CHAPTER 30

Study of the effectiveness of constructive methods through the evaluation of the surface using the LVC method: Case study of the Antônio Carlos Belchior highway in the city of Sobral, CE

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ABSTRACT

Transport infrastructure plays a crucial role in the socio-economic development of a country both at regional and national levels. However, this segment faces difficulties to develop essential activities that can offer differentiated support in the transport sector. The main difficulties are related to the lack of permanent investments in the construction, maintenance, and inspection of highways. The present research work had as its main focus to evaluate the surface conditions of the pavement of a highway using a Continuous Visual Survey Method. For this purpose, a comparative analysis was carried out between the project of the enterprise and its execution, as well as the pathologies presented as a result of its use. The studied highway, named Av. Antônio Carlos Belchior, is located in the city of Sobral, Ceará, Brazil. For the evaluation of the surface of the pavement, the Norm DNIT 008/2003 - PRO was adopted, where the required conditions for the accomplishment of the evaluation of the surface of flexible and semi-rigid pavements are fixed. During the work, the pathologies present in the pavement were detected and classified according to the characteristics presented during the evaluation. Therefore, in this work, an approach was carried out from the elaboration of the project to the execution of the highway, analyzing the factors that contributed to the wear and/or emergence of pathologies. The Continuous Visual Survey Method made it possible to diagnose the critical points of the highway from the pathologies detected during the evaluation process.

Keywords: Transport Infrastructure, Continuous Visual Survey Method, Highways, Flexible Floors.

1 INTRODUCTION

The transport infrastructure acts in the displacement of people and goods, composed of highways, railways, airports, ports, and waterways. One of the main challenges of the infrastructure is in the mapping of the problems and definition of priorities, in addition to the lack of investment in recent years. Therefore, for improvement in this area, the planning and transparent use of public resources is paramount, and it is worth mentioning that the lack of these services low generates competitiveness among companies, difficulty in future investments and with this, affects the generation of new jobs (Viana et al, 2021; Silva Junior et al, 2019; Santos et al., 2021; Oliveira, 2022; Maganinho, 2013; Santos & Silva Junior, 2018).

Paving is a step of paramount importance to have quality highways and due to the deterioration of the roads, the cost of transportation is high and penalizes the productive sector and final consumers.

For the execution of a highway, it is important to know the types of pavements, characterized as flexible, semi-rigid, and rigid (Antas et al., 2010; Balbo, 2007; Bernucci et al., 2010; Curcio, 2008; Pinto & Preussler, 2002).

According to the final version of the DNIT Paving Manual (IPR – 719/2006), the flexible and semi-rigid floors will have coating based on bitumi materials, and it is worth mentioning that the semi-rigid pavement has a base cemented by some binder with cementitious properties (soil-cement). Already the rigid pavements will be obtained through the use of concrete, so it absorbs practically all the stresses generated by the applied loading (DNIT, 2003a; DNIT, 2003b; DNIT, 2005a; DNIT, 2005b; DNIT, 2006a; DNIT, 2006b; DNER, 1999;).

According to the National Confederation of Transport (CNT), after an analysis of the national road network in 2019, 59.2% of the highways presented some type of problem in their general state. Thus, the analysis of the surface condition and the shoulder pavement was made, and it was observed that 47.6% of the evaluated stretches presented problems and defects in their paving. Therefore, the transport infrastructure is a prerequisite for the development of a city, or a country and must be well cared for. According to a survey by the National Confederation of Transportation (CNT) in 2016, 48.3% of Brazilian highways have some type of problem with the pavement, being evaluated as regular, bad, or very bad the condition of pavement surface, where structural and functional problems appear early, on average, seven months after the delivery of the road work.

The objective of this research work was to present, through a case study, the pathologies present in the pavement and to evaluate the constructive methods used in the construction of the Antônio Carlos Belchior highway. In addition, an analysis was carried out on the effectiveness of the methods used during the execution of the project and the potential pathologies that may arise due to the application of the inadequate construction method. The mentioned highway connects the neighborhoods Cohab II and Vila Boa Bairro, both located in the city of Sobral, Ceará, Brazil. The choice of the study site had priority because it is recent work and, even in the execution phase, already presents pathologies.

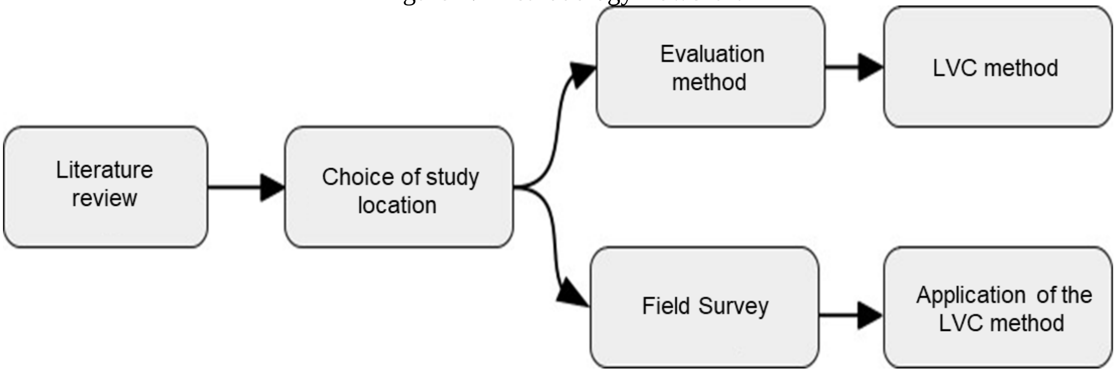
Therefore, the development of the work focused on the following problem: in the phase of execution of the highway, were the technical criteria established in the project properly followed? What are the causes of the pathologies presented and how could they have been prevented? To answer the questions object of this study, the following topics were considered: the need for implementation of the highway, highway projects, types of defects in the pavement, and the Continuous Visual Survey Method. The Continuous Visual Survey (CVL) method was used to obtain the flexible pavement condition index (ICPF) to analyze the conditions of use of the pavement, the age of the work, and for which type of loading it was dimensioned.

2 METHODOLOGY

For the development of this work, initially, a bibliographic survey was carried out on the types of pavements, road engineering projects, pavement paths, field surveys, etc. The work was divided into four stages: bibliographic research, choice of the study site, a survey in the field (Continuous Visual Survey)

- LVC) and classification of data collected in the field. The stages of development of the work are outlined in the flowchart below (Figure 1).

Figure 1. Methodology flowchart



Source: Authors.

The highway studied has an extension of 2 km and connects the neighborhoods Cohab II and Vila Boa Bairro, both in the city of Sobral, Ceará, Brazil. The study was done throughout its length, emphasizing that it has intersections with the roundabout and intersection with the railway. Figure 2 shows an image of the highway covered in this study.

Figure 2. Highway under study

Source: Google Earth, 2021.

The LVC method was used to evaluate the pavement surface of the highway (Procedure), according to DNIT 008/2003 – PRO. The aforementioned standard sets the conditions required for the evaluation of the pavement surface, being flexible or semi-rigid.

The survey was carried out from the interior of a vehicle at a speed of approximately 40 km / h, traveling the entire highway. When necessary, the vehicle was exited to analyze the most prominent pathologies and for photographic records of them. The highway consists of two single-lane lanes totaling 1km in each lane. For the evaluation, the highway is divided into two segments, since, according to the Standard, the highway must be divided into segments with an extension of 1km to 6km. During the survey, the spreadsheet of Annex B of DNIT 008 /2003 was used

– PRO to register the defects presented on the surface of the pavement during the survey.

Table 1 provides the ICPF values and Table 2 class identifies the frequency as High (A), Medium (M), and Low (B). The frequency is determined by the number of pathologies in each segment that the highway has been divided. Tables 1 and 2 show how these classifications were.

Tabela 1. ICPF Concepts

Concept	Description	Description
Very good	It only needs routine maintenance.	5 - 4 Ads
Good	Application of asphalt mud- Surface wear, not very severe cracks in not very extensive areas	4 – 3
Regular	Correction of localized points or resurfacing - cracked pavement, with infrequent "pans" and patches and with longitudinal or transverse irregularity	3 - 2 Ads
Bad	Resurfacing with previous corrections - generalized defects with previous corrections in localized areas - superficial or deep patches.	2 – 1
Lousy	Reconstruction - generalized defects with previous corrections to the full extent. Degradation of the coating and other layers - water infiltration and decompaction of the base	1 - 0 Ads

Source: DNIT (2003a).

Table 2. Frequency of defects

Pots (P) and Patches		
Code	**Frequency**	**Quant./Km**
The	Discharge	≥ 5
M	Average	2 – 5
B	Low	≤ 2
Code	**Frequency**	**Quant./Km**
The	Discharge	≥ 50
M	Average	50 - 10 Ads
B	Low	≤ 10

Source: DNIT (2003a).

Following the instructions established by DNIT 008/2003 and according to the frequency will be obtained the values of the factors that determine the severity indices and the weights for calculation. Tables 3 and 4 show how these factors are determined.

Table 3. Determination of the Gravity Index

Pots (P) and Patches (R)		
Frequency	**Factor (Fpr) Quant. / Km**	**Gravity**
A – High	≥ 5	3
M - Average	2 – 5	2
B - Low	≤ 2	1
Other defects (cracks, deformations)		
Frequency	**Factors Ft and Foap (%)**	**Gravity**
A – High	≥ 50	3
M - Average	50 – 10	2
B - Low	≤ 10	1

Source: DNIT (2003a).

Table 4. Weights for calculation

Gravity	En	Poap	Ppr
3	0,65	1,00	1,00
2	0,45	0,70	0,80
1	0,30	0,60	0,70

Source: DNIT (2003a)

The last stage of the survey is to classify the Pavement Surface State Index (IES). The HEI values according to Table 5 are between 0 and 10. This index is evaluated according to the ICPF and IGGE already calculated.

Table 5. IES Classification

Description	HEIs	Code	Concept
GGE ≤ 20 and ICPF > 3.5	0	The	VERY GOOD
IGGE ≤ 20 and ICPF ≤ 3.5	1	B	GOOD
20 ≤ IGGE ≤ 40 and ICPF > 3.5	2		
20 ≤ IGGE ≤ 40 and ICPF > 3.5	3	C	REGULAR
40 ≤ IGGE ≤ 60 and ICPF > 2.5	4		
40 ≤ IGGE ≤ 60 and ICPF > 2.5	5	D	BAD
60 ≤ IGGE ≤ 90 and ICPF > 2.5	7		BAD
60 ≤ IGGE ≤ 90 and ICPF > 2.5	8	And	LOUSY
IGGE > 90 10			

Source: DNIT (2003a)

3 RESULTS AND DISCUSSION

Following the parameters established by the DNIT standard – 008/2003 (PRO), the LVC was held in February 2022. The DNIT standard – 008/2003 (PRO) establishes unique conditions and procedures for carrying out the survey, focusing on the evaluation of the surface of flexible and semi-rigid pavements through the determination of the following indices: Condition Index of Flexible or

Semi-rigid Pavements (ICPF), Expedited Global Severity Index (IGGE) and the Surface State Index (IES).

The highway studied consists of two single-hand lanes containing a kilometer in length given one of them. Thus, the analyzed stretch contains two kilometers. Figure 3 shows the highway in the printing and earthmoving stages of the bike path.

Figure 3. Highway in the stages of earthmoving and printing.

Source: Authors

After the application of the LVC and analysis of the survey method, the data obtained in the field were organized in tables. These results were later used to diagnose the actual conditions of the highway studied.

3.1 RESULTS OF THE CONTINUOUS VISUAL SURVEY METHOD (CVL)

To obtain the data from the field survey, based on the DNIT standard – 008/2003, the highway was divided into two segments (1 km each). The evaluation was carried out with the aid of annexes A and B of the DNIT standard – 008/2003. Annex A consists of a summary table of defects with the codings and classification and B is a form that must be completed according to the continuous visual survey is accomplished.

The field study using the LVC made it possible to perform the calculations of ICPF, IGGE, and IES. These calculations will indicate the state of the pavement surface according to its condition and overall severity.

Table 6. ICPF Results

No. OF MON	Odometer/KM BEGINNING	END	Ext P	CRACKS TR	TJ	TB	R	DEFORMATIONS AF	Or	OTHER DEFECTS D	EX	ICPF And
1	KM 0	KM 1	B	B						B		4
2	KM 1	KM 2		M		M		M				3

SEGMENT FREQUENCY OF DEFECTS (A, M, B, or S)

CAPTION: P – Pot TJ – Alligator

Leather Crack R – AF Patch – Sinking D – Wear

Source: Adapted from DNIT /2003

From the data shown in Table 1, it is observed that the highway has some defects such as pan, sinking, wear, cracks, and patches, resulting in ICPF ranging between 3 and 4.

The next step consisted of calculating the IGGE as shown in Table 7.

Table 7. IGGE Results

SEGMENT				CRACKS			DEFORMATIONS			PAN + PATCH			(Ft x Pt) + (Foap x Poap) + (Fpr x Ppr) = IGGE
No. of Mon	Miles Beginning	Km End		Ft Ext n %	E	Ft X En	Foap %	Poap	Foap X Poap	FP R No	Ppr	FP R X Ppr	
1	Miles 0	Miles 1	1 Mile	10	0,3	3 Ads	0	0 Ads	0	10 -	0.70	7	10
2	Miles 1	Mile 2	1 Mile	30	0,45	13.5	30	0.70	21	30	0.80	24	58,50

Source: Adapted from DNIT /2003

Based on the data obtained and analyzed, it is verified that the highway presents a certain degree of criticality on its surface, especially in Segment 2, because it presents an IGGE value higher than Segment 1.

Ultimately, the surface assessment brings together the values of the ICPF, IGGE, and IES, where the HEI of the pavement will define the condition of the surface. The HEI is between 0 and 10, evaluated in excellent (A), good (B), regular (C), poor

(D) , and very bad (E). Table 8 shows the data that determine the conditions of the highway through the HEI.

Table 8. LVC Method Results

Mon.	RESULTS SEGMENT							
	Km Start	Km End	Extension	ICPF	IGGE	HEI s		
						Val or	Code.	Concept
1	0 Km 1	Km	4	10	1	B	Good	
2	1 km	2 km	1 km	3	58.5 5		d	bad

Source: Adapted from DNIT /2003.

3.2 IDENTIFICATION AND ANALYSIS OF DEFECTS PRESENT ON THE FLOOR SURFACE

According to the LVC performed in the field, segments 1 and 2 presented defects in their surface. In follow-up 2, the defects were more recurrent.

According to the data collected in Table 1, segment 1 presents defects of the type pans, cracks of the tipo alligator leather, and wear, while in segment 2, cracks of the alligator leather type, patch, and sinking were observed. With this, these defects will be analyzed in more detail.

3.2.1 Segment 1

In segment 1, pots or holes, interlocking cracks of the alligator leather type, and wear were observed. Next, the defects will be illustrated according to their possible causes and sizing. Figure 4 illustrates the thickness of the asphalt coating.

Figure 4. The thickness of asphalt coating

Source: Authors

According to the dosage design, the coating should be 5 centimeters thick. However, according to Figure 3, this thickness was reduced to 2 centimeters. Based on this analysis, the thickness of the pavement may be the cause of the defects presented on the paving surface. Cracks were observed throughout the analyzed segment. Figure 5 illustrates some pathologies present in Segment 1.

Figure 5. Pathologies observed in segment 1.

Source: Authors

As shown in Figure 5a, these cracks were partially maintained after the coating layer was executed. These cracks are positioned longitudinally to the axis of the highway, presenting as possible causes of the poor dosage of the asphalt coating or excessive compaction or at an inappropriate time.

Figure 5b shows an interlocking crack like alligator leather accompanied by wear of the pavement, having as possible causes, the collapse of the asphalt coating due to the repetition of the actions of the traffic and poor quality of the structure or one of the layers of the pavement, low capacity of support of the soil.

Defects such as pot/holes were also detected in the segment both at the entrance to the roundabout and at the roundabout itself, as shown in Figure 5c. These types of defects can be caused by fatigue cracks, localized disintegration on the surface of the pavement, deficiency in compaction, excessive moisture in soil layers, and Print failure.

The observed wear and tear are largely present on the highway in general. Figure 5d illustrates this type of defect present in segment 1. This type of pathology, in general, is linked to adhesive failures between the binder and aggregate, deficiency in the binder content, and executive or mixture design problems.

3.2.2 Segment 2

In segment 2 the defects detected were interlocking trenches of the alligator leather type, patch, and sinking. This segment was the most critical in comparison to segment 1, presenting HEI equal to 5, therefore, classifying it as a bad state. Figure 6 shows some defects detected in this along this segment.

Figure 6. Pathologies detected in segment 2.

Source: Authors

Figure 6a shows a defect detected along segment 2. It is a plastic wheel track sinking. This type of sinking consists of a permanent deformation of the surface of the pavement, accompanied by a lateral volumetric compensation(lifting) that is indicated by the arrows in red. This defect can be caused by the plastic creep of one or more layers of the pavement or subbed, or failure to select the type of asphalt coating for the requesting load.

Figure 6b is a deep patch due to sewer installation after paving is done. This type of installation should be done before any layer of the pavement, to avoid future pathologies and structural damage to the pavement. As it is a deep patch, there must be a replacement of the coating and, eventually, of one or more lower layers of the pavement. Thus, the cause of this pathology may have been caused by improper construction or management in the execution stage.

Figures 6c show interlocking alligator leather cracks. These defects were detected at various points on the highway. Nonetheless. The most prominent is located at the intersection of the highway and the railway. The interlocking cracks like alligator leather, are considered a structural defect caused by the collapse of the asphalt coating due to the repetition of traffic actions, inferior quality of the structure or one of the layers of the pavement, and/or low capacity of soil support.

Table 1 shows the general result obtained with the aid of the LVC method contemplating the values of ICPF, IGGE, and IES. From the results obtained, it is observed that segment 1 presented values of ICPF = 4 and IGGE = 10. Considering the value of ICPF $\leq$ 3.5 and IGGE $\leq$ 20 this results in the value of IES = 1, whose concept is considered good. On the other hand, segment 2 presented ICPF values $\leq$ 2.5 and IGGE between 40 and 60. These results provide the value of IES = 5, considered a bad concept

Table 8. Overall Result of the Continuous Visual Survey

SEGMENT	IES		VALUES	
	ICPF	IGGE	VALUE	CONCEPT
1	4	10	1	Good
2	3	58.50	5	Bad

Source: Apt of the DNIT/2003 Standard.

Thus, according to the evaluation by the LVC method, it was concluded that 50% of the highway is in good condition, and 50% in a state classified as bad.

4 CONCLUSION

The Continuous Visual Survey Method was successfully applied to study the pathologies and carry out a diagnostic survey of the highway known as Av. Antônio Carlos Belchior located in the city of Sobral, CE, Brazil. The analysis of the state of the asphalt pavement followed the conditions proposed by DNIT 008/2003 – PRO using the Continuous Visual Survey Method. From a field study, the main pathologies detected along the highway were: cracks, interconnected cracks like alligator leather and "block" type, deep patching, wear, pantheism, and plastic sinking. The data collected in the field and the projects were used to compare whether the execution of the highway followed the values dimensioned in the project. Based on the study carried out and the results obtained, it was possible to evaluate the real conditions of use of the highway studied its critical points, and compare the execution of the project with the projected values. In addition, to detect the potential causes of the pathologies mapped on the highway. From the evaluation using the Continuous Visual Lift Method, it was concluded that 50% of the highway is in good condition and 50% is in a state classified as poor. The research work has potential and can assist researchers in the structural analysis of highways.

REFERENCES

Antas, P. M., Vieira, A., Gonçalo, E. A., & Lopes, L. A. (2010). Estradas: Projeto geométrico e de terraplenagem. Editora Interciência. Balbo, J. T. (2007). Pavimentação asfáltica: materiais, projeto, e restauração. Oficina de Textos.
Bernucci, L. B., Motta, L. G. M., Ceratti, J. P. C. & Soares, J. B. (2010). Pavimentação Asfáltica: formação básica para engenheiros. Abeda.

Curcio, R. C. L. (2008). Pontes Rodoviárias: Levantamento das principais patologias estruturais. Trabalho de Conclusão de Curso, Curso de Engenharia Civil, Unidade Acadêmica da Área de Ciências Exatas e Tecnológicas, Universidade São Francisco, Itatiba.

DNIT - Departamento Nacional de Infraestrutura de Transportes - NORMA 005/2003. Diretoria de Planejamento e Pesquisa / IPR. (2003a). Defeitos nos pavimentos flexíveis e semirrígidos: Terminologia

DNIT – Departamento Nacional de Infraestrutura de Transportes NORMA DNIT 008/2003. Diretoria de Planejamento e Pesquisa / IPR. (2003b).
Levantamento visual contínuo para avaliação da superfície de pavimentos flexíveis e semi-rígidos: Procedimento

DNIT - Departamento Nacional de Infraestrutura de Transportes. Diretoria de Planejamento e Pesquisa. Coordenação Geral de Estudos e Pesquisa. Instituto de Pesquisas Rodoviárias. (2005a). Manual de conservação rodoviária.

DNIT - Departamento Nacional de Infra-Estrutura de Transportes. Diretoria de Planejamento e Pesquisa. Coordenação Geral de Estudos e Pesquisa. Instituto de Pesquisas Rodoviárias. (2005b). Manual de projeto de interseções.

DNIT - Departamento Nacional de Infraestrutura de Transportes. Diretoria de Planejamento e Pesquisa. Coordenação Geral de Estudos e Pesquisa. Instituto de Pesquisas Rodoviárias. (2006a). Manual de pavimentação.

DNIT - Departamento Nacional de Infra-Estrutura de Transportes. Diretoria de Planejamento e Pesquisa. Coordenação Geral de Estudos e Pesquisa. Instituto de Pesquisas Rodoviárias. (2006b). Manual de Restauração de pavimentos asfálticos.

DNER - Departamento Nacional de Estradas de Rodagem. Diretoria de Desenvolvimento Tecnológico. Divisão de Capacitação Tecnológica. (1999). Manual de projeto geométrico de rodovias rurais.

Santos, D. C. M. F. & Silva Júnior, F. V. (2018). Levantamento visual contínuo: análise da rodovia TO-255, trecho de Porto Nacional a Monte do Carmo.
Engineering Sciences, 6(1), 10-20. http://doi.org/10.6008/CBPC2318-3055.2018.001.0002

Maganinho, L. G. O. (2013). Desenvolvimento de uma base de dados de patologias para a avaliação da qualidade de pavimentos rodoviários com recurso a GPS, imagem vídeo e SIG. (2013). Dissertação de Mestrado, Engenharia Civil: Geotecnia e Ambiente, Universidade da Beira Interior, Covilhã, Portugal.

Oliveira, C. A. A. & Almeida, W. M. S. (2022). Análise da pavimentação asfáltica do DNIT e do município de Gurupi – TO. Research, Society and Development, 11(7), e5011729922. http://dx.doi.org/10.33448/rsd-v11i7.29922

Pinto, S. & Preussler, E. S. (2002). Pavimentação rodoviária: conceitos fundamentais sobre pavimentos flexíveis. Synergia.

Santos, Y. R. P., Barbosa, C. E. B., Lima, J. J., Meneses, M. M. M. & Nascimento, P. D. L. (2021). Classificação e diagnóstico do estado de conservação de uma via em pavimentação asfáltica do município de Caruaru, Pernambuco, Brasil. Research, Society and Development, 10(17) e212101724257. http://dx.doi.org/10.33448/rsd-v10i17.24257

Silva Junior, T. L. , Suica, A. V., Silva, C. M. & Cavalcante, L. B. (2019). Utilização do método de levantamento visual contínuo (LVC) para avaliação de Vias pertencentes a cidade de Maceió/AL. Ciências Exatas e Tecnológicas, 5(2), 213-222. https://periodicos.set.edu.br/fitsexatas/article/view/6787

Viana, A. V. C., Freitas, O. F., França, F. A. N. & Amorim, E. F. (2021). Evaluation, diagnosis and recovery of hydraulic concrete flooring in stretches located in Natal/RN City and in the Metropolitan Region. Research, Society and Development, 10(16), e261101623448. http://dx.doi.org/10.33448/rsd-v10i16.23448