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Systematic Literature Review on Crack Measurement in Concrete Silos

Diogo Cavalcanti Oliveira
Master Degree, UPE, Brasil.
dco@poli.br

Alberto Casado Lordsleem Jr
Professor Doctor, UPE, Brasil.
acasado@poli.br

Laura Nogueira Cordeiro
Master's Student, UPE, Brasil.
lrnogueira1@gmail.com

Thais Cohen de Almeida Costa
Master's Student, UFPE, Brasil.
thaiscohen01@gmail.com

Emanoel Silva de Amorim
Master Degree, UPE, Brasil.
esa7@poli.br

Yêda Vieira Póvoas
Professor Doctor, UPE, Brasil.
yvp@poli.br

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ABSTRACT

This research presents a Systematic Literature Review (SLR) on the main methods for crack identification in concrete structures, focusing on their applications in silos, as well as their advantages and disadvantages. The aim of this artide is to conduct a critical analysis of the most relevant scientific publications on crack measurement in concrete structures, emphasizing the comparison of different methods. Throughout this study, the characteristics and pathological manifestations of concrete silos are discussed, along with traditional and advanced methods for crack identification. Using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, articles published between 2016 and 2023 were selected from the Web of Science, Science Direct, SCOPUS, and Engineering Village databases. The results highlight a growing trend in the use of technologies such as UAVs, Laser Scanning, and emerging techniques like machine learning and deep learning. These technologies are seen as promising for improving the accuracy and efficiency of early structural damage detection, with significant practical implications for industrial and civil construction sectors. The contribution of this study lies in the analysis of market trends, providing a critical perspective on existing technologies that propose solutions to the challenges faced in concrete infrastructure inspection.

KEYWORDS: Concrete silo. Cracks. Structural rehabilitation.

Revisão Sistemática de Literatura Relativa à Medição de Fissuras em Silos de Concreto

RESUMO

A pesquisa apresenta uma Revisão Sistemática de Literatura (RSL) sobre os principais métodos de identificação de fissuras em estruturas de concreto, com foco em suas aplicações e em silos, bem como vantagens e desvantagens. Este artigo tem como objetivo de realizar uma análise crítica das publicações científicas mais relevantes para a medição de fissuras em estruturas de concreto, com enfoque na comparação dos métodos do tema. Ao longo do presente trabalho é abordado as características e manifestações patológicas dos silos de concreto, além dos métodos tradicionais e avançados de identificação dessas fissuras. Utilizando o protocolo PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), foram selecionados artigos publicados entre 2016 e 2023, das bases de dados Web of Science, Science Direct, SCOPUS e Engineering Village. Os resultados destacam uma tendência crescente no uso de tecnologias como VANT, Varredura a Laser e técnicas emergentes como machine learning e deep learning. Essas tecnologias são vistas como promissoras para melhorar a precisão e eficiência na detecção precoce de danos estruturais, com implicações práticas significativas para os setores industriais e de construção civil. A contribuição do estudo reside na análise das tendências mercadológicas, fornecendo uma visão crítica das tecnologias existentes que propõem soluções para os desafios enfrentados na inspeção de infraestruturas de concreto.

PALAVRAS-CHAVE: Silo de concreto. Fissuras. Recuperação estrutural.

Revisión Sistemática de Literatura Relativa a la Medición de Fisuras en Silos de Concreto

RESUMEN

La investigación presenta una Revisión Sistemática de Literatura (RSL) sobre los principales métodos de identificación de fisuras en estructuras de concreto, con enfoque en sus aplicaciones en silos, así como sus ventajas y desventajas. Este artículo tiene como objetivo realizar un análisis crítico de las publicaciones científicas más relevantes sobre la medición de fisuras en estructuras de concreto, con énfasis en la comparación de los métodos del tema. A lo largo de este trabajo se abordan las características y manifestaciones patológicas de los silos de concreto, además de los métodos tradicionales y avanzados de identificación de estas fisuras. Utilizando el protocolo PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), se seleccionaron artículos publicados entre 2016 y 2023 en las bases de datos Web of Science, Science Direct, SCOPUS y Engineering Village. Los resultados destacan una tendencia creciente en el uso de tecnologías como UAV, Escaneo Láser y técnicas emergentes como machine learning y deep learning. Estas tecnologías se consideran prometedoras para mejorar la precisión y eficiencia en la detección temprana de daños estructurales, con implicaciones prácticas significativas para los sectores industriales y de la construcción. La contribución del estudio radica en el análisis de las tendencias del mercado, proporcionando una visión crítica de las tecnologías existentes que proponen soluciones a los desafíos enfrentados en la inspección de infraestructuras de concreto.

PALABRAS CLAVE: Silo de concreto. Fisuras. Rehabilitación estructural.

ISSN 2318-8472, v. 13, n. 88, 2025

1. INTRODUCTION

The measurement of cracks in concrete structures is an intriguing challenge in civil engineering. With the increasing academic and industrial interest in this topic, new methods are being developed to optimize crack inspection and measurement processes (Khan et al., 2023). However, issues such as efficiency, operational costs, time, safety, and accuracy still pose considerable obstacles (Ali et al., 2021; Khan et al., 2023).

The occurrence of cracks is among the most common pathological manifestations in concrete structures. The causes of these cracks vary and may include plastic shrinkage, design and construction failures, thermal shrinkage, and plastic settlement of the concrete (Rocha & Póvoas, 2019).

According to Maj (2017), Khalil et al. (2022), and Bilčík et al. (2021), the appearance of horizontal and vertical cracks in silos can be attributed to several common causes. Among them are errors during the design, construction, and maintenance of the walls. Additionally, external factors such as temperature, pressure from stored material, wind loads, humidity, and the influence of construction joints play significant roles. These potential issues can compromise the structural reliability of the silo and reduce its load-bearing capacity, directly impacting its functionality and operational safety.

Maj (2017) highlights that cracks can lead to steel reinforcement corrosion, reduced stiffness, increased deflection, and enhanced carbonation of the concrete layer. Furthermore, he emphasizes the importance of repairing cracked concrete structures in silos to ensure durability and prevent future structural failures, guaranteeing that the strength and stiffness of the structure are maintained in all areas, allowing for uniform load distribution.

In general, the resolution of pathological manifestations follows a standard process that includes several stages, such as inspection, anamnesis, examinations, diagnosis, prognosis, and intervention. The inspection phase involves an assessment to verify performance and determine the necessary preventive and corrective measures. This inspection influences all subsequent steps in resolving pathological manifestations. When it comes to concrete silos, the challenge of inspection arises due to the complexity of these structures, particularly their height, accessibility difficulties, and exposure conditions (Ballesteros & Lordsleem Junior, 2021).

1.2 CHARACTERIZATION OF SILOS

Silos are structures specifically designed for storing a variety of granular materials, such as grains and cement. These constructions are characterized by their lateral dimensions being disproportionate to their height, making them particularly suitable for large-scale storage. They are commonly found in industrial contexts such as cement mills and large construction projects (Kumar, 2023).

These facilities are designed with loading systems and ideally allow emptying by gravity, although mechanical or pneumatic devices may also be used for this purpose (Yu et al., 2017; Zhang et al., 2018).

Despite significant progress in recent studies, many uncertainties persist regarding the behavior of stored materials and the effects observed during the emptying process. During this

ISSN 2318-8472, v. 13, n. 88, 2025

phase, the pressures exerted on the silo walls by the stored materials reach their maximum levels (Gallego, 2015).

Silos are subject to a variety of failures and collapses caused by different mechanisms. As discussed by Khalil et al. (2022) and Prusiel (2020), design failures are frequently reported in silo collapse cases. These failures occur at multiple stages of concrete silo analysis, starting with inadequate foundations that fail to support unexpected overloads to design errors that do not account for thermal variations, which can induce significant stresses in the structure.

As discussed by Maraveas (2020) and Yuan (2011), design failures in silos can have severe consequences, often requiring complex and costly structural recovery interventions. Such failures can negatively affect the functionality of silos. The early detection of deterioration signs is crucial, as it enables the implementation of simpler and more effective solutions, preventing more severe issues in the future and consequently extending the service life of the structures.

According to Bilčík et al. (2021), Carson (2003), and Carson (2001), in addition to design failures, other common causes of collapse include corrosion, construction defects, improper use leading to unforeseen stresses, neglect in maintenance, explosions, and earthquakes. This set of causes highlights the need for a rigorous approach in the design, construction, and maintenance of silos to ensure the safety and durability of these critical structures.

Pathological manifestations affect civil structures in various aggressive environments. Therefore, technical inspections and interventions must be carried out using methods that minimize subjectivity and ensure appropriate durability solutions. Even with technological advancements in construction materials and building processes over the years, there are still numerous reports of failures and anomalies in structures. These failures compromise building performance and consequently lead to pathological manifestations, which can occur at any stage of a building's life cycle—during design, construction, or even years after the operational phase (Medeiros, 2020).

Thus, cracks are identified as one of the main pathological manifestations in concrete silos, and they will be the focus of this study. According to Santos (2023), the causes of cracks in concrete silos stem from errors in silo assembly, design failures, lack of specialized personnel to operate equipment, structural settlement, and insufficient maintenance.

Structural damage in buildings reduces their service life and poses risks to occupant safety. Regular inspections are essential to identify and assess the severity and type of damage, providing a solid foundation for necessary repairs and ensuring safe operations. In particular, concrete cracking is one of the most critical types of damage, affecting durability, safety, and maintenance while also reducing load-bearing capacity. Early detection and correction of these cracks can lead to substantial maintenance cost savings and prevent more significant property losses and life-threatening risks (Wang et al., 2024).

Like other constructions, storage units also exhibit pathological problems that can compromise their structures, reducing expected performance and service life. Errors in silo construction or assembly can result in irreversible damage, including grain loss or contamination, deterioration of concrete and/or metal structures, replacement costs, environmental issues, and legal liability with third parties (Santos, 2023).

ISSN 2318-8472, v. 13, n. 88, 2025

1.3 AVAILABLE TECHNOLOGIES FOR CRACK DIAGNOSIS

1.3.1 UAVs

Unmanned Aerial Vehicles (UAVs), also known as Remotely Piloted Aircraft Systems (RPAS) or more commonly as "drones," can provide high-resolution spatial datasets in both local and large-scale areas (Woodget, 2017; Koutalakis, 2019). As defined by Watts (2012), a UAV is a component of an unmanned aircraft system, which includes the tool, the pilot, and the communication system.

In particular, UAVs are becoming increasingly relevant as a new approach to data acquisition and visual inspections, standing out for their ability to reduce execution time and improve risk identification (Rocha & Póvoas, 2019; Ballesteros & Lordsleem Jr., 2021; Lima & Costa, 2023).

UAVs have gained prominence in civil infrastructure applications due to their low maintenance costs, ease of operation, ability to hover in place, and remarkable mobility. According to Sivakumar (2021), UAVs can capture images more quickly and accurately than satellite imagery, enabling a faster assessment of structural conditions. The inspection and maintenance of vertical structures must be conducted periodically, with crack detection being a critical aspect of the inspection process. Additionally, as noted by Bhowmick et al. (2020), the entire process is prone to human error, and due to the size and complexity of civil structures, some areas are difficult to access for manual inspection.

Crack detection is of significant importance in structural concrete inspections. Various UAV-based crack detection systems exist, but quantifying cracks remains a challenge (Ding et al., 2023).

1.3.2 LASER SCANNER

In recent years, the use of Terrestrial Laser Scanners (TLS) for graphic and metric documentation of objects has expanded significantly. This growth is mainly due to the fact that TLS is a non-destructive and non-invasive technique, eliminating the need for direct contact. Remote sensing equipment, such as laser scanners, enables the capture of large amounts of data from points distributed across the examined surface, offering high precision and a rapid acquisition rate—ranging from thousands to millions of points per second (Pavi et al., 2014).

1.3.3 PERIODIC INSPECTIONS

Periodic inspections are an essential procedure for monitoring the progress and development of each stage of activities in a construction project. These inspections must follow the recommendations of NBR 16747 (ABNT, 2020), which provides guidelines, concepts, and methods for conducting building inspections. The objective is to offer elements that assist in diagnosing potential failures, anomalies, or pathological manifestations.

According to Amorim et al. (2023), building inspections are classified based on the inspector's qualification level and the purpose of the inspection, as follows:

ISSN 2318-8472, v. 13, n. 88, 2025

- Level 1: Inspection conducted by a qualified professional to identify apparent anomalies through visual assessment.
- Level 2: Inspection aimed at detecting apparent anomalies with the aid of equipment, performed by specialists from different fields and including relevant technical recommendations.
- Level 3: Inspection to identify both apparent and hidden anomalies that can be detected using specialized equipment, including specific tests and analyses conducted in the field or laboratory. This level is carried out by professionals from various disciplines and includes detailed technical recommendations. It is generally applied to buildings with suspected significant hidden defects.

However, it is common for evaluations to be conducted using only visual inspection (Level 1), where a subjective assessment is assigned to the structural components by the responsible inspector. Visual inspection provides useful information about visible defects that begin to appear in structural elements. Crack detection, for example, can provide valuable insights but often becomes visible only at a later stage, when structural deterioration has already progressed. Many internal damages within a structure are difficult to identify and visualize (Choquepuma, 2011).

Visual inspection does not replace other types of non-destructive testing. However, it can support the inspection process by guiding the selection of additional tests that may be required subsequently.

2. METHODS

This research has a quantitative character, as it consists of a Systematic Literature Review of articles. It is classified as applied research, as it focuses on methods applicable to the industrial sector. The study is exploratory-descriptive, as it provides a broad overview of the topic while also delving deeper into the subject, compiling an extensive database and incorporating cross-sectional studies.

The research strategy for this systematic review was based on the guidelines of the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). This structured approach ensured a comprehensive and methodical analysis of relevant literature on the topic (Liberati, Altman & Tetzlaff, 2009). The protocol guided the selection and analysis of recent and relevant scientific articles outlining crack measurement methods in concrete.

The research was conducted in October 2023, covering articles published between 2016 and 2023. The search was performed using the CAPES Journal Portal, filtering by "subject" and "title" of the articles. During the article selection process, specific keyword concatenations were used, adapted according to the limitations of each database.

For the Engineering Village and SCOPUS databases, the following search string was used: "Fissuras" OR "Detecção de fissuras" OR "Crack detection" OR "Crack" OR "Damage" OR "Durability" OR "Failure" AND "Concreto" OR "Concrete" OR "Reinforced concrete" AND "Quantificação" OR "Mensuração" OR "Medir" OR "Mensurar" OR "Detectar" OR

ISSN 2318-8472, v. 13, n. 88, 2025

"Quantification" OR "Measurement" OR "Detection" OR "Detect" OR "Inspeção" OR "Inspector" OR "Inspection" AND "Silo" OR "Tank".

For Web of Science, the following string was used: "Fissuras" OR "Detecção de fissuras" OR "Crack detection" OR "Crack" AND "Concreto" OR "Concrete" OR "Reinforced concrete" AND "Quantificação" OR "Mensuração" OR "Medir" OR "Mensurar" OR "Detectar" OR "Quantification" OR "Measurement" OR "Detection" OR "Detect" OR "Inspeção" OR "Inspector" OR "Inspection" AND "Silo" OR "Tank".

For ScienceDirect, the search included: "Crack" OR "Damage" OR "Failure" AND "Concrete" OR "Reinforced concrete" AND "Detection" OR "Inspection" AND "Silo" OR "Tank".

These logical keyword sequences were formulated to cover relevant terms associated with crack measurement and detection in concrete structures, with a specific focus on silos. The use of these sequences ensured a comprehensive and effective search across the databases, enabling the identification of significant studies for the systematic literature review.

For the selection of articles, several criteria were applied: (a) Articles accessible through the CAPES journal portal for free download; (b) By language (works in Portuguese and English); (c) By topic (articles related to civil engineering, architecture, and construction); (d) By duplicates (non-duplicated scientific works); (e) By title (articles not considering concrete were excluded); (f) By abstract (articles not containing the parameters of interest analyzed in the review were excluded). Criteria were also used to synthesize the following data: authorship; year of publication; study methodology; technologies used; concrete elements studied; study objectives; advantages and disadvantages of the methods; comparison with traditional inspection; results, and conclusions. Articles were excluded if they were not in English or Portuguese, were duplicates, were systematic reviews, meta-analyses, without the full text available, or had no abstract available. Table 1 presents the Inclusion Criteria (IC) and Exclusion Criteria (EC) applied in this research.

Table 1 - Inclusion Criteria (IC) and Exclusion Criteria (EC)

Critérios	Descrição
Inclusion criteria	(IC1) Journal articles
Exclusion criteria	(EC1) By language, not in English or Portuguese
	((EC2) Duplicates
	(EC3) Not related to Architecture, Engineering, and Construction, or the theme
	(EC4) Articles that do not have the keywords from the research in the title, abstract, and content

Source: Prepared by the authors (2024)

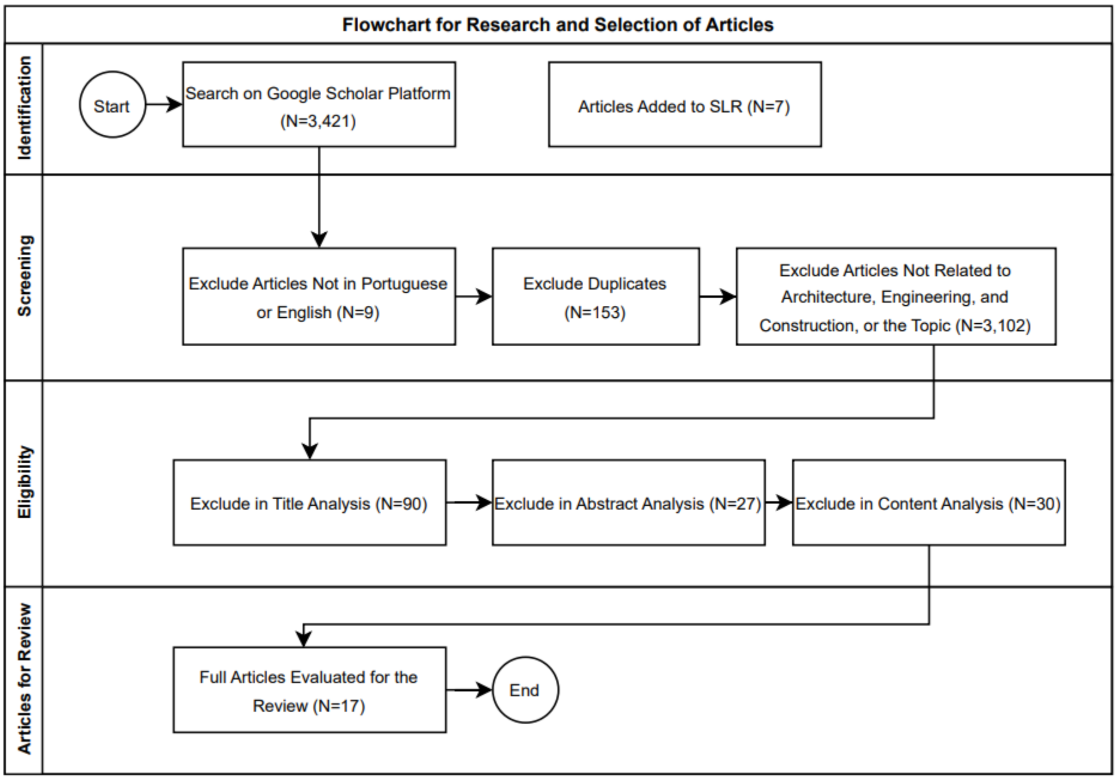
The research methodology consists of a systematic literature review (SLR), aimed at critically analyzing the most relevant scientific publications on the topic, with a focus on comparing methods for measuring cracks in concrete structures. The complexity of the methods used and the technologies employed for a more robust evaluation of the procedures are addressed.

The identification of relevant studies in the databases resulted in 17 articles included in this SLR. Detailing the application of the filters, we have: a) identification stage – 3,421 articles were selected in the database; b) screening stage – according to the application of inclusion and exclusion criteria, 9 were excluded for language, 153 for duplication, and 3,102 for not being

ISSN 2318-8472, v. 13, n. 88, 2025

relevant to the theme; c) eligibility stage: 90 by title, 27 by abstract, and 30 by content. This entire process of selection and application of eligibility criteria can be observed through the article selection flowchart in Figure 1.

Figure 1 – Flowchart of the Article Selection Process



Source: Prepared by the authors (2024)

3. RESULTS

3.1 QUANTITATIVE ANALYSIS OF RESULTS

According to the data search, Table 1 shows the number of articles at each stage, resulting in the 17 articles relevant to the research.

Table 1 – Number of Articles by Stage

Stage	Number of Articles
Selected Articles	3428
Excluded by Language	9
Duplicated Articles	153
Not Relevant to Research	3102
Excluded in Title Review	90
Excluded in Abstract Review	27
Excluded in Content Review	30

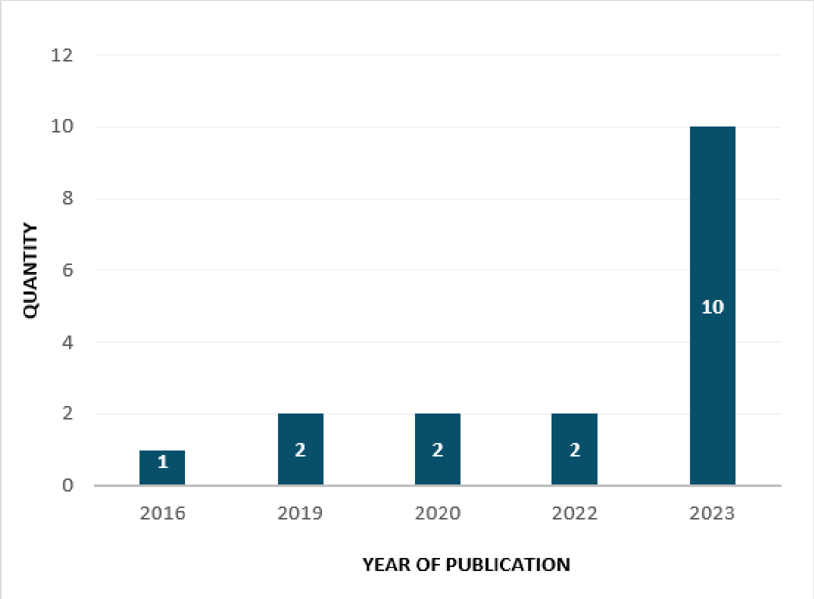
Source: Prepared by the authors (2024)

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 13, n. 88, 2025

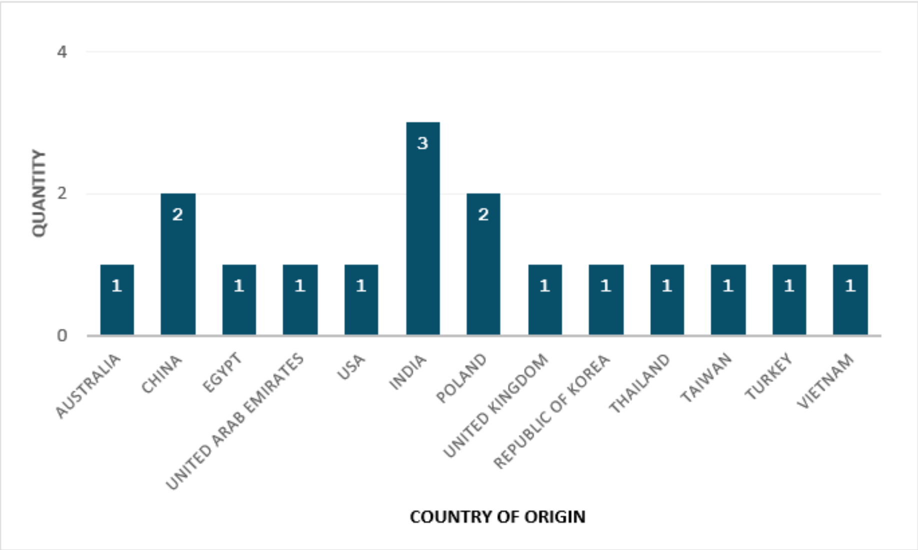
In the analysis of the collected data, several relevant points stand out for the study in question. One of these is the investigation of the publication years of the articles, as shown in Figure 2. Furthermore, information was gathered about the countries where the research was conducted, as evidenced in Figure 3. Notably, a diversity of countries has been using crack measurement in concrete structures. It can be observed that most of the research is concentrated in recent years, with a peak in 2023, with 10 articles published (Figure 2), demonstrating the importance and the current context of the topic.

Figure 2 – Years of Publication



Source: Prepared by the authors (2024)

Figure 3 – Countries of Origin



Source: Prepared by the authors (2024)

3.2 QUALITATIVE ANALYSIS OF RESULTS

ISSN 2318-8472, v. 13, n. 88, 2025

In Table 2, the 17 studies selected for the research are presented in a summarized form.

Table 2 – Selected Articles for the Systematic Literature Review

No	References	Tools Used
1	Ding et al. ,2023	UAV (VANT)
2	Howiacki et al. ,2023	Tests
3	Woo H.-J et al. ,2023	UAV (VANT)
4	Fawzy et al. ,2023	Laser Scanning
5	Prieto et al. ,2023	UAV (VANT)
6	Sztubecki et al. ,2022	Laser Scanning
7	Chaiyasarn et al. ,2022	Deep Learning
8	Mohammadi et al. ,2019	3D Point Cloud Data Analysis
9	Pitchaiah et al. ,2020	Neural Network
10	Dinh et al. ,2023	Machine Learning
11	Philip et al. ,2023	Neural Network
12	Ozkaya et al. ,2023	Machine Learning
13	Li; Zhao ,2020	Deep Learning
14	Nyathi et al. ,2023	Laser Scanning
15	Giri et al. ,2016	Laser Scanning
16	Li et al. ,2023	UAV (VANT)
17	Barkavi et al. ,2019	Digital Image Processing

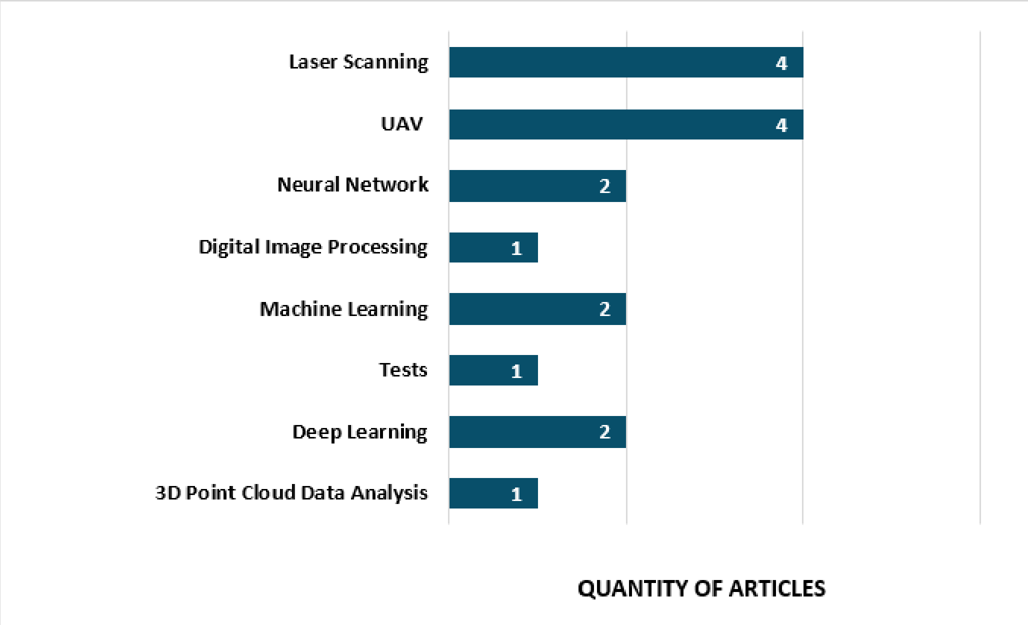
Source: Prepared by the authors (2024)

The qualitative analysis was structured into the following topics, aiming to gather recent publications from various authors on methods related to crack measurement in concrete silos.

Figure 4 presents the tools used in the research resulting from the systematic literature review (SLR), while Figure 5 indicates the tools used by year, thus revealing a chronological sequence in the use of these tools in order to present emerging technologies and market trends. It is possible to observe the diversity of methods applied in crack measurement in concrete structures, covering various technologies, applications, and levels of precision. The use of specialized software for pattern recognition emerges as an advanced solution. These technologies enable progress in the accuracy, efficiency, and safety of crack measurements, minimizing the need for direct human inspection and allowing for a more comprehensive and detailed analysis of cracks in concrete.

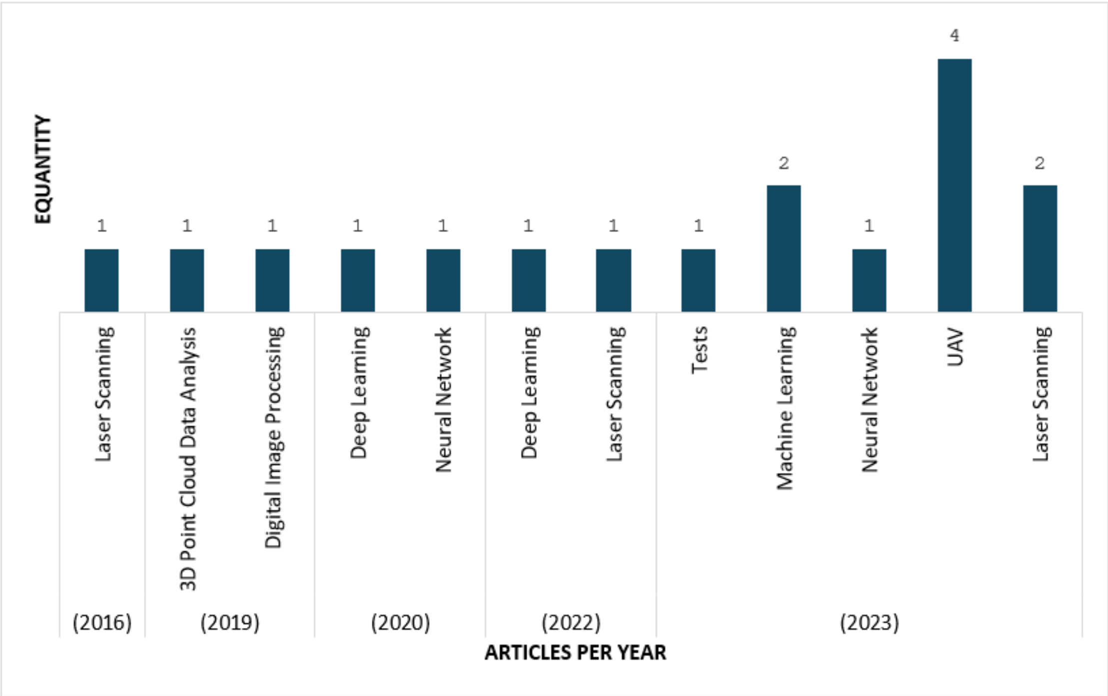
ISSN 2318-8472, v. 13, n. 88, 2025

Figure 4 – Most used tools for crack measurement



Source: Prepared by the authors (2024)

Figura 5 – Most used tools for crack measurement



Source: Prepared by the authors (2024)

In relation to the systems used in the analyzed studies, several authors employed more than one method in their research. Among them, UAVs (Unmanned Aerial Vehicles) and Laser Scanning stand out as the most commonly used. Their functionalities allow for the collection of visual data, facilitating decision-making in the renovation projects of these structures, optimizing time management, and reducing errors.

ISSN 2318-8472, v. 13, n. 88, 2025

According to the group of authors who used UAVs to capture images of cracks, Ding et al. (2023), Woo H.-J et al. (2023), Ko et al. (2023), and Li et al. (2023), UAVs achieved success in the detection and precise quantification of cracks in concrete. However, limitations were identified regarding dependence on image quality, lighting conditions, and camera calibration accuracy, which can affect the detection of very fine cracks.

The use of Laser Scanning, cited by authors such as Fawzy et al. (2023), Sztubecki et al. (2022), Nyathi et al. (2023), and Giri et al. (2016), highlighted that mapping with laser scan-generated images was effective, with accuracy similar to the monitoring of cracks using the traditional visual inspection method. However, for large and tall structures, such as concrete silos, access and the distance required for the equipment setup may complicate the process.

Authors Li and Zhao (2020) and Chaiyasarn et al. (2022) present the Deep Learning method and demonstrate that it is possible to process large volumes of image data quickly and automatically, enabling efficient real-time crack detection. However, large and well-labeled datasets are necessary for proper training, and the computational complexity and implementation of models require significant hardware resources and technical expertise.

Dinh et al. (2023) and Ozkaya et al. (2023) used machine learning for crack identification in concrete structures, emphasizing the efficient processing of large volumes of image data, allowing automated and accurate crack detection. Furthermore, these models can learn complex patterns of cracks in the images. However, challenges like the need for robust and representative datasets for adequate training, as well as dependence on well-adjusted parameters and correct algorithm choice, can directly influence the system's effectiveness.

The studies by Philip et al. (2023) and Pitchaiah and Srinivasa Rao (2020) highlight significant advances in using neural networks for crack detection in concrete structures. Philip et al. (2023) used transfer learning to adapt pre-trained models, improving detection accuracy, while Pitchaiah & Srinivasa Rao explored an optimized approach to identify cracks in thick concrete beams. Both methods presented effective results in creating robust models but faced challenges such as the need for extensive data and computational complexity.

Mohammadi et al. (2019) proposed an advanced method of non-temporal point cloud analysis to detect cracks and defects in concrete surfaces. The study proposes accurate and efficient damage detection without relying on continuous temporal data, facilitating its implementation. It demonstrates efficacy in the objective detection of cracks in structures using a method based on geometric descriptions of the surface.

According to Barkavi et al. (2019), the digital image processing method offers high accuracy in measuring cracks in concrete using an algorithm developed in MATLAB, capable of measuring both the length and width of the crack. However, the need for human intervention to capture images and select reference points on the crack can be considered a weakness.

Howiacki et al. (2023) compared various Optical Fiber Distributed Fiber Optic Sensors (DFOS) tools for monitoring cracks in concrete, focusing on the shape coefficient of these cracks. Through comparison of results, it is presented that the choice of cable or sensor type should be made carefully and preceded by a detailed analysis of advantages and possible limitations. The study shows that the ideal solution depends on low axial rigidity and the maximum deformation range.

ISSN 2318-8472, v. 13, n. 88, 2025

In comparison with the methods, it is evident that the use of UAVs brings benefits such as access to restricted and safety-risk areas, reduced project time, low cost, and accuracy of the collected data. The approach overcomes the limitations of visual inspection, offering a safer, more consistent process that does not rely on direct human intervention, in addition to not requiring the interruption of operations in the structure.

4. CONCLUSION

From the systematic literature review, it was possible to confirm the diversity of methodologies applied in the measurement of cracks in concrete structures, encompassing various technologies, applications, and levels of precision. This investigation highlighted a significant evolution from conventional practices, primarily based on visual inspection and direct intervention in compromised areas, to the incorporation of innovative and autonomous techniques.

The increasing use of these approaches in the studies signals a paradigmatic shift in crack inspection procedures, indicating a growing trend toward the adoption of automated and non-invasive methods. This advancement represents not only an increase in the accuracy of assessments but also contributes to the optimization of the structural rehabilitation process, enabling cost and time reductions.

The research also indicates that the use of UAVs in the civil industry is associated with standardized techniques for image capture, which enhance the quality and characteristics of the results in crack measurement, thus allowing for more rigorous technical analysis. The technical feasibility of crack inspection with UAVs was confirmed by the results obtained from the systematic literature review, demonstrating their capability to differentiate between structural and non-structural elements.

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STATEMENTS

CONTRIBUTION OF EACH AUTHOR

- **Study Conception and Design**: Diogo Cavalcanti Oliveira e Alberto Casaldo Lordsleem Jr.
- **Data Curation**: Diogo Cavalcanti Oliveira e Laura Nogueira Cordeiro
- **Formal Analysis**: Diogo Cavalcanti Oliveira
- **Funding Acquisition**: Yêda Vieira Póvoas
- **Investigation**: Diogo Cavalcanti Oliveira e Alberto Casaldo Lordsleem Jr.
- **Methodology**: Diogo Cavalcanti Oliveira
- **Writing - Initial Draft**: Diogo Cavalcanti Oliveira
- **Writing - Critical Review**: Laura Nogueira Cordeiro, Alberto Casaldo Lordsleem Jr., Thais Cohen de Almeida Costa, Emanoel Silva de Amorim e Yêda Vieira Póvoas.
- **Review and Final Editing**: Diogo Cavalcanti Oliveira, Laura Nogueira Cordeiro, Alberto Casaldo Lordsleem Jr., Thais Cohen de Almeida Costa, Emanoel Silva de Amorim e Yêda Vieira Póvoas.
- **Supervision**: Diogo Cavalcanti Oliveira e Laura Nogueira Cordeiro.

DECLARATION OF CONFLICTS OF INTEREST

We, [Diogo Cavalcanti Oliveira, Laura Nogueira Cordeiro, Alberto Casaldo Lordsleem Jr., Thais Cohen de Almeida Costa, Emanoel Silva de Amorim and Yêda Vieira Póvoas], declare that the manuscript entitled "Systematic Review of Literature Related to the Measurement of Cracks in Concrete Silos":

1. **Financial Relationships:** The author has no financial relationships that could influence the results or interpretation of the work.
2. **Professional Relationships:** The author does not have/has any professional relationships that could impact the analysis, interpretation or presentation of the results.
3. **Personal Conflicts:** The author has no personal conflicts of interest related to the content of the manuscript.