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Analysis of the Degree of Deterioration of Concrete Posts Utilized by the Electrical Transmission and Distribution System

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***Abstract*-** The objective of this study is to evaluate the degree of deterioration of poles in the city of Recife that are used in electrical distribution and transmission networks. These poles are often forgotten, despite their obvious contribution to society, which depends on electrical energy to operate industries, hospitals, commerce, public institutions, the financial system, public lighting, and transportation hubs such as airports. These structures are continually exposed to weather and need to be inspected in order to schedule interventions and ensure the safety of users. The research was conducted as an applied case study, examining the poles along Boa Viagem Avenue, a total of 250 units, where 71 units were chosen randomly with an estimated error of 10% and degree of confidence of 95%. The methodology is known as GDE/UnB and was originally elaborated by Castro [3] and modified by Fonseca [1], used to evaluate the degree of deterioration of the poles quantitatively and qualitatively in order to identify the principal pathological manifestations. A checklist was applied throughout the study that allowed for the degree of element deterioration (GDE) to be determined, augmented with results from the carbonatation tests and the total chloride test, conducted on 12 and 4 posts, respectively. It was observed that the pathological manifestations observed were principally due to the concrete type and in some cases, the coating used during production of the posts, not being suitable for the environment in which they are being used, impacting their useful life and performance. As a result, 40.85% of the posts will require interventions either immediately or within one year, with a further 45.07% that will need to undergo a planned intervention in two years.

***Keywords*-** *Poles, Pathological Manifestations, Inspections*

I. INTRODUCTION

Durability, service life, and performance are factors interconnected in such a manner that they are increasingly reflected in changes to municipal, state, and federal legislation and performance standards necessary to meet structural safety and comfort requirements.

Methodologies exist to evaluate the degree of degradation of concrete structures. By applying these methodologies to the evaluation of concrete posts, it is possible to determine the degree of degradation of these structures that, while simple, are also critically important for the transmission of electrical energy from its point of generation.

These structures are designed and engineered to meet stress demands and be resistant to damage from mechanical, chemical, and physical agents that can reduce the projected 35-year life expectancy during use. As natural resources are becoming increasingly scarce, it is necessary that the project reach its full lifetime and that service performance meets the recommended standards.

A. Justification

The concrete posts utilized for energy transmission and distribution are of strict importance to society, but attention to pathological manifestations that affect their performance and useful life is lacking. They are exposed to microclimate, macroclimate, atmospheric pollution, the action of microorganisms, animal excretion, and temperature variation throughout their useful life.

Substations are high-power electrical installations that contain electrical power transmission and distribution equipment, as well as control protection equipment. In this context, the performance of concrete structures and poles must be fully achieved, because in the event of collapse, serious accidents and consequent interruption of the energy supply for residents, industry, hospitals, commerce, and others may occur.

II. MATERIALS AND EXPERIMENTAL PROGRAM

The choice of poles to analyze was determined using a simple method of random sampling without replacement.

Seventy-one of the 250 poles existing along the coast were randomly inspected, with an estimated error of 10% and a 95% confidence level. The inspection of the concrete power poles occurred in two phases: preliminary and detailed. During the preliminary inspection, the posts located within the study area were marked and numbered. During the detailed inspection, a visual inspection of each pole will be carried out, and a photographic record maintained.

All visual symptoms were annotated, environmental aggressiveness was identified, the coating was removed in order to directly visualize the steel reinforcement, and a photographic record of the sample extraction zone was made for the chloride depth test.

The opportunity was also taken to obtain the following data: a) coating thickness, b) reduction of the armature diameter, c) oxide color, and d) concrete aspect. Other tests were also performed, including carbonatation tests, chloride ion presence, chloride profile, and ultrasound.

The purpose of this study is to survey the amount of degradation these structures are subjected to, with the inspection performed adapted from the methodology reformulated by Fonseca [1], without using the element family classification or the damage weighting factor, as these are inapplicable to the study of a single element type. The procedures referred to in the methodology followed the steps as described in (Figure 1) in order to list the pathological manifestations acting on the concrete posts.

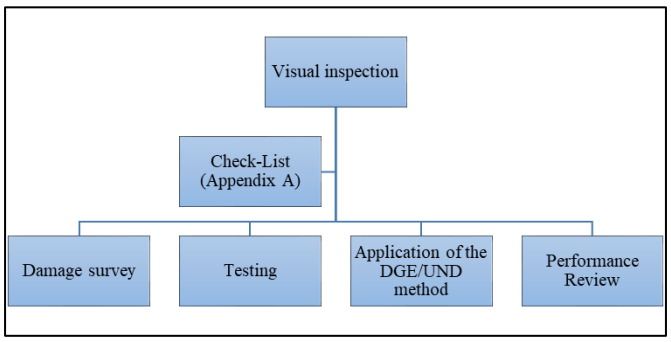

Figure 1. Inspection methodology application stages.

The GDE/UnB methodology was reformulated by Fonseca [1] based on the proposal by Boldo [2], modifying Castro's methodology [3] that had been previously modified by Lopes [4], who systematized procedures to be followed for structural inspections and evaluation of results.

In order to eliminate subjectivity from the inspection, non-destructive and semi-destructive tests were carried out on the concrete. Carbonatation and total chloride tests were carried out in a specialized laboratory using the potentiometric method.

III. Results and Discussion

In (Figure 2) shows a T-type post in which the main frame has been ruptured as a consequence of corrosion caused by pathological manifestations, having an element damage degree of 121.00, indicating that immediate intervention is required. The damages with the highest indices are “stains” and “cracks”, “disintegration”, “reinforcement corrosion”, and “concrete failure".

Figure 2. Post with broken reinforcement.

All poles, whether of new or old manufacture, have stains on their surfaces of more or less intensity. These surface stains are due to the humid environment, the highly-polluted atmosphere, and biological agents. In (Figure 3), the percentages for each pathological manifestation found during the performed inspections is shown. “disintegration”, “reinforcement corrosion”, and “concrete failure".

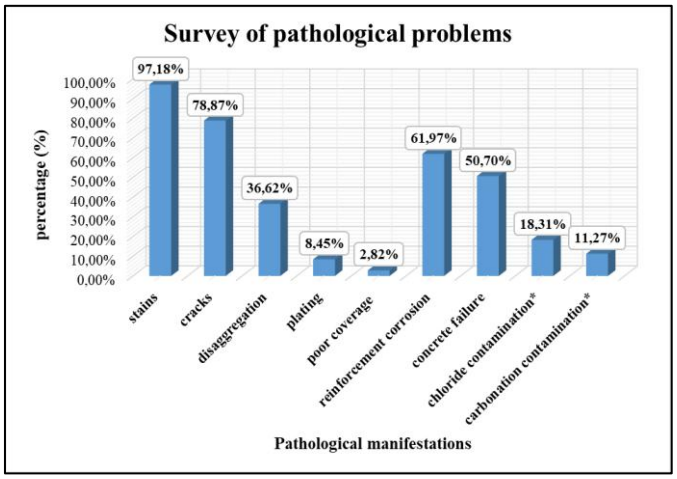

Figure 3. Rate of pathological manifestation incidence in concrete posts.

The degree of element degradation, shown in (Figure 4), was alarming in terms of the level classification, because 4.23%, 5.63%, and 30.99% will require interventions within one year, six months, or immediately. The posts that fall within the 15-50 classification represent 45.07% of the total and are continuously exposed to the aggressive environment.

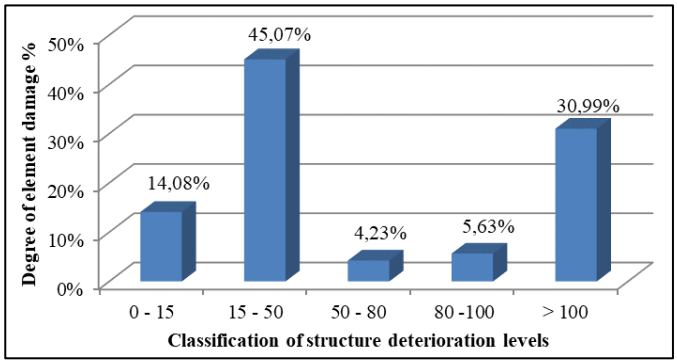

Figure 4. Degree of deterioration of elements classification of the levels of structural deterioration.

Another type of damage the poles were subject to are fissures that facilitate the access of pathological agents into the concrete, stripping the protection from the reinforcement and leading to corrosion. A post that was only two years old was found to be cracked, reducing its useful life in the absence of intervention

The test procedures are not imposed by the methodology, but it is important for the study to be aware of some of the concrete properties, such as which agent is acting upon the concrete, because there is a microclimate caused by the constant presence of saline mist and exhaust gases from vehicle combustion. The security of several poles was compromised because the pathological manifestation caused current leakage. Therefore, tests were performed on only 15 posts.

The carbonatation depths ranged from 7 to 25 mm among those with greater depth and the degree of element deterioration varied from 5.4 to 125.4. One of the posts located on Boa Viagem Avenue that was only one year old and without cracks, had corrosion spots on its concrete surface, which is an unacceptable failure when occurring within the first five years, according to NBR 8451 [4].

The average age of 19 years, shown in (Figure 5), for posts having a degree of element deterioration (GDE) between 50 and 80, according to the Castro [3] GDE/UnB methodology, modified by Fonseca [1], require detailed specialized inspection to define a plan for medium-term intervention (up to one year).

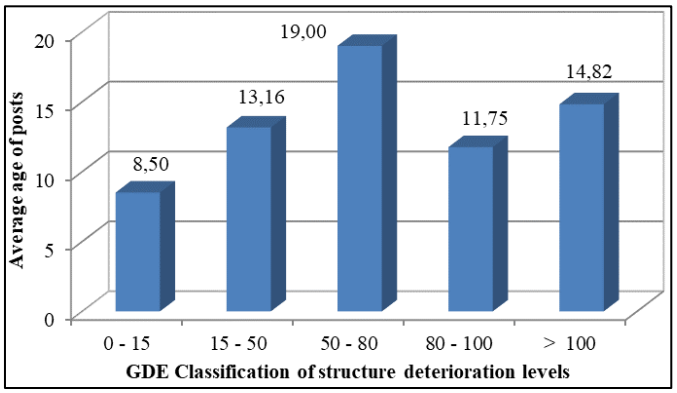

Figure 5. Average age of posts in the degree of element deterioration classification intervals.

Posts having GDE between 80 and 100 require intervention within six months, while those with GDE greater than 100 will need immediate intervention to halt the worsening of their current structural situation.

One post was found that had been manufactured in 1971 and two that were manufactured in 1976. These had degree of element deterioration values of 47.5, 26.6, and 75.4, respectively.

Despite the age of these structures, they remain within the categories of medium- to long-term intervention. It is worth mentioning that such structures have already passed the 35-year useful life limit recommended by standard NBR 8451 [5].

The pole shown in (Figure 6) is 23 years old and has not reached the limit of its design life, but it already shows signs of reinforcement corrosion with a high level of concrete deterioration.

Figure 6. Corrosion of reinforcement with loss of concrete section.

IV. CONCLUSIONS

The objective of this study was to evaluate the physical situation of the concrete posts used in the electrical energy distribution network, seeking to propose a preventive and predictive maintenance program that will promoting durability of the structures and provide more safety to the system and its users.

It is important to note the difficulty encountered in carrying out the inspections and tests because these posts are located in an area with a very high vehicle and pedestrian flow every day of the week. Because of this and the structural conditions of these posts, the number of tests conducted was reduced.

The methodology applied was consistent with the results obtained from the inspections. The evaluation of these structural elements made it possible to determine the current conditions of the structures and whether they were in a condition suitable for fulling their purpose.

Inspections of concrete posts are essential to monitor their performance and to quantify their deterioration in order to establish deadlines for further inspections and interventions, depending on the severity of the damage.

The methodology of this study has shown that the continuous exposure of these structures to an aggressive microclimate has caused an accumulation of damage at various classification, such that within two years there will be a backlog of compromised structures having poor levels of safety, useful life, and performance, and which, most critically, could endanger user safety.

By means of the research described in chapter 4, a set of information was obtained that:

- Characterized the types of pathological manifestations that act on these structures;
- Verified the influence of the microclimate on the degree of element deterioration through the constant saline mist and combustion from vehicles through the analysis of existing deleterious actions;
- Determined that the useful life has been compromised as a result of the pathological manifestations, preventing the expected performance of the project from being reached and, in many cases, provoking imminent ruin;
- Quantified severity bands by means of a classification of element deterioration.

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