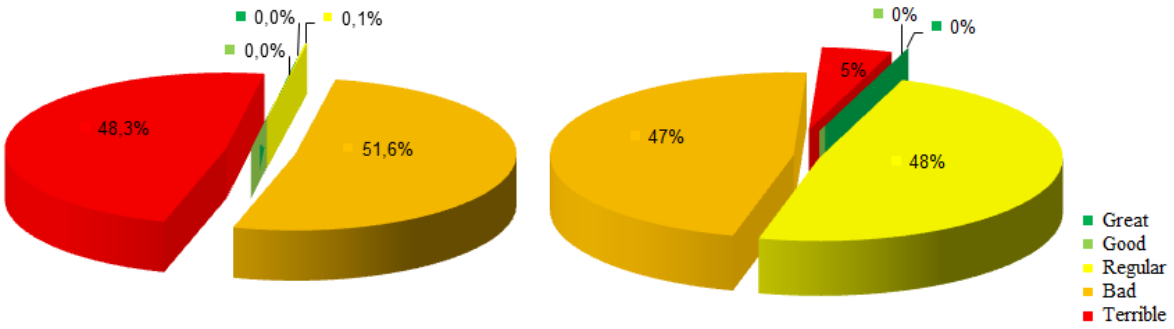

FIGURE 1 Percentage of pavement condition - SSI (left) and GSI (right)

In relation to GSI, the pavement presented a Terrible concept for only 5% of the stretch. On the other hand, the concepts Bad and Regular represented, respectively, 47% and 48% of the stretch. The concepts Great and Good, as well as for the SSI, were not found in any HS of the stretch.

5. CONCLUSIONS

It can be observed that the pavement of the section of the BR-116 does not present adequate structural behaviour to the volumes of Moderate, High and Very high traffic. The evaluation indicated reinforcement in more than half of the stretch for these types of traffic. The analysis of the functional evaluations between GSI and SSI showed differences in several HS. The SSI indicated a worse condition to the pavement. This can be seen when, for example, an HS was considered Regular by GSI, but as Bad by SSI. This contrast can be explained by the greater subjectivity of the CVS method.

The aspect that most influences are the opinion of the observer, as it may present disagreements about the surface state of the pavement. During the survey, the frequencies of the distresses can be registered in an equivocal way, just as there may be distresses that were not computed. These errors can occur due to several factors that make it difficult or impossible for the evaluator to see.

6. REFERENCES

[1]BERNUCCI, L. B., MOTA, L. M. G., CERATI, J. A. P.; SOARES, J. B. Pavimentação Asfáltica. Formação Básica para Engenheiros. Rio de Janeiro: Petrobras. Abeda, 2007.

[2]DNER. Avaliação estrutural dos pavimentos flexíveis, procedimento B. Norma DNER-PRO 11/79. Departamento Nacional de Estradas de Rodagem. Instituto de Pesquisas Rodoviárias. Rio de Janeiro, RJ, 1979.

[3]SENÇO, Wlastermiler. Manual de Técnicas de Pavimentação. 2ª Edição. São Paulo: Pini. 1 v,2007

[4]BALBO, José Tadeu. Pavimentos asfálticos: patologias e manutenção. São Paulo: Plêiade, 1997.

[5]DEPARTAMENTO NACIONAL DE INFRAESTRUTURA DE TRANSPORTES. DNIT 005/2003 – TER: Defeitos no pavimentos flexíveis e semi-rígidos – Terminologia. Rio de Janeiro, 2003a.

[6]DEPARTAMENTO NACIONAL DE INFRAESTRUTURA DE TRANSPORTES. DNIT 006/2003 – PRO: Avaliação objetiva da superfície de pavimentos flexíveis e semi-rígidos – Procedimento. Rio de Janeiro, 2003b.

[7]DEPARTAMENTO NACIONAL DE INFRAESTRUTURA DE TRANSPORTES. DNIT 008/2003 – PRO: Levantamento visual contínuo para avaliação da superfície de pavimentos flexíveis e semi-rígidos – Procedimento. Rio de Janeiro, 2003c.

[8]CERATTI, J. A. P., BERNUCCI, L. B.; SOARES, J. B. Utilização de Ligantes Asfálticos em Serviços de Pavimentação. Rio de Janeiro: Abeda, 2015.