RIMA
Revista Interdisciplinar e do Meio Ambiente
Interdisciplinary and Environment Journal
v.6, n.1, 2024, DOI: 10.52664/rima.v6.n1.2024.e234

Analysis of the cavitation phenomenon: A case study in the drainage channel of the Aruana neighborhood located in the city of Aracaju-SE

Análisis del fenómeno de cavitación: Un estudio de caso en el canal de drenaje del barrio Aruana localizado en la ciudad de Aracaju-SE

Ana Paula Cardoso Melo Barreto[1], Misael Santana Silva[2], Vitória Elisabeth de Oliveira Santos[3] & Zacarias Caetano Vieira[4]

Abstract: Drainage channels are intended for the drainage of surface water and watercourses. Having a high construction cost, over time they present pathologies requiring inspection and maintenance. Among these pathologies, we can mention the wearing caused by cavitation. Given the above, this research aims to carry out a visual survey, and subsequent analysis, of the occurrences of wearing by cavitation in a drainage channel, in the neighborhood of Aruana, city of Aracaju-SE. First, a visual survey was achieved to assess the situation of the structure; Then, an analysis was performed through the registration of images and a bibliographic survey of the main causes and consequences of this phenomenon. It was possible to verify the occurrence of cavitation wear next to the culverts, on the side walls of the channel, and more intensely, at the junction of the rainwater galleries with the channel. It is concluded that, in many points, the pathology is at an advanced level, requiring urgent intervention; the intervention prevents the evolution of pathologies; the cost of repairs at an advanced stage is high, justifying the importance of periodic maintenance and correction at an early stage; And finally, problems can be avoided or mitigated in the design phase, with the use of better quality materials, and with constant inspections of the structure.
Keywords: *Pathologies; Wear; Maintenance*.

Resumen: Los canales de drenaje se destinan a la evacuación de aguas superficiales y cauces, teniendo un elevado coste de construcción, con el tiempo presentan patologías que requieren inspección y mantenimiento. Entre estas patologías, podemos mencionar el desgaste causado por la cavitación. En vista de lo anterior, esta investigación tiene como objetivo realizar un levantamiento visual, y posterior análisis, de las ocurrencias de desgaste por cavitación en un canal de drenaje, en el barrio de Aruana, ciudad de Aracaju-SE. En primer lugar, se realizó un levantamiento visual para evaluar la situación de la estructura; a continuación, se realizó un análisis a través del registro de imágenes y levantamiento bibliográfico de las principales causas y consecuencias de este fenómeno. Fue posible verificar la ocurrencia de desgaste por cavitación junto a las alcantarillas, en las paredes laterales del canal y, más intensamente, en la unión de las galerías pluviales con el canal. Se concluye que en muchos puntos la patología se encuentra en un nivel avanzado, requiriendo una intervención urgente; la intervención previene la evolución de las patologías; el coste de las reparaciones en una fase avanzada es elevado, justificando la importancia del mantenimiento periódico y la corrección en una fase temprana; y, por último, los problemas pueden evitarse o mitigarse en la fase de diseño, con el uso de materiales de mejor calidad, y con inspecciones constantes de la estructura.
Palabras clave: *Patologías; Desgaste; Mantenimiento.*

*Autor para correspondência
Received for publication on 2024/04/04; approved on 2023/10/25.
[1] Bachelor's student in Civil Engineering, Federal Institute of Sergipe, anap_melo95@hotmail.com, https://orcid.org/0009-0006-5684-1070;
[2] Bachelor's student in Civil Engineering, Federal Institute of Sergipe, misa.santana2199@gmail.com, https://orcid.org/0009-0005-6769-4902;
[3] Bachelor's student in Civil Engineering, Federal Institute of Sergipe, vitoria.eos00@gmail.com, https://orcid.org/0000-0001-5502-5529;
[4] Master Professor at the Federal Institute of Sergipe, zacariascaetani@yahoo.com.br, https://orcid.org/0000-0001-5019-0971.

INTRODUCTION

Urban drainage is a system of fundamental importance for preserving the quality of life of cities and their populations. As well as contributing to sustainable development, it has a direct influence on climate change and environmental conservation, since the construction and the expansion of cities has reduced rainwater runoff due to soil sealing.

A well-designed and executed drainage system not only brings health to the inhabitants it serves, but also brings cities closer to a more sustainable and safer environment, protecting the soil from erosion, water pollution, and preventing flooding due to its resilience to climate change, contributing to the conservation of cities and the environment.

Effective urban drainage brings economic, social and health benefits, because it reduces risks, preserves infrastructure, and promote a safer and healthier urban environment. This is why proper planning, maintenance, conservation and investment are fundamental to the well-being of cities and their inhabitants.

The advance of urbanization and the reduction of permeable areas in metropolises have led to several factors that hinder the soil's water balance, leading to complications such as flooding and waterlogging. As Nunes (2015) and Tucci (2016) point out, these changes have caused to the degradation of these natural systems, especially in large cities, where the increase in the effective built-up area in each household has contributed to a generalized reduction in the areas set aside for infiltration, preventing the soil from performing its hydrological functions efficiently.

Regarding the maintenance of drainage channel systems in Brazil and around the world, in recent years, a very controversial and challenging policy has been adopted by municipalities, as it is a problem that encompasses environmental, social, political, and hydrological aspects, among others. Silva *et al.* (2018), reports that the maintenance practices commonly adopted by Brazilian municipalities are generally limited to street sweeping and cleaning. Therefore, maintenance on drainage channels is usually started in municipalities when a significant accumulation of solid waste is observed, causing flooding in the region, in other words, in practice this occurs in a corrective rather than preventive manner.

In view of this, it is very important to take preventive maintenance of drainage channels into account, in order to avoid higher costs due to lack of planning. However, we have seen that measures are only taken when there are floods. According to data from the 2008 National Basic Sanitation Survey (IBGE, 2010a), 92.6% of Brazilian municipalities that made maintenance on their drainage networks only adopted the method of street sweeping and cleaning. This issue needs to be given greater priority, as it affects public health and can lead to disease, damage to property and the inability to move around the area.

Based on the above, the main objective of this article is to analyze the condition of the drainage channels in the Aruana neighborhood, located in the city of Aracaju-SE, mentioning the periodicity and need for proper maintenance, according to the data collected in the field.

THEORETICAL BACKGROUND

The cavitation phenomenon

According to Andrade (1992) cavitation is the degradation of the concrete surface caused by the rupture or implosion of water vapor bubbles when the flow velocity or direction undergoes a sudden change. This phenomenon causes wear and structural damage, increases the generation of noise and vibrations, and can create turbulence and agitation in the water, which reduces the transport capacity of sediments and materials in the channel. Reduced transport capacity in the channel can result in its siltation, as well as clogging. In water pumping systems, cavitation can, for example, reduce the energy and functional efficiency of the system.

Cavitation in canals

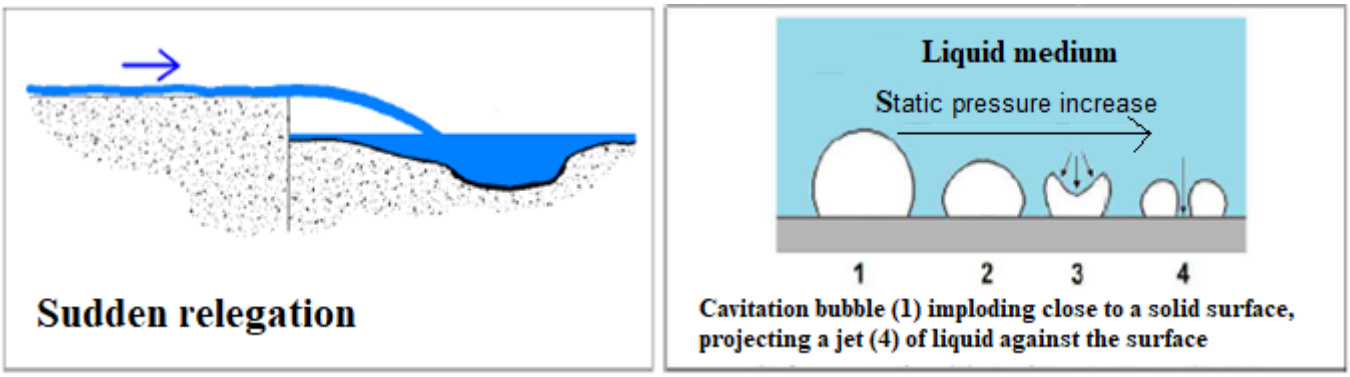
The drainage channel used in this study was made of concrete. However, concrete can present problems of a chemical, physical, biological, and mechanical nature, causing it to lose some of its functionality and potentially lead to ruin. Souza and Ripper (1998) report that the causes of pathological problems can be generated during the structural design stage, the execution of structures, and the use phase.

Weakened concrete, that presents cracks or poor workmanship increases the chances of cavitation occurring, especially in works such as drainage channels. The main material used in these structures is concrete, and the larger elements are one of the main reasons for this phenomenon. According to Liu and Mcdonald (1981), the laminar flow of water does not normally damage concrete, but erosion caused by coarse particles such as sand or gravel can be as severe as cavitation, which tends to increase with the loss of the surface layer of concrete, which is usually more resistant than the lower layers. As a result, many drainage channels tend to deteriorate.

Lima (2019) reports that the most common sources of cavitation in hydraulic structures are irregularities on the flow surface. According to the same author, once the damage is formed by the cavitation process, it is assumed that the damaged area becomes a source of cavitation, which creates another area of damage downstream because the area is larger than the irregularity that caused it, the process continues to produce larger and larger areas of damage.

Cavitation, generally, occurs in places where there is running water, causing degradation of the concrete surface caused by the bursting of bubbles formed when the speed or direction of the flow undergoes a sudden change, as in the sudden recess in the figure below, causing erosion (Gonçalves, 2017).

FIGURE 01: Mechanism of surface wear by cavitation.



SOURCE: Gonçalves (2017).

Actions to prevent and/or mitigate the occurrence of cavitation in drainage channels

Among the actions to prevent the occurrence of cavitation and recover the structures affected by this phenomenon, Gonçalves (2017) mentions:

> "replacing the eroded concrete with a more resistant concrete - since simply filling the eroded site with any concrete does not guarantee good long-term performance; the hydraulic design must be free of abrupt curvatures and undercuts, and the surface finish of the concrete must be very resistant, smooth, aligned, without defects such as protrusions and depressions; the material properties that best define resistance to cavitation are resistance to traction, impact, compression and shear; the aggregates must be a maximum of 38 mm in diameter, hard, dense and with an excellent bond between the paste and the aggregates; and finally, another alternative would be the use of concrete with fibers (except metallic fibers)".

METHODOLOGY

Study Area

This study used an urban drainage channel located in the Aruana neighborhood, in the city of Aracaju, Sergipe, which is approximately 2.1 km long, and consists of a rectangular section (600 m) and a trapezoidal section (1,500 m).

FIGURE 02: Rectangular section (left) and trapezoidal section (right) of the urban drainage channel in the Aruana neighborhood, Aracaju-SE.

SOURCE: Authors' data (2023).

The canal has a stretch on street Y and another stretch on Adalberto Fonseca Street, which converge and flow into the stretch of canal on Praia de Aruana Street, (all three stretches with trapezoidal sections), and this flows into the stretch of canal located on Eliza Correia Oliveira Street (rectangular section). The water collected by this channel flows into an extensive area of non-urbanized vegetation.

FIGURE 03: Sections of the drainage channel in the Aruana neighborhood, Aracaju-SE.

SOURCE: www.google.com/maps (2023).

After the on-site inspection, which took place on 14/07/2021, a visual survey of the occurrences of cavitation wear was carried out, with images recorded, in order to assess the condition of the structure.

Next, a literature review was conducted to identify the causes of this phenomenon and, finally, to list the actions that can be taken to avoid or mitigate its occurrence.

RESULTS AND DISCUSSION

Below, some of the points in the channel affected by cavitation wear will be presented.

FIGURE 04: Erosion and cavitation wear at points near the culverts.

SOURCE: Research's data (2023).

An analysis of Figure 04 shows that the outlet areas of culverts are susceptible to this type of occurrence, as they create pressure differences due to the change in water flow, which favor the appearance of bubbles, and causing cavitation damage. The pathological effects of cavitation on drainage structures always occur downstream from the source that caused it (Aguiar; Batista, 2011).

FIGURE 05: Erosion and cavitation wear at the connection between the rainwater galleries and the urban drainage channel.

SOURCE: Research's data (2023).

It's observed in figure 05 that the points where the rainwater galleries connect to the canal can be considered critical points for the occurrence of erosion and cavitation. These points are characterized by a sudden change in the speed and direction of the flow, which Andrade (1992) cites as causing cavitation.

FIGURE 6: Erosion and cavitation wear on the side walls of the channel.

SOURCE: Research data (2023).

Figure 06 shows sections with severe erosion and cavitation on the side walls of the channel caused by the flow of water. This action of the water, together with other occurrences, such as erosion of the soil that serves as the base for the concrete slab, has led to this structure breaking down in some stretches. According to Guabiroba (2012), one pathology is usually the gateway to the development of other pathologies; the process feeds back on itself, leading the structure to deteriorate sharply or even collapse.

CONCLUSIONS

After carrying out a visual survey and then analyzing the occurrences of cavitation wear in the drainage channel in the Aruana neighborhood, in the city of Aracaju-SE, it was concluded that:

a) In some stretches of the canal, especially at the junction of the rainwater galleries with the canal, the problem is at a very high level of extension, which could compromise the structure, making it urgently necessary to intervene;
b) The best time to carry out interventions on the canal would be when the occurrences are at an early stage, because over time the pathologies evolve to higher levels of extension, and consequently can lead to higher costs, as well as the risk of the structure collapsing;
c) The phase in which some eroded points of the channel are presented, indicates failure or lack of maintenance, a situation that, if maintained, could end up compromising the structure in the long term.

REFERENCES

[1] AGUIAR, J. E.; BAPTISTA, M, P.; Erosões nas estruturas de concreto das galerias de águas pluviais urbanas. Revista IBRACON de Estruturas e Materiais, 2011. Vol. 4, Nº 1. p70-90. ISSN 1983-4195.

[2] ANDRADE, M. del C.; Manual para diagnóstico de obras deterioradas por corrosão de armaduras. Tradução e adaptação de Antônio Carmona e Paulo Helene. 1. ed. São Paulo: Pini, 1992. 104 p. ISBN 85-7266-011-9.

[3] CASCUDO, O. O.; controle da corrosão de armaduras em concreto. Inspeção e técnicas eletroquímicas. 1. ed. São Paulo: Pini. 1997.

[4] GONÇALVES, G. S.; Patologia e Recuperação de Estruturas. 2017. Notas de Aula. Disponível em: https://meumaterialsite.wordpress.com/2017/01/31/25/. Acesso em: 28 out. 2023.

[5] GUABIROBA; R. T.; Patologias em canais de drenagem em concreto – Estudo de caso de BH. 2012. 62 p. Monografia (em Engenharia Civil) – Escola de Engenharia da UFMG, Departamento de Engenharia de Materiais e Construção, Pós-Graduação em Construção Civil.

[6] IBGE (2010a).; Censo Demográfico, 2010. Disponível em: http://www.ibge.gov.br. Acessado em: 31 ago. 2023.

[7] IPEA; Centro de Pesquisa em Ciência, Tecnologia e Sociedade, 2023. Disponível em: https://www.ipea.gov.br/cts/pt/central-de-conteudo/artigos/artigos/231-controle-de-enchentes. Acesso em: 23 out. 2023.

[8] LIMA, D. da S. de.; Avaliação dos Índices de Cavitação a Jusante de Comportas Segmento Invertida em Condutos Retangulares. 2019. 85 f. TCC (Graduação) - Curso de Engenharia Civil, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2019.

[9] LIU, T. C.; MCDONALD, J. E.; Abrasion-erosion resistence of fiber-reinforced concrete. Cement, Concrete and Aggregates. v. 3, n. 2, p. 93-100. 1981.

[10] NUNES, L. H.; Urbanização e desastres naturais, abrangência América do Sul. São Paulo: Oficina de Textos, 2015, 112 p.

[11] SILVA, A. C.; SILVA JUNIOR, M. A. B.; SILVA, S. R.; CABRAL, J. J. S. P.; Medidas para a reabilitação da microdrenagem no entorno da Escola Politécnica de Pernambuco (POLI/UPE). In: XII [1] ENCONTRO NACIONAL DE ÁGUAS URBANAS, Maceió, 2018. Anais...

[12] SOUZA, V.; RIPPER, T.; Patologia, Recuperação e Reforço de Estruturas de Concreto. 1. ed. São Paulo: Pini, 1998.

[13] TUCCI, C. E. M.; Inundações urbanas. Coleção Associação Brasileira de Recursos Hídricos, v. 11. Porto Alegre: ABRH/RHAMA, 2016. 389 p.