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EVALUATION OF PATHOLOGICAL MANIFESTATIONS AND CONSERVATION STATUS OF REINFORCED CONCRETE VIADUCTS IN THE MUNICIPALITY OF LUANDA

AVALIAÇÃO DAS MANIFESTAÇÕES PATOLÓGICAS E DO ESTADO DE CONSERVAÇÃO DE VIADUTOS EM BETÃO ARMADO NO MUNICÍPIO DE LUANDA

EVALUACIÓN DE LAS MANIFESTACIONES PATOLÓGICAS Y DEL ESTADO DE CONSERVACIÓN DE VIADUCTOS DE HORMIGÓN ARMADO EN EL MUNICIPIO DE LUANDA

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ABSTRACT

This study aimed to evaluate the pathological manifestations and conservation status of four reinforced concrete viaducts in the Municipality of Luanda, aged over 21 years. The methodology was based on detailed visual inspections and the application of the DNIT evaluation method, which assigns scores from 1 to 5 to structural and non-structural elements. The results indicated that all viaducts received a final score of 3, corresponding to "apparently good stability conditions". The main pathologies identified include cracking, concrete delamination, exposure of reinforcements, degradation of expansion joints, deficiencies in signaling and drainage, among others. It is concluded that, although the viaducts are in acceptable conditions, preventive and corrective maintenance interventions are necessary to ensure their durability and safety. The study reinforces the importance of patrimonial management systems for special works of art, aligning with international best practices.

Keywords: Viaducts. Reinforced Concrete. Pathological Manifestations. Inspection. Conservation Status. DNIT Method.

RESUMO

O presente estudo teve como objetivo avaliar as manifestações patológicas e o estado de conservação de quatro viadutos em betão armado no Município de Luanda, com idade superior a 21 anos. A metodologia baseou-se em inspeções visuais detalhadas e na aplicação do método de avaliação do DNIT, que atribui notas de 1 a 5 aos elementos estruturais e não estruturais. Os resultados indicaram que todos os viadutos apresentaram nota final de classificação 3, correspondente a "condições de estabilidade boa

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aparentemente". As principais patologias identificadas incluem fissuração, delaminação do betão, exposição de armaduras, degradação de juntas de dilatação, deficiências na sinalização e drenagem, entre outras. Conclui-se que, embora os viadutos se encontrem em condições aceitáveis, são necessárias intervenções de manutenção preventiva e corretiva para garantir a sua durabilidade e segurança. O estudo reforça a importância de sistemas de gestão patrimonial para obras de arte especiais, alinhando-se com as melhores práticas internacionais.

Palavras-chave: Viadutos. Betão Armado. Manifestações Patológicas. Inspeção. Estado de Conservação. Método DNIT.

RESUMEN

Este estudio tuvo como objetivo evaluar las manifestaciones patológicas y el estado de conservación de cuatro viaductos de hormigón armado en el Municipio de Luanda, con más de 21 años de antigüedad. La metodología se basó en inspecciones visuales detalladas y en la aplicación del método de evaluación del DNIT, que asigna puntuaciones de 1 a 5 a los elementos estructurales y no estructurales. Los resultados indicaron que todos los viaductos obtuvieron una puntuación final de 3, correspondiente a "condiciones de estabilidad aparentemente buenas". Las principales patologías identificadas incluyen fisuras, deslaminación del hormigón, exposición de armaduras, degradación de juntas de dilatación, deficiencias en señalización y drenaje, entre otras. Se concluye que, aunque los viaductos se encuentran en condiciones aceptables, son necesarias intervenciones de mantenimiento preventivo y correctivo para garantizar su durabilidad y seguridad. El estudio refuerza la importancia de los sistemas de gestión patrimonial para obras de arte especiales, alineándose con las mejores prácticas internacionales.

Palabras clave: Viaductos. Hormigón Armado. Manifestaciones Patológicas. Inspección. Estado de Conservación. Método DNIT.

1 INTRODUCTION

Special engineering works (SSOs), such as bridges and viaducts, are vital elements in the transport infrastructure of any country, ensuring regional connectivity and socio-economic development (DEBS & TAKEYA, 2007). In the Municipality of Luanda, the rapid post-conflict urban growth, from 2002 onwards, resulted in the accelerated construction of a considerable park of these infrastructures. Many of them, with more than two decades of service, are beginning to show signs of degradation, highlighting the need for effective asset management, based on periodic inspections and proper maintenance (JESUS, 2015).

The degradation of reinforced concrete structures is a complex process, influenced by intrinsic (quality of materials, construction details) and extrinsic (environmental actions, overloads, maintenance) factors (HELENE, 1993). Systematic inspection is, therefore, the fundamental tool for diagnosing the real state of these works, allowing the early identification of pathologies and the programming of interventions (DNIT, 2004; RYALL, 2010).

In this context, this article presents a detailed evaluation of four reinforced concrete viaducts located in Luanda, Angola. The study aims to: (i) identify and characterize the main pathological manifestations; (ii) apply the evaluation method proposed by DNIT (2004) to classify the conservation status; and (iii) discuss the probable causes of the pathologies and propose mitigating measures, contributing to the preservation of the existing heritage and the safety of users.

2 THEORETICAL FRAMEWORK

2.1 PATHOLOGIES IN REINFORCED CONCRETE STRUCTURES

The pathological manifestations in reinforced concrete structures can be classified according to their origin in: defects in design, materials, execution and use (SOUSA & RIPPER, 1998 apud GIOVANNETTI, 2014). For bridges and viaducts, the combined action of cyclic loads, aggressive environmental agents (such as chlorides from salt spray or anti-ice) and carbonation of concrete are the main deterioration mechanisms, often culminating in reinforcement corrosion (MEHTA & MONTEIRO, 2014).

Corrosion is an electrochemical process that causes the expansion of the volume of the steel, generating internal stresses that lead to cracking, peeling and, finally, delamination of the covering concrete. This phenomenon, in addition to compromising aesthetics and durability, significantly reduces the resistant capacity of the cross-section of structural elements (ANDRADE, 1993).

2.2 INSPECTION AND EVALUATION OF BRIDGES AND VIADUCTS

Inspection is defined as a set of technical procedures carried out according to prior planning, which provides information about the work at a given time (GIOVANNETTI, 2014). The DNIT Road Bridge Inspection Manual (2004) establishes a robust methodology, classifying inspections as: cadastral, routine, special, extraordinary and intermediate.

The DNIT evaluation method is based on the attribution of grades (from 1 to 5) for each component element of the work, considering the severity and extent of the pathologies. The final grade of the structure corresponds to the lowest grade assigned to one of its elements with a structural function, adopting a conservative approach that prioritizes safety (DNIT, 2004). This system allows an objective quantification of the conservation status, facilitating the prioritization of interventions and the allocation of resources. Similar systems are used internationally, as proposed by the COST 345 report (2007) in Europe and the Bridge Inspection Manual (BIRM) in the USA.

3 METHODOLOGY

The research is characterized as applied, with a qualitative-quantitative approach and exploratory-descriptive objectives (SILVA & MENEZES, 2005). The multiple case study was conducted on four viaducts (OAE) built in 2001, located in the Municipality of Luanda, Angola, and aged over 21 years at the time of inspection (2023):

- OAE 1: 4 de Fevereiro International Airport Viaduct
- OAE 2: Cassenda Viaduct
- OAE 3: Zamba 2 Viaduct
- OAE 4: Underpass of the Portuguese Embassy

The selection of the sample was based on the criterion of homogeneity in terms of age and construction material (reinforced concrete), allowing a comparative analysis of the degradation patterns.

The detailed visual inspection, in line with the procedures for a "Special Inspection" according to the DNIT (2004), was carried out with equipment that included a digital camera, drone for access to hard-to-reach areas, a tape measure, a laser meter and a fissurometer. The following components were systematically evaluated:

- *Carriageway and platform elements*: accesses, expansion joints, protective barriers (New Jersey), guardrails, wheel guards, drainage devices, signaling and lighting.
- *Superstructure*: support equipment (neoprene), deck and public pipes.

- *Mesostructure:* wall pillars.
- *Infrastructure*: abutments and slope protection.

Each element was classified with a score from 1 to 5, according to the severity and extent of the pathologies observed, following the scale of the DNIT (2004):

- 5 (Excellent): No or insignificant defects.
- 4 (Good): Minor defects, no significant affectation.
- 3 (Regular): Moderate defects, requiring medium-term intervention.
- 2 (Poor): Serious defects, requiring priority intervention.
- 1 (Very Poor): Critical defects, with imminent risk of collapse.

The final grade of the work corresponded to the lowest grade attributed to one of its elements with a structural function, ensuring a conservative and safe evaluation.

4 RESULTS AND DISCUSSIONS

4.1 CHARACTERIZATION OF THE MAIN PATHOLOGICAL MANIFESTATIONS

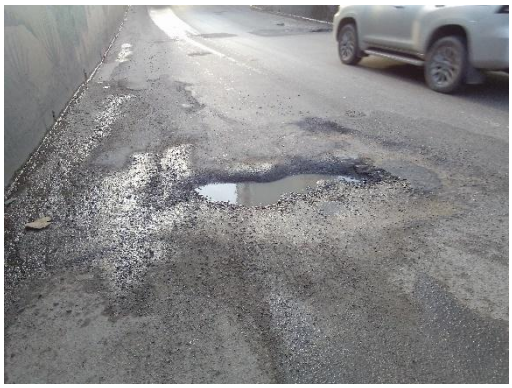
The detailed inspection revealed a consistent pattern of pathologies on the four viaducts, indicating systemic problems related to environmental exposure, the quality of execution and, above all, the lack of scheduled maintenance. The most significant manifestations were:

- *Runway*: Widespread presence of sinking, exudation, slipping and inadequate punctual repairs (patches), which compromise the comfort and safety of the roll. These defects are often associated with compaction problems of the access embankment and the degradation of the pavement layers (Figure 1a).
- *Expansion joints*: Elastomer and steel monobloc joints showed debris accumulation, loss of sealing capacity, and edge damage (Figure 1b). This situation compromises watertightness, allowing the infiltration of water and aggressive agents on the support devices and lower structural elements, a problem widely documented in the literature (VITÓRIO, 2002).
- *Safety and security elements*: The New Jersey barriers, metal guardrails, and wheel guards exhibited cracking, delamination of the concrete, exposure and severe corrosion of the reinforcements, and deteriorated paint (Figures 1c and 1d). Corrosion of reinforcement, triggered by the carbonation of concrete and/or the penetration of chlorides, is the predominant pathological mechanism (HELENE, 1993).

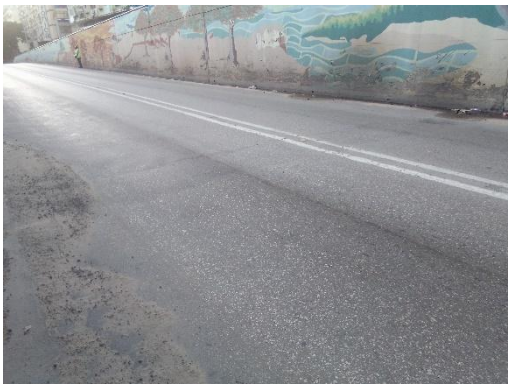
- *Signage and lighting*: There was a near absence or severe degradation of vertical and horizontal signage, as well as public lighting. This condition poses a high risk to road safety, especially at night or in adverse weather conditions.
- *Structural Elements*: In the pillars and abutments, cracking, peeling of the concrete, dark spots due to humidity and, in some cases, the presence of efflorescence were identified (Figure 1e). The misuse of infrastructure, such as the occurrence of physiological needs at the base of the pillars, introduces aggressive chemical agents that accelerate degradation.

Figure 1

Examples of pathological manifestations identified: (a) Pans and sinkings in the roadway (OAE 4); (b) Damaged expansion joint (OAE 1); (c) Wheel guard with severe reinforcement corrosion (OAE 2); (d) New Jersey Barrier (OAE 3); (e) Cracking and peeling of concrete in a column (SO 1)

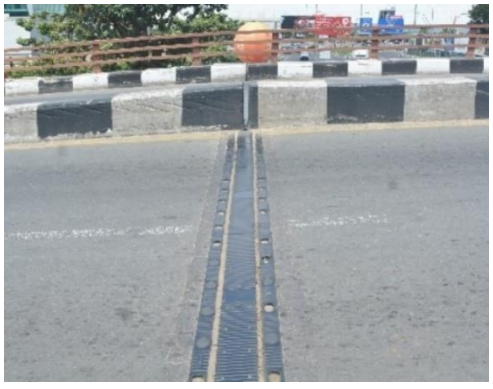


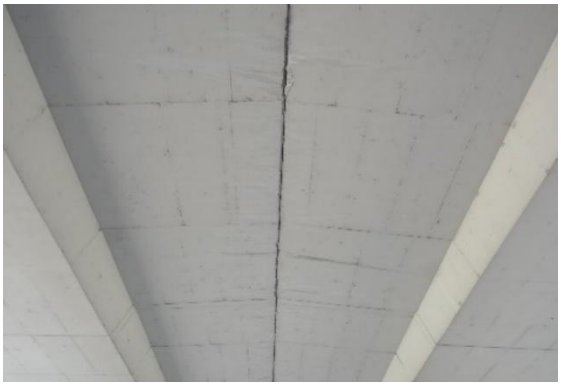
Bad patch and/or pans



Sags

(a) Pans and sinks on the raceway (OAE 4)

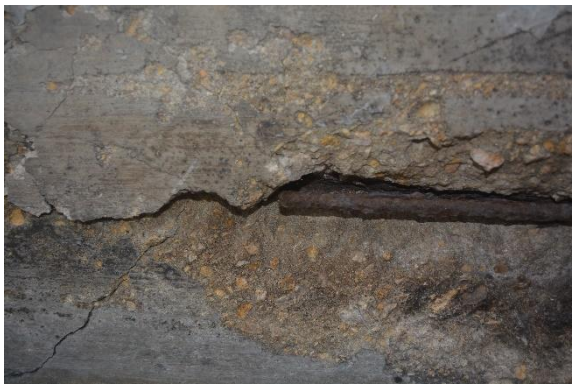


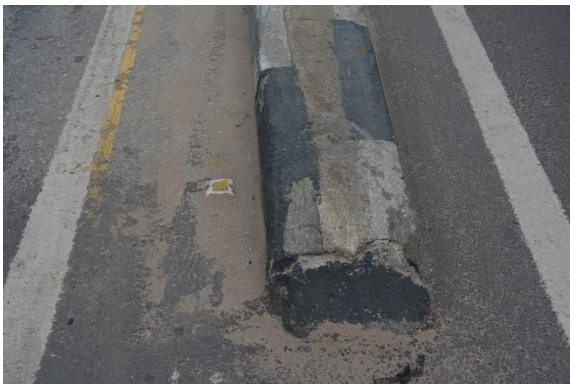


Stormwater runoff

Absence of clamping sockets and slit in the finial between the joint and the transition layer

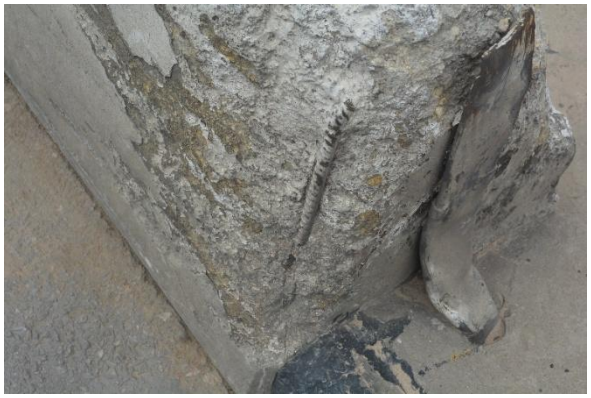
(b) Damaged expansion joint (OAE 1)



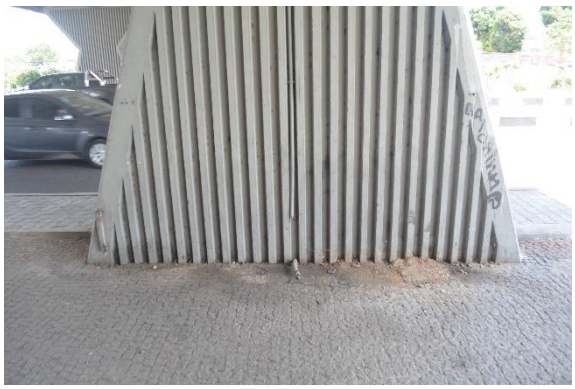


Exposure and corrosion of reinforcements *Partial disintegration*

(c) Wheel guard with severe reinforcement corrosion (OAE 2)



(d) Delaminated New Jersey Barrier (OAE 3)



(e) Cracking and peeling of concrete in a column (SO 1)

Source: Author (2025).

4.2 EVALUATION AND CLASSIFICATION BY THE DNIT METHOD

The application of the evaluation method resulted in the attribution of the final grade 3 (Regular) to all the viaducts studied. Table 1 summarizes the classification by main component, showing the homogeneity of the conservation status of the sampled park.

Table 1

Classification of viaducts by main structural component

Component	OAE 1	OAE 2	OAE 3	OAE 4
Runway and platform	3	3	3	3
Superstructure	3	3	3	3
Mesostructure (Columns)	3	3	3	3
Infrastructure (Meetings)	3	3	3	3
Final Note of the Work	3	3	3	3

Source: Author (2025).

4.3 CRITICAL DISCUSSION OF RESULTS

The uniformity in the final classification (Note 3) reflects not only the constructive and age similarity of the viaducts, but also the exposure to analogous environmental and traffic conditions. The "Regular" grade indicates that the structures still have apparent global stability, but have a moderate state of degradation that, if not stopped, will progress in an accelerated way, and may evolve to "Bad" or "Very Bad" conditions in a short period of time (JESUS, 2015).

The pathologies observed are, for the most part, the consequence of a combination of factors:

1. *Deficiencies in the Execution Phase*: The poor vibration of the concrete, the insufficient covering of the reinforcements and the inadequate construction details, identified in various elements (e.g., wheel guards), are failures at the origin that compromise the long-term durability (HELENE, 1993).
2. *Absence of Preventive Maintenance*: The lack of routine inspections and conservation interventions, such as cleaning joints and drains, applying protective paints, and punctual repairs, allowed small defects to evolve into significant pathologies. This is perhaps the most critical cause identified, and it is a common problem in contexts where wealth management is not fully implemented (GIOVANNETTI, 2014).

3. *Environmental and Exploration Actions*: Exposure to the tropical climate, heavy traffic and, possibly, the circulation of vehicles with loads higher than those foreseen in the project, contributed to the acceleration of the fatigue process and degradation of materials.

The case study corroborates Reis' (2006) view that intuition in design should always be accompanied by strict supervision in execution and active management during the exploration phase. The situation found in Luanda is a warning of the urgent need to implement a management system for OAE, as recommended by DNIT (2004) and authors such as Ryall (2010), which allows a systematic control of the state of these critical infrastructures.

5 CONCLUSION

The present study allowed us to conclude that the four reinforced concrete viaducts in the Municipality of Luanda, with more than 21 years of service, have a state of conservation classified as "Regular" (Note 3) according to the DNIT method. This condition is characterized by the generalized presence of moderate pathological manifestations, which do not compromise global stability imminently, but which signal the urgent need for maintenance interventions.

The application of DNIT's inspection and evaluation methodology proved to be an effective and practical tool for the objective quantification of conservation status, allowing the prioritization of interventions based on technical criteria.

As recommendations, it is proposed:

- *Immediate Interventions*: Execution of corrective maintenance on the most critical elements, namely: cleaning and replacement of expansion joints; repair and corrosion protection of guardrails and wheel guardrails; and repair of drainage and signaling systems.
- *Medium and Long Term Management*: Implementation of a permanent program of routine (biannual) and special (five-yearly) inspections, using a property management system (e.g., specific software) for data storage and evolutionary analysis.
- *Future Research*: Conducting non-destructive tests (e.g., sclerometry, potentiostat) for a more accurate quantification of the strength of the concrete and the corrosion state of the reinforcements, complementing the visual inspections.

The preservation of this infrastructural heritage is crucial not only for the safety of users, but also for the economic sustainability of Luanda, ensuring the flow of traffic and avoiding costs associated with deep repairs or premature reconstructions in the future.

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