Study of Bridge Pathologies in the Federal District/Brazil

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***Abstract*– Bridges are important elements for the mobilization of society both in the scope of cargo and people transport and in the connection of roads, seeking to guarantee the continuity of the trajectory. For this, they must have adequate durability and useful life for the purposes for which they are intended. Thus, the objective of this research was to study the pathologies found on a bridge located in Brasilia, Federal District, Brazil. The study was developed through visual inspections and the carbonation test. The results show that the lack of periodic maintenance directly interferes with the reduction of the useful life of the structure, bringing out pathologies and negatively interfering with the bridge's functionality. It was possible to conclude that the bridge under study presents a critical state of conservation of the structure, requiring immediate interventions.**

***Keywords*– Bridges, Carbonation, Durability and Pathologies**

I. INTRODUCTION

The bridges are designed to overcome obstacles that prevent the continuity of a road. The main functions of a bridge are to cross valleys and other large depressions or to overlap another road. It can be constructed from different materials, but in Brazil it is usually made of reinforced concrete [1].

Over time, a structure presents pathologies. Pathology can be understood as the part of engineering that studies the symptoms, mechanisms, causes and origins of defects found in civil construction. That is, it is the study of the parts that make up the diagnosis of the problem. Through this study it is possible to reduce the degradation of the structure [2].

The analysis of the degradation of the structures cannot be developed without considering the characteristics of the pathological manifestations and their respective phase or stage of occurrence. These are necessary conditions to obtain more certainty of the diagnosis of pathological [3].

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The concrete carbonation, for example, is the transformation of hydrated cement compounds into carbonates by the action of carbon dioxide (CO_2). The carbonation, although responsible for a small increase in concrete shrinkage, does not, in itself, harm simple concrete. The carbonated concrete is even more resistant and more impervious to the penetration of aggressive agents than the same non-carbonated concrete. However, the carbonation causes a reduction in the alkalinity of the solution present in the pores around the reinforcement. The pH of calcium carbonate ($CaCO_3$), around 8 to 9, reduces the chemical stability of the passive layer of reinforcement, around 13 to 14, facilitating the start of corrosion of the reinforcement and the appearance of cracks [4].

The cracks allow the absorption of moisture, which has its presence in the concrete evidenced by the formation of superficial white deposits, known as efflorescence. This is the combination of calcium carbonate, extracted from the cement paste with other carbonates and chloride compounds [5].

Carbonation reduces the protection of reinforcement against corrosion and is caused by the reaction of calcium oxide in concrete with carbon dioxide. The depth of the carbonation can be measured with the exposure of the concrete to phenolphthalein solutions. The concretes without carbonation change color while concretes with carbonation remain the same color [6].

In view of the recent cases of bridge collapse in Brazil, it is important to carry out periodic inspections on bridges to mitigate the effects of pathological manifestations. Thus, the present study aims to carry out the study of pathological manifestations through the inspection of a bridge in Brasilia, DF, Brazil. For this, the methodology used, the results and discussions and the conclusions about the research are shown.

II. METHODOLOGY

The Phenolphthalein ($C_{20}H_{14}O_4$) was used to carry out the research, which is an organic compound commonly used to classify substances as basic or acidic. This compound has the property to change color depending on the pH: colorless if the pH is less than 9 and magenta if it is higher. A phenolphthalein solution, in which the solvent is ethanol, can be used as a qualitative test to indicate the depth of carbonation in concrete elements.

The survey consisted of inspections of a bridge located in Brasilia, DF, Brazil. Visual inspections were carried out on

the bridge and it was decided to choose points that presented more degradation and located in easily accessible areas to carry out analyzes.

To carry out the carbonation test, the tested surface was cleaned with a brush to ensure the credibility of the test results and to avoid dust residues in undesirable areas. In the structure, some points with unplugged concrete were found. With this, the tests were done in these areas, avoiding the need for openings. A spray containing a solution of 1 g of phenolphthalein, 50 g of alcohol and 50 g of water was applied to the openings of the pillars and tray. If a specific area of the concrete was not carbonated, its color would be differentiated, thus the depth of the carbonation front could be measured.

III. RESULTS AND DISCUSSIONS

The Fig. 1 illustrates the pillars with a high degree of deterioration, being possible to observe the exposure of reinforcement.

Fig. 1. Reinforcement exposed in different pillars of the bridge

As shown in Fig. 1, the inspection of the bridge pillars revealed the presence of horizontal and vertical cracks, concrete peeling, exposed reinforcement, reinforcement carbonation and corrosion. These pathologies are directly related to the gradual loss of performance of the structure.

The Fig. 2 shows the lateral edge of the bridge. On the side edge of the bridge, apparent anomalies were also identified. The presence of moisture, cracks, dirt and exposed reinforcement was observed in several points of the structure under analysis. The darker points in the images are characteristic of the presence of moisture with the presence of cracks, where water percolates.

Fig. 2. Lateral edge with the presence of efflorescence, exposed reinforcement, dirt, cracks and cracks

In the study of the images presented in Fig. 3, it is possible to analyze the presence of many areas with apparent efflorescence with an advanced degree. In Fig. 3C, it is possible to observe the presence of humidity, in which it passed through the tray and dripped on the support curtain of the bridge.

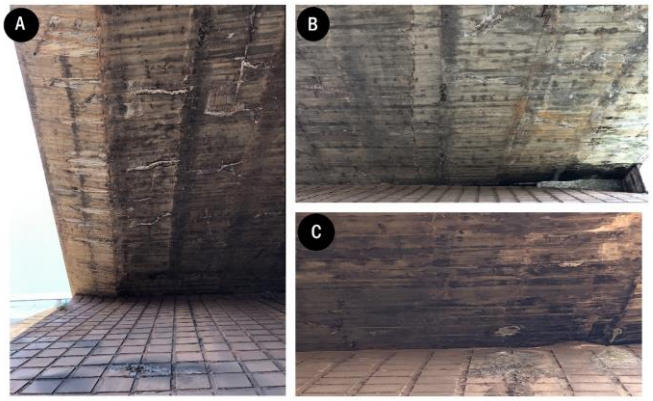

Fig. 3. A) Edge; B) and C) end of the bridge

The Fig. 4 shows the center of the board of the bridge. It was observed in the technical inspection that the lack of maintenance made possible the appearance of pathological manifestations. The cracks were not sealed, allowing moisture to enter, which contributes to the carbonation of the concrete, decreasing its pH and starting the corrosion of the reinforcement.

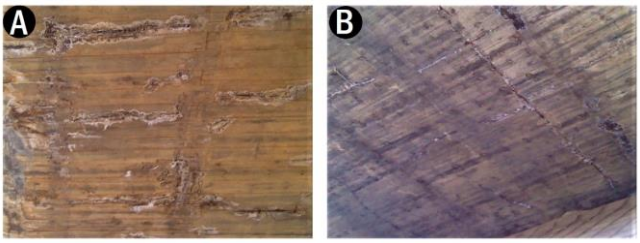

Fig. 4. Center of the board

In Fig. 5, it is possible to observe the presence of exposed reinforcement and corrosion of reinforcement. At the point where the problem was found, it is recommended to remove all surface concrete. The reinforcement must be treated by means of a reinforcement brush and application of an anticorrosive primer, so that the upper concrete layer can be redone.

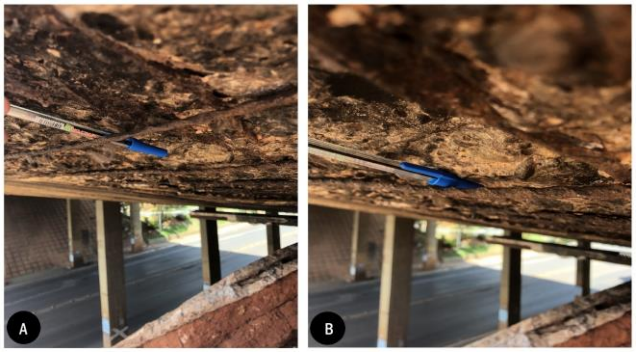

Fig. 5. Exposure and corrosion of reinforcement.

Some carbonation points were observed on the bridge where there was concrete detachment, which even had exposed reinforcement, as can be seen in Fig. 6, Fig. 7 and Fig. 8.

It was noted that some points on the bridge showed fragility in the concrete, as shown in Fig. 6. In order not to cause any major damage to the structure, by using sampling techniques removed with the use of impact equipment, critical points were chosen for the analysis of concrete carbonation, as shown in Fig. 6.

It was observed that several points analyzed are carbonated. This was due to humidity, as the points under analysis have higher rates of rain and infiltration, therefore the pores of the concrete may be more saturated. Fig. 7 shows carbonated areas, in which there was no reaction with the phenolphthalein compound. Thus, there was no change in color, that is, the analyzed points suffered carbonation.

The carbonated area in the structure means that the pH of the concrete has been reduced, resulting in less concrete strength. Therefore, the structure may present other pathologies, weakening the system and causing accidents. Fig. 8 shows points analyzed through the carbonation test.

Fig. 6. A) Cracking of the concrete in the tray; B) Fragility in concrete, peeling point; C) Abutment of the concrete in the pillar

Fig. 7. A) Carbonation test on the pillar; B and C) Carbonation test on the tray

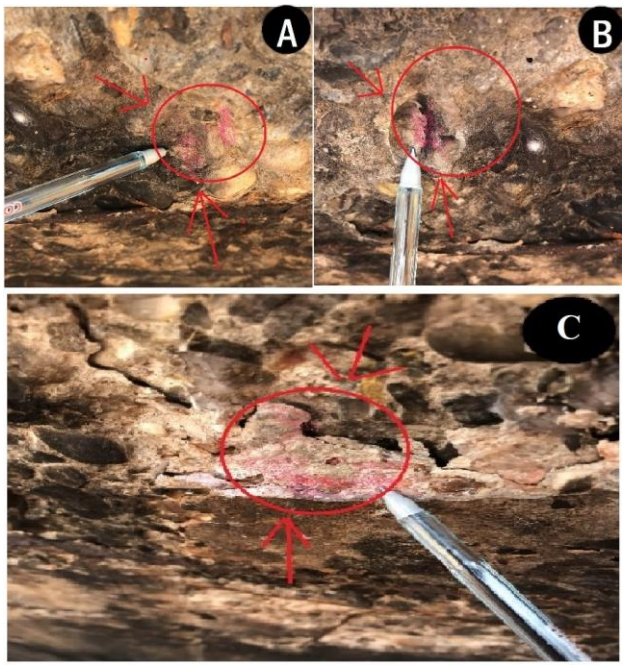

Fig. 8. Carbonation test points on the tray

In the tests performed on the points analyzed in Fig. 8, it is possible to observe the color change of the phenolphthalein compound. Small areas with a violet hue have no carbonation front, that is, the pH of the concrete remained unchanged. However, these are very small points, as can be seen next to a pen.

IV. CONCLUSION

Based on the studies carried out and, on the results, obtained in this research, it was possible to identify pathological manifestations such as cracks, carbonation of the concrete, corrosion of the reinforcement, efflorescence and dirt. In addition, it can be seen that the lack of periodic maintenance touches on pathologies and aggravates existing pathologies.

An advanced degree of degradation can be noted, which consists of carbonation at various points in the structure of the bridge. The exposure of the reinforcement to CO_2, together with the advanced age of the bridge without proper maintenance, aggravated the corrosion of the reinforcement, also causing the chipping of the concrete in carbonated regions and reinforcements that present corrosion.

Thus, it is necessary to perform an intervention on the bridge to carry out the treatment of the identified anomalies. If this is not done, there is a tendency for the existing pathologies to worsen and, consequently, a potential collapse of the structure, which can cause deaths, damage to people who use this bridge daily and a higher cost for the reconstruction of the structure.

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