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# Qualitative analysis of the bibliographic portfolio on the theme "Durability in coating mortars".

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## ABSTRACT

This study aims to analyze scientific production on the durability of rendering mortars. To this end, the Methodi Ordinatio method was applied in a bibliometric review of articles published between 2018 and 2023. A total of 323 studies were identified across four databases, of which 16 met the selection criteria. The studies indicate that research on rendering mortars is mainly focused on mechanical properties, particularly compressive and flexural strength. About durability, water absorption and carbonation resistance tests are the most used indicators of degradation, although the lack of standardized regulations makes it difficult to compare results across studies. A growing trend toward the use of alternative materials with promising results in improving performance and reducing environmental impacts was also observed. In addition, the application of Life Cycle Assessment tools reinforces the need to integrate durability and sustainability, promoting more efficient and long-lasting construction solutions.

**Keywords:** coating mortar; sustainability; methodi ordinatio; systematic review.

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# Análise qualitativa sobre o portfólio bibliográfico com o tema “Durabilidade em argamassas de revestimento”.


## RESUMO

Este estudo objetiva analisar a produção científica sobre a durabilidade de argamassas de revestimento. Para isso, aplicou-se o método Methodi Ordinatio em uma revisão bibliométrica de artigos publicados entre 2018 e 2023. Foram identificados 323 trabalhos em quatro bases de dados, dos quais 16 atenderam aos critérios de seleção. Os estudos evidenciam que as pesquisas sobre argamassas de revestimento concentram-se nas propriedades mecânicas, especialmente na resistência à compressão e à flexão. No que se refere à durabilidade, os ensaios de absorção de água e de resistência à carbonatação são os mais recorrentes como indicadores de degradação, embora a ausência de padronização normativa dificulte a comparação entre os resultados. Foi possível observar uma tendência crescente de materiais alternativos com resultados promissores na melhoria do desempenho e na redução dos impactos ambientais. Além disso, a aplicação de ferramentas de Avaliação do Ciclo de Vida reforça a necessidade de integrar durabilidade e a sustentabilidade, promovendo soluções construtivas mais eficientes e duráveis.

**Palavras-chave**: argamassa de revestimento; sutentabilidade; methodi ordinatio; revisão sistemática.

# Análisis Cualitativo del Portafolio Bibliográfico sobre el tema “Durabilidad en morteros de revestimiento”.


## RESUMEN

Este estudio tiene como objetivo analizar la producción científica sobre la durabilidad de los morteros de revestimiento. Para ello, se aplicó el método Methodi Ordinatio en una revisión bibliométrica de artículos publicados entre 2018 y 2023. Se identificaron 323 estudios en cuatro bases de datos, de los cuales 16 cumplieron con los criterios de selección. Los resultados indican que las investigaciones sobre morteros de revestimiento se centran en las propiedades mecánicas, especialmente en la resistencia a la compresión y a la flexión. En cuanto a la durabilidad, los ensayos de absorción de agua y resistencia a la carbonatación son los más recurrentes como indicadores de degradación, aunque la falta de estandarización normativa dificulta la comparación entre resultados. También se observó una tendencia creciente hacia la incorporación de principios de sostenibilidad, mediante el uso de materiales alternativos que han mostrado resultados prometedores en la mejora del desempeño y la reducción de los impactos ambientales. Además, la aplicación de herramientas de Evaluación del Ciclo de Vida refuerza la necesidad de integrar durabilidad y sostenibilidad, promoviendo soluciones constructivas más eficientes y duraderas.

**Palabras clave**: mortero de revestimiento; sostenibilidad; methodi ordinatio; revisión sistemática.

# 1. INTRODUCTION

Rendering mortar is essential for surface leveling, aesthetics, acoustics, heat resistance, and the durability of buildings, and it can distribute loads uniformly, smooth out block irregularities, and accommodate deformations associated with thermal expansion and shrinkage (Haddad et al., 2020; Aragón et al., 2024). However, it is one of the first facade components to deteriorate, being considered a sacrificial material (Arizzi et al., 2012).

The long-term performance of materials exposed to their external environments is a topic of significant interest. In addition to studies of fresh state properties and mechanical strength that must meet standards, durability has become an increasingly relevant aspect to be considered in recent years (Lunardi et al., 2024).

To optimize the planning of building maintenance actions, it is important to understand how components degrade and determine the appropriate timing for interventions. Without this information, it is common to face high unexpected costs resulting from unnecessary interventions or urgent repairs that could have been avoided (Silva et al., 2014).

When addressing the degradation of mortars, it is important to consider that the use of mortars with new specifications and formulations is becoming increasingly common. Currently, new formulations of rendering mortars, especially those incorporating waste or partially replacing cement, require a detailed understanding of the material to ensure technical, economic, and environmental suitability. Several studies have analyzed the properties of mortars made with waste from different origins (Gao et al., 2022; Garg and Shivastava, 2023; Abadel et al., 2023; Kazmierczak et al., 2020; Ramezanianpour and Moeini, 2018; Trigo et al., 2021; Pederneiras et al., 2021; Marvila et al., 2020).

In this context, the study of sustainable development has become a major concern in all areas of engineering, particularly in the construction field. To evaluate the entire life cycle of a building, a complete approach is necessary, from the choice of materials that generate fewer manufacturing impacts to the assessment of the building component's durability throughout its useful life and its possibility of more suitable final disposal or reinsertion into the production chain (Lunardi et al., 2024).

In addition to deterioration caused by natural aging, usage conditions and external factors such as solar radiation, water, wind, exposure to pollutants, temperature variations, and colonization by microorganisms can accelerate degradation processes. This degradation causes pathological manifestations in the mortars, which need to be prevented (Flores-Colen et al., 2016). To understand the durability of rendering mortars, it is essential to investigate their properties through technological tests that evaluate performance against different types of environmental aggressions.

In this context, this study aims to perform a systematic bibliographic review of the main methods used in the evaluation of the durability of rendering mortars, identifying the parameters that influence their behavior over time. Based on a critical analysis of the literature, it seeks to highlight the existing gap regarding the standardization of experimental procedures and the practical application of the results obtained in the formulation of rendering mortars.

# 2. RESEARCH METHODOLOGY

A systematic literature review was developed to identify works relevant to the study topic, aiming to evaluate the research problem related to the durability of rendering mortars. The systematic review was based on the Methodi Ordinatio multicriteria methodology, proposed by Pagani, Kovaleski, and Resende (2015), which classifies scientific articles considering three aspects: impact factor, number of citations, and year of publication. From these three variables, it is possible to generate an index called "InOrdinatio," which indicates the scientific relevance of the articles

that make up the portfolio, allowing for their classification. To establish this index, the method is composed of the steps described below.

The selected databases were Science Direct, Web of Science (WoS), Scopus, and Scielo. The choice of databases was based on the large amount of literature relevant to the research topic found in these sources. The search period considered was from January 2018 to December 2023. This stage corresponds to an initial and exploratory search on the proposed theme, with the objective of identifying publications related to durability in rendering mortars. To this end, the keywords "Durability," "Coating mortar," and "Rendering mortar" were used. The search was performed in the title field of the consulted databases. After defining the databases, the time, and the keywords, the final search for works was conducted, which resulted in a total of 323 scientific articles. Table 1 shows the results obtained from this research.

Table 1. Articles obtained in each database

| **Keywords** | **Database** | | | | **Total** |
|---|---|---|---|---|---|
| | Science Direct | Web of Science | Scopus | Scielo | |
| Durability AND Coating mortar | 117 | 24 | 17 | 2 | 323 |
| Durability AND Rendering mortar | 111 | 29 | 19 | 2 | |

The filtering procedure was performed to harmonize the results obtained from the databases, which were analyzed individually using the following filters: elimination of duplicate articles across databases; exclusion of articles belonging to books, book chapters, or conferences; and removal of articles with topics outside the scope of this research, identified by reading the titles and abstracts. All documents were uploaded to the Mendeley management software. These exclusions, detailed in Table 2, were conducted to ensure that the systematic review identified only articles addressing durability in rendering mortars

Table 2. Filtering procedures for article selection

| **Filtering Procedures** | **Selected Articles** | **Excluded Articles** | **(%)** |
|---|---|---|---|
| Gross total of articles | 323 | | 100 |
| Book chapters / Conference papers | | 34 | 10.5 |
| Article duplicates | | 48 | 14.9 |
| Articles excluded after title reading | | 213 | 65.9 |
| Articles excluded after abstract reading | | 12 | 3.7 |
| Total discarded articles | | 307 | 95.0 |
| Total selected articles | | 16 | 5.0 |

Through the filtering procedure, based on the InOrdinatio equation, 16 articles remained to compose the scope of the research. The exclusions were made after a detailed analysis of the articles, discarding those that did not address the durability of rendering mortars, such as concrete, asphalts, adhesive mortars, and masonry laying mortars. An analysis of the publication year and the number of citations was conducted. The data was obtained manually through the Scopus Source Browse. The subsequent step was to classify the scientific articles using the InOrdinatio equation (1).

$$\text{InOrdinatio} = \frac{\text{Fi}}{1000} + \alpha \times (10 - (\text{Research year} - \text{Publication year})) + \sum \text{Ci} \quad (1)$$

Where:
Fi = journal impact factor.
α = relevance coefficient of the research year (1 a 10).
Ci = number of article citations.

Finally, the article ranking was obtained using the InOrdinatio index, along with the identification of parameters, in which 16 articles were classified from the highest to the lowest Ordinatio index using an alpha value equal to 10. The alpha value of 10 represents that the publication year of the article is a relevant factor for the research (Pagani et al., 2015), however, as equation (1) indicates, the journal's impact factor and the number of article citations are factors that significantly impact the article's classification.
Based on the InOrdinatio ranking of the articles, it was possible to establish a hierarchy of importance. This allowed for thorough analysis, as well as the standardization of tests that measure durability in rendering mortars. Additionally, mitigating factors for pathological manifestations were considered, which allowed for the identification of the most relevant aspects of the proposed theme

## 3. RESULTS AND DISCUSSION

### 3.1 Bibliometric analysis of the selected articles

For the prioritization and classification of the selected articles, the InOrdinatio index, derived from the Methodi Ordinatio method, was used. This index considers criteria such as the journal's impact factor, the number of article citations, and the year of publication, allowing for the establishment of a relevance ranking among the analyzed studies. The values obtained for each article are presented in the InOrdinatio column of Table 3.

Table 3. Ranking of articles by the InOrdinatio index

| Ranking | Article Title | Nº of citations | InOrdinatio | Year |
|---|---|---|---|---|
| 1st | Mechanical and durability properties of alkali activated slag coating mortars containing nanosilica and silica fume | 114 | 184.011 | 2018 |
| 2nd | Effect of pores on the mechanical and durability properties on high strength recycled fine aggregate mortar | 23 | 103.005 | 2022 |
| 3rd | Effect of recycled powders on the mechanical properties and durability of fully recycled fiber-reinforced mortar | 21 | 101.008 | 2022 |
| 4th | Non-hydrophobized perlite renders for repair and thermal insulation purposes: Influence of different binders on their properties and durability | 37 | 97.009 | 2020 |

| | | | | |
|---|---|---|---|---|
| 5th | Mechanical, durability and sustainability assessment of rendering mortar with synergistic utilization of recycled concrete and ceramic insulator fine aggregates | 5 | 95.010 | 2023 |
| 6th | Rendering mortars with crumb rubber: Mechanical strength, thermal and fire properties and durability behaviour | 31 | 91.009 | 2020 |
| 7th | Potential Use of Rendering Mortar Waste Powder as a Cement Replacement Material: Fresh, Mechanical, Durability and Microstructural Properties | 1 | 91.006 | 2023 |
| 8th | Chalcedonite aggregate in lime mortars: Assessment of strength, microstructure, and durability | 0 | 90.003 | 2023 |
| 9th | Lightweight pumice mortars for repair of historic buildings –Assessment of physical parameters, engineering properties and durability | 0 | 90.001 | 2023 |
| 10th | Durability-related properties of early-age and long-term resistant laboratory elaborated polymer-based repair mortars | 19 | 79.009 | 2020 |
| 11th | Incorporation of Natural Fibres in Rendering Mortars for the Durability of Walls | 3 | 73.003 | 2021 |
| 12th | Performance and Durability of Rendering and Basecoat Mortars for ETICS with CSA and Portland Cement. | 3 | 73.001 | 2021 |
| 13th | The effects of mixture's components on the mechanical properties and durability indicators of mixed mortar using simplex network method | 8 | 68.009 | 2020 |
| 14th | Laboratory-scale Method to Assess the Durability of Rendering Mortar and Concrete Adhesion Systems | 5 | 65.009 | 2020 |
| 15th | Efficiency and durability of g-C3N4-based coatings applied on mortar under peeling and washing trials | 5 | 65,003 | 2019 |
| 16th | Durability of coating mortars containing açaí fibers | 4 | 64.005 | 2020 |

Where: Higher values of the InOrdinatio index indicate greater relevance of the article for scientific research.

Based on the results obtained, 16 relevant articles were identified within the period analyzed. It is important to consider that different aspects related to durability may be investigated in specific studies that are not always explicitly described with the term "durability" in the title. Thus, the quantity of identified works may be related to the keyword combinations employed in the search strategy. Consequently, the obtained sample represents the segment defined by the adopted methodological criteria, which does not necessarily imply the totality of scientific production on the subject, but rather the portion of the literature identified from the established search strategy. Using the VOSviewer tool, a co-occurrence map was generated, as shown in Figure 1.

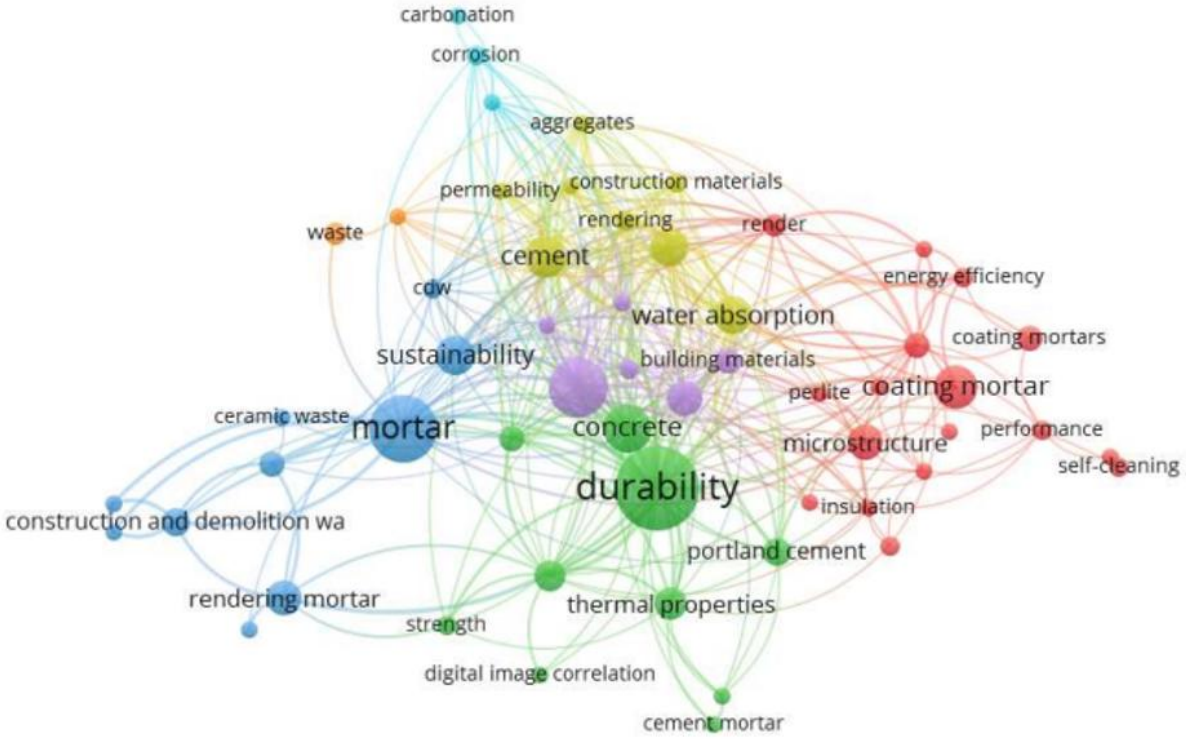


Figure 1. Bibliometric map created in VOSviewer based on Keywords.

The study of keyword recurrence in published literature can be very useful for identifying research trends in specific topics related to the durability of rendering mortars. This map resulted in a total of five clusters, four of which are highlighted in different colors, containing the words "durability," "mortar," "coating mortar," and "cement". These words stood out as the most recurrent in the titles and abstracts of the analyzed publications. This analysis allowed for a deeper investigation into these keywords and an understanding of the connection between the titles. Regarding the temporal analysis, the number of publications per year can be observed in Figure 2.

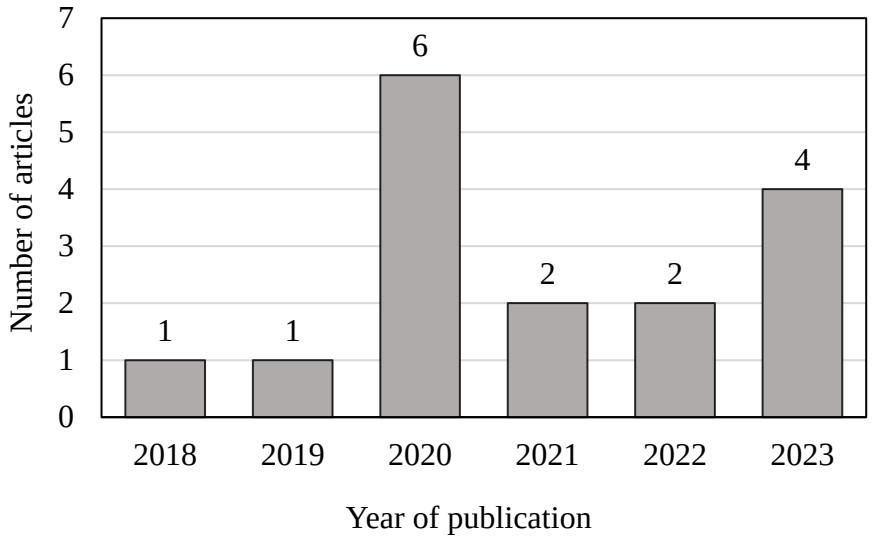


Figure 2. Number of articles published between 2018 and 2023, by year.

As observed in Figure 2, the year 2020 presented the highest number of publications, accounting for 37.5% of the articles in the portfolio. The topic has sparked growing scientific interest, with the last four years accounting for 87.5% of the portfolio's articles. Although it is not a recent theme, it remains the subject of relevant research due to concerns regarding the long-term performance of rendering mortars, which becomes evident when alternative materials incorporated into these mortars are tested. The geographical distribution of the publications is shown in Figure 3.

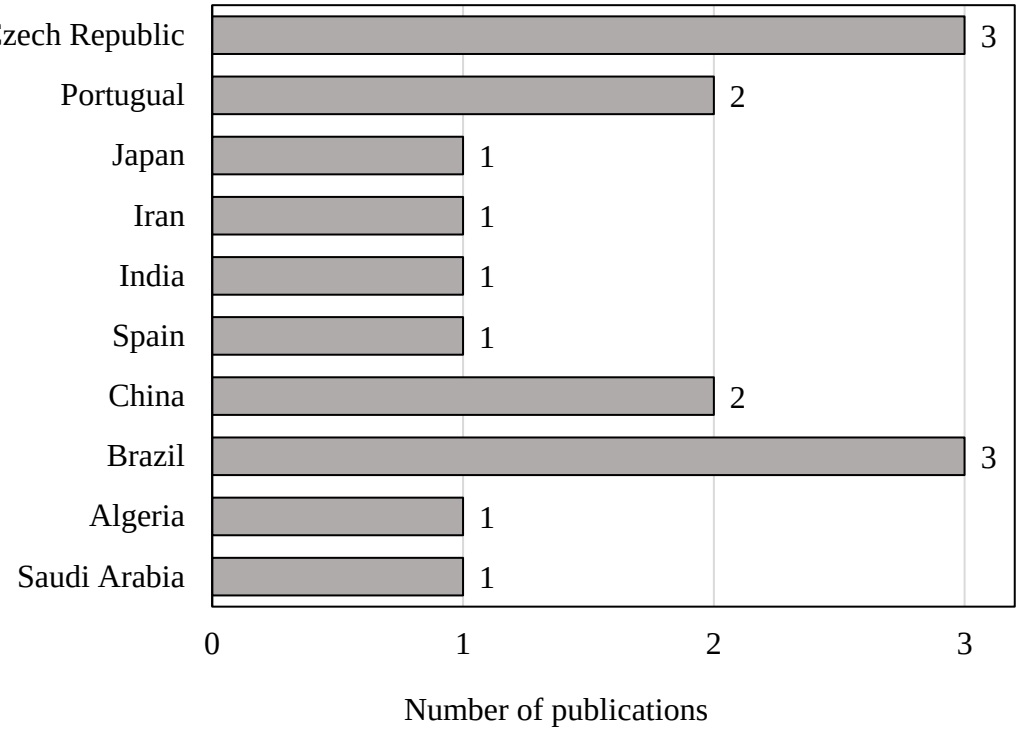


Figure 3. Articles per country

It is observed that Brazil and the Czech Republic present the highest number of publications related to the theme of durability in rendering mortars among the studies identified in this research. In the Brazilian case, the presence of studies in this area may be associated with the widespread use of construction systems based on masonry and mortar coatings. However, based on the data obtained, it is not possible to conclusively establish the factors that explain this distribution of publications.

### 3.2 Methodological procedures of the tests in the selected articles

From the analysis of the articles, it was possible to examine the mechanical properties and the methods used to evaluate the durability of rendering mortars. The tests conducted by the authors in the research can be observed in Figures 4 and 5 and are highlighted by their frequency of occurrence in the selected articles.

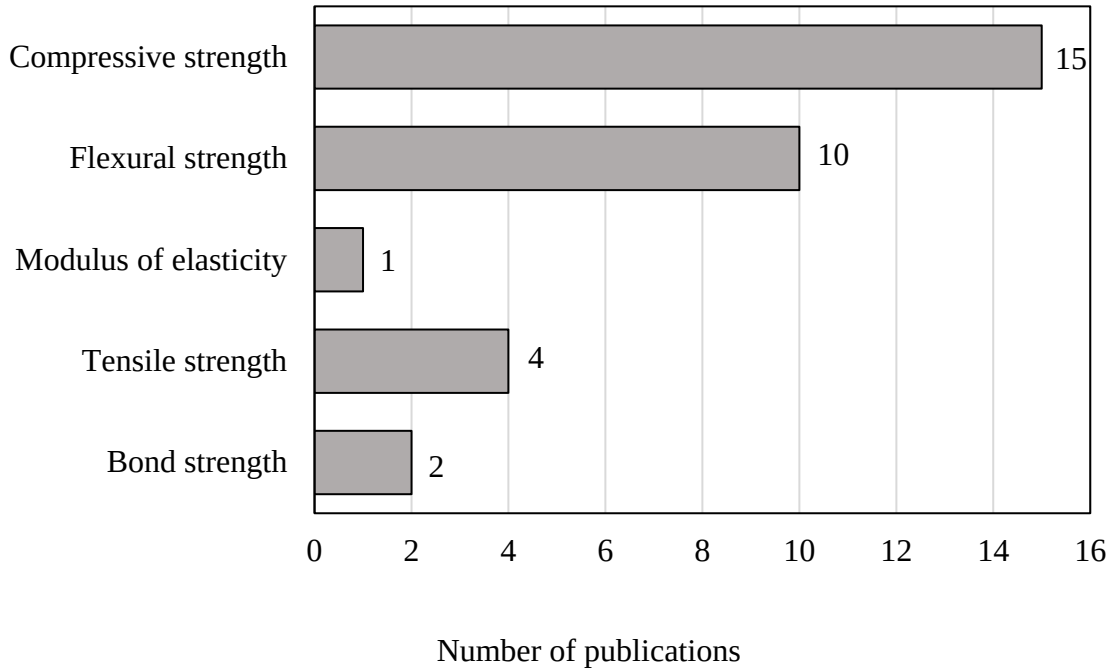


Figure 4. Mechanical properties analyzed in the selected papers.

Based on Figure 4, the analysis highlights that the mechanical properties most frequently evaluated in mortars are compressive strength, followed by flexural strength, emphasizing flexibility and ductility as determining factors for the analyzed mortars. Tensile strength is addressed in only 4 of the studies.

Compressive strength is considered a primary property of rendering mortars, according to the frequency reported in the selected articles. However, its representativeness in full-scale applications is limited, as mortar exhibits distinct behavior when confined within masonry systems. Furthermore, it can be observed that increasing the compressive strength of the mortar has a limited effect on increasing the compressive strength of the masonry system (Cunha et al.; 2001; Steil et al., 2001).

The properties of modulus of elasticity and bond strength were found less frequently in the analyzed articles, although they are determining factors for rendering mortars. The mechanical behavior of the mortar depends on its response (deformation) to applied loads, which can cause cracking if the stiffness is excessive (Aragón et al., 2019).

The methods for evaluating the durability of rendering mortars are shown in Figure 5.

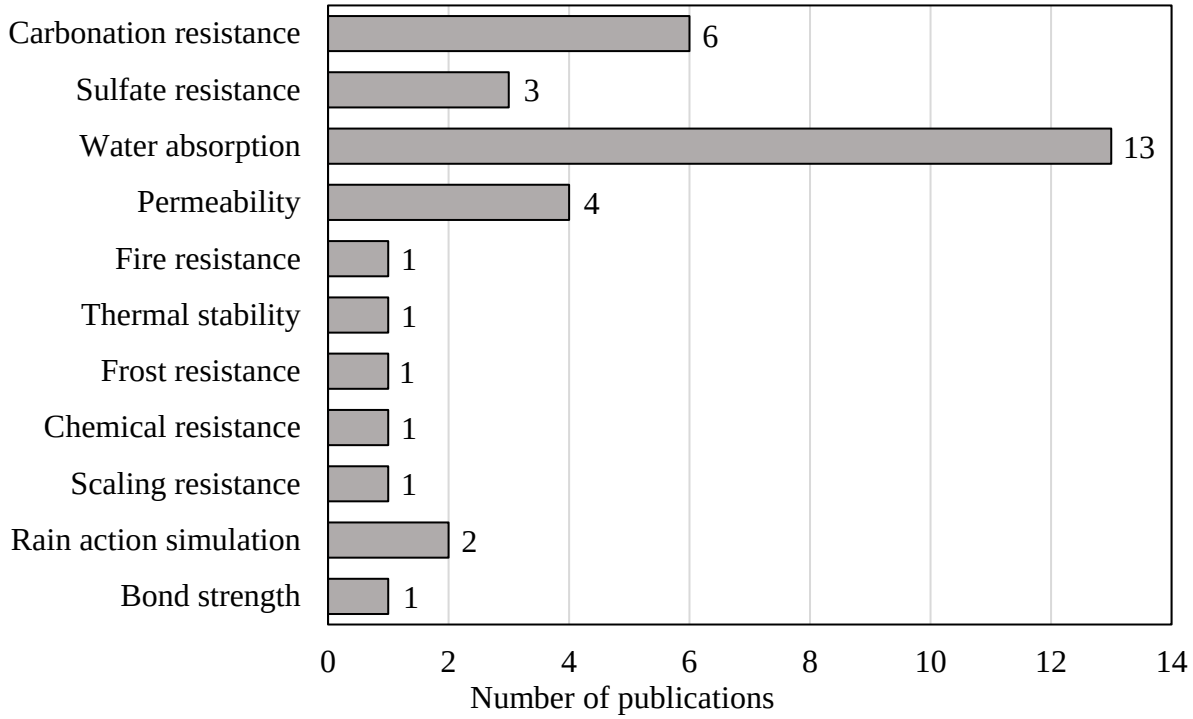


Figure 5. Durability evaluations analyzed in the ranked articles.

Observing Figure 4, it is possible to note that the water absorption test is common to almost all articles, serving as an indicator of durability and resistance to degradation by moisture. Baptista Junior et al. (2024) focused on the study of methodologies applied to mortar durability and obtained results like those of this research. A key factor in the degradation of cementitious matrix materials is the presence of water, which can act as a transport agent for aggressive ions and be responsible for deleterious chemical processes in porous solids (Baptista Junior et al., 2024). Water is typically involved in mortar deterioration mechanisms and governs its rate of decay (Lunardi et al., 2024). The carbonation resistance test is also frequently evaluated, indicating the durability of rendering mortars in environments exposed to $CO_2$ In cementitious and mixed rendering mortars, the formation of carbonates can yield significant advantages. This process causes a clogging effect (pore-blocking) in the pores, increasing the compressive strength of the mortars. Furthermore, carbonate formation acts as a method for sequestering $CO_2$ present in the air. The long-term reduction in mortar permeability decreases the possibility of air and water ingress and egress (Mansour et al., 2022). Thus, the more carbonated the mortars are, the less susceptible they become to other pathological manifestations associated with porosity and permeability. Therefore, for rendering mortars, the consequent clogging of surface pores can benefit mechanical performance and durability. Given this context, recurrent studies on carbonation resistance as an evaluation of rendering mortar durability are justified.Some articles analyze sulfate resistance and permeability tests, simulating different environmental conditions. The variability in durability tests reflects the diversity of mortar applications, highlighting the lack of consensus regarding the tests and standards that best describe the durability of rendering mortars, as they can be applied in many different contexts.It was found that the articles selected by the InOrdinatio method did not investigate the properties of rendering mortars in the fresh state, with the exception of the studies by Abadel et al. (2023) and Zizlavsky et al. (2023). These properties are important indicators for evaluating the workability of rendering mortars, directly influencing the ease of application and, consequently, impacting the properties in the hardened state and durability (Jesus et al., 2024). However, most articles did not address this analysis of fresh state Properties.

### 3.3 Contribution of alternative materials and sustainability to rendering mortar durability

The listed articles cover a variety of topics related to durability in rendering mortars, including the use of several types of materials in the production of these mortars, focusing on mechanical properties and different methods for evaluating durability, as shown in Figure 4. Furthermore, the selected articles address different aspects of durability in rendering mortars, highlighting the importance of the materials used and the application conditions to optimize their mechanical properties and wear resistance.

García et al. (2022) and Souza et al. (2020) analyzed the impact of porosity on the mechanical properties and durability of rendering mortars. García et al. (2020) employed fine aggregates in the mortar, concluding that higher porosity reduces compressive strength and durability, evidenced by higher water absorption and lower chloride resistance. In turn, Souza et al. (2020) explored how the combination and dosage of components in the mortar mix affect its mechanical strength and durability, using the simplex network method to identify the best proportions of materials that result in lower porosity and higher mechanical strength.

Yang et al. (2019) evaluated the effectiveness of coatings based on graphitic carbon nitride g-C3N4) in mortar, observing that this material provides better adhesion and resistance to wear and adverse environmental conditions, such as ultraviolet (UV) radiation and temperature variations. Zhang et al. (2020) focused on the durability of adhesion systems between mortars and concrete surfaces, highlighting the importance of mortar composition, surface preparation, and exposure to extreme environmental conditions to ensure durability and adhesion.

These studies offer a comprehensive view of how materials and dosage techniques influence the durability and performance of rendering mortars, emphasizing the need for an adequate evaluation in the choice of components and application conditions to ensure a longer service life and mechanical resistance.

Repair mortars are essential for the maintenance and conservation of buildings, especially historical ones, ensuring structural and aesthetic integrity over time; they must be compatible with historical materials and resist adverse environmental conditions. Developing more durable repair mortars significantly contributes to the preservation and longevity of constructions, maintaining their historical and functional value.

In this context, research by Zizlavsky et al. (2023), Pavlík et al. (2023), Aattache and Soltani (2020), and Vysvaril et al. (2020) explored methods to improve mortars used in repairs of historical surfaces. Zizlavsky et al. (2023) highlighted improvements in porosity, water absorption, flexural strength, and freeze-thaw cycles with chalcedony aggregates. Pavlík et al. (2023) observed greater compatibility with historical materials, flexibility, and adhesion when using pumice as a mortar component. Aattache and Soltani (2020) noted that the addition of polymers improved compressive strength, flexural strength, durability, and resistance to chemical agents. Finally, Vysvaril et al. (2020) concluded that cementitious binders increase mechanical properties and durability, while lime and gypsum offer better compatibility with historical materials. These studies emphasize the importance of lightweight aggregates, polymers, and the proper choice of binders for the functionality and durability of mortars in historical building restorations. Depending on the age of the building, it is common to observe cement-free mortars containing only lime, clay, and sand. For this reason, in these cases, the study of the materials that will compose the restoration mortar is of paramount importance, as there may be incompatibility with existing construction materials, leading to greater degradation if incorrect materials are applied.

The construction industry, especially in the production of building materials, causes significant environmental impacts. This scenario has driven the search for materials with better performance, especially in terms of durability and environmental and economic sustainability. Given this context, some analyzed articles employed an additional study of sustainability and highlighted its relevance in durability studies of rendering mortars.

Based on the studies by Gao et al. (2022) and Garg and Shivastava (2023), recent investigations have focused on construction and demolition waste (CDW) as potential resources to improve the mechanical properties, durability, and sustainability of rendering mortars. It was found that the incorporation of recycled aggregates, in adequate dosages, results in significant improvements in compressive and flexural strength, in addition to increasing the service life of the produced mortars. The optimization of the type and proportion of recycled aggregate are crucial factors for maximizing the performance of rendering mortars. Similarly, Abadel et al. (2023) explored the use of rendering mortar waste powder as a partial cement replacement, observing that, despite promoting waste recycling and reducing cement demand, there are limitations in the mechanical and durability properties of the resulting mortars. Therefore, optimizing the replacement ratio is essential to maximize the desired properties of rendering mortars while taking advantage of the environmental benefits associated with sustainability in construction resulting from the reuse of materials that would otherwise be discarded at the end of their life cycle.

Kazmierczak et al. (2020) examined the impact of adding crumb rubber on the mechanical and thermal properties, fire resistance, and durability of rendering mortars. The inclusion of rubber can significantly improve the thermal properties and fire resistance of the mortars, although with a reduction in mechanical properties. To optimize performance, it is crucial to evaluate the maximum levels of crumb rubber that can be incorporated without compromising the required properties. Given this, and considering the challenge of proper rubber waste disposal, the use of tire waste emerges as a promising alternative.

Research conducted by Ramezanianpour and Moeini (2018) and Trigo et al. (2021) established a correlation between the improved properties of the produced rendering mortars and their contribution to environmental sustainability. Ramezanianpour and Moeini (2018) developed alkali-activated mortars with additions of nano-silica and silica fume, resulting in significant improvements in compressive strength through pore-filling and matrix densification, which provided lower water absorption. Additionally, an increase in the ductility of the mortars and the capacity to withstand tensile stresses was observed, along with improvements in carbonation resistance and chloride penetration, thus increasing durability and, consequently, the sustainability of these materials. Trigo et al. (2021) discussed the evaluation of the physical-mechanical and durability properties of mortars used in External Thermal Insulation Composite Systems (ETICS), incorporating calcium sulfoaluminate (CSA) cement. Compared to traditional Portland cement mortars, those with CSA presented enhanced properties while significantly reducing $CO_2$ emissions and the energy consumption associated with cement production. Optimizing the CSA ratio in the mixture proved crucial for achieving maximum performance in terms of mechanical properties and environmental sustainability, standing out as a more eco-efficient alternative in contemporary construction.

Pederneiras et al. (2021) and Marvila et al. (2020) investigated the incorporation of natural fibers in rendering mortars aiming to increase the durability of constructions. Pederneiras et al. studied the inclusion of fibers such as wool, coconut, and flax, at a ratio of 20% of the total mortar volume, evaluating various properties such as water absorption, drying rates, water permeability, bond strength, and shrinkage. The results demonstrated that the fibers reduce shrinkage and the modulus of elasticity of the mortars, minimizing susceptibility to cracking and improving durability over time. Marvila et al. (2020) evaluated açaí fibers, observing an increase in the tensile, flexural, and compressive strength of the mortars, as well as better performance in durability tests such as wear resistance and moisture and freeze-thaw cycles. The addition of açaí fibers also contributes to reducing cracking and delamination of the coatings, offering a sustainable solution by using a locally available agricultural byproduct, which promotes more eco-efficient practices in civil construction.

Finally, it is highlighted that Garg and Shivastava (2023) and Abadel et al. (2023) evaluated the

environmental profile of mortars produced with the addition of waste as aggregates and the partial replacement of the binder, respectively, employing the Life Cycle Assessment (LCA) methodology. In both studies, the results indicate a significant reduction in environmental impacts, especially in greenhouse gas emissions (kg $CO_2$ equivalente). The use of waste managed to reduce emissions by up to 26%. It is concluded, therefore, that the use of input previously treated as waste, but now classified as co-products or by-products and used in the composition of mortars, contributes to their performance and durability, besides suppressing the need for raw material extraction, applying sustainability effectively and relevantly.

Table 4 presents the incidence of standards identified in the selected articles, highlighting the frequency with which each was used and the main parameters evaluated in studies on the durability of rendering mortars.

Table 4. Technical standards used in the reviewed studies and parameters evaluated for rendering mortar durability.

| Standard | Property/Parameter | Frequency |
|---|---|---|
| ABNT NBR 13276:2016 | Consistency index | 1 |
| ABNT NBR 13277:2005 | Water retention | 1 |
| ABNT NBR 13278:2005 | Bulk density / Entrained air content | 2 |
| ABNT NBR 13279:2005 | Flexural strength | 2 |
| ABNT NBR 13279:2005 | Compressive strength | 2 |
| ABNT NBR 13280:2005 | Hardened state bulk density | 1 |
| ABNT NBR 13528:2019 | Bond strength | 1 |
| ABNT NBR 13554:1996 | Mass loss | 1 |
| ABNT NBR 15259:2005 | Water absorption by capillarity | 1 |
| ABNT NBR 15630:2008 | Ultrasonic pulse modulus of elasticity | 2 |
| ABNT NBR 5739:2018 | Compression test | 1 |
| ABNT NBR 9778:2009 | Water absorption by immersion | 4 |
| ABNT NBR 9779:2012 | Water absorption by capillary rise | 1 |
| ABNT NBR NM 47:2002 | Air content of fresh concrete | 1 |
| ASTM C 109 | Compressive strength of hydraulic cement mortars | 2 |
| ASTM C 1437 | Flow of hydraulic cement mortars | 2 |
| ASTM C 1556 | Apparent chloride diffusion coefficient of cementitious mixtures | 1 |
| ASTM C 177 | Thermal performance of insulation systems | 1 |
| ASTM C 267 | Chemical resistance of mortars | 1 |
| ASTM C 270-14 | Standard specification for unit masonry mortar | 1 |
| ASTM C 403 | Water absorption in mortars | 1 |
| ASTM C 597 | Ultrasonic pulse velocity | 1 |
| ASTM C 642 | Density, absorption, and voids | 1 |

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|---|---|---|
| ASTM C 876 | Corrosion of uncoated reinforcing steel | 1 |
| ASTM D 4541 | Pull-off strength of coatings | 1 |
| BS EN 480–5 | Capillary absorption | 1 |
| CSN 722452 | Frost resistance of mortar | 2 |
| EN 1015-10 | Bulk density | 4 |
| EN 1015-11 | Flexural strength | 6 |
| EN 1015-11 | Compressive strength | 1 |
| EN 1015-12 | Bond strength | 2 |
| EN 1015-18 | Water absorption by capillarity | 6 |
| EN 1015-18 | Water absorption coefficient | 1 |
| EN 1015-19 | Water vapor permeability | 1 |
| EN 1015-21 | Compatibility of mortar with substrate | 1 |
| EN 1015-3 | Consistência flow (Spread diameter) | 2 |
| EN 1015-6 | Bulk density | 2 |
| EN 1015-7 | Entrained air content | 1 |
| EN 1015-9 | Determination of workable life | 1 |
| EN 12004 | Adhesives for ceramic tiles | 2 |
| EN 12370 | Resistance to crystallization | 1 |
| EN 12371 | Freeze-thaw resistance | 1 |
| EN 12504-4 | Determination of ultrasonic pulse velocity | 1 |
| EN 1348 | Tensile adhesion strength of tile adhesives | 2 |
| EN 13755 | 24 hours water absorption | 1 |
| EN 13755 | Thermal shock | 2 |
| EN 1504-3 | Protection and repair systems | 1 |
| EN 196-1 | Determination of cement strength | 3 |
| EN 196-3 | Determination of setting times and soundness | 1 |
| EN 197-1 | Cement specifications | 1 |
| EN 459-2 | Water retention | 1 |
| EN 83980 | Water absorption, density, and porosity of concrete | 1 |
| EN 998-1 | Specification for rendering and plastering mortar | 1 |
| EN ISO 1182 | Non-combustibility test for building products | 1 |
| EN ISO 11925-2 | Reaction to fire tests | 1 |
| EN ISO 12571 | Hygrothermal performance of building materials | 1 |
| EN ISO 12572 | Water vapor resistance factor | 2 |
| EN ISO 12572 | Water vapor permeability | 1 |

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| EN ISO 14040 | Life cycle assessment (LCA) | 1 |
| GB/T 17,671 | Method of testing strength of cement mortar | 1 |
| GB/T 50082 | Long-term performance and durability | 1 |
| Helium pycnometry | Matrix density | 1 |
| JGJ/T70 | Basic properties of construction mortar | 2 |
| JSCE | Toughness and residual strength | 1 |
| MIP | Pore size distribution | 3 |
| NF B 10-511 | Deformation modulus | 1 |
| NordTest Build 492 | Chloride migration | 1 |
| Pycnometry/gravimetry | Total open porosity | 2 |
| Transient impulse technique | Thermal conductivity | 1 |

The analysis of the incidence of standards in the selected articles highlights a wide variety of methods employed to evaluate the durability of rendering mortars. The standards EN 1015-11 (flexural strength) and EN 1015-18 (water absorption by capillarity) were the most recurrent, appearing six times each, which reinforces the importance of these parameters in characterizing the mechanical and hygrothermal performance of rendering mortars. Among the Brazilian standards, ABNT NBR 9778:2009 (water absorption by immersion) stands out, along with others such as ABNT NBR 13279:2005 and ABNT NBR 15630:2008, which address strength and modulus of elasticity. These results indicate that national and international research converge on the concern for properties directly associated with durability and behavior regarding moisture.

A predominance of EN and ABNT standards is also observed, reflecting the leading role of Europe and Brazil in the scientific production on this topic. ASTM and CSN standards appear less frequently but demonstrate the effort to incorporate microstructural approaches and specificities from different climatic and construction contexts. In general, the normative diversity identified reveals both the internationalization of research and the need for harmonization of testing methods, in order to allow more consistent comparisons between studies conducted in different regions and environmental conditions.

## 4. CRITICAL ANALYSIS OF THE MAIN CONTRIBUTIONS TO RENDERING MORTAR DURABILITY

The investigated studies frequently highlight mechanical properties such as compressive and flexural strength. Compressive strength, although widely studied, presents limitations in representing the actual performance of rendering mortar when applied to masonry construction systems. On the other hand, properties such as the modulus of elasticity and bond strength, which are fundamental for evaluating deformation and cracking, were less explored, which may compromise a more comprehensive assessment of the mechanical behavior of rendering mortars (Colombo et al., 2019).Regarding durability, it was observed that tests such as water absorption and carbonation resistance are the most recurrent, reflecting their relevance as indicators of mortar susceptibility to degradation processes. The lack of standardization in testing methods hinders comparisons between studies, signaling the need for more consistent normative protocols for evaluating the durability of rendering mortars.The use of alternative materials aiming at

sustainability and performance enhancement is a widely discussed topic in the research found. The incorporation of construction and demolition waste (CDW), crumb rubber, and fibers has shown promise, not only due to improvements in mechanical properties but also because of a significant reduction in environmental impacts, such as decreased demand for natural resources and lower $CO_2$ emissions (Pederneiras et al., 2021; Marvila et al., 2020; Kazmierczak et al., 2020; Gao et al., 2022; Garg and Shivastava, 2023). Synergistic combinations between additives and waste have the potential to optimize performance, although they still require systematic investigations into dosages, compatibility, and long-term behavior. The incorporation of environmental criteria into mortar development, through tools such as Life Cycle Assessment (LCA), reinforces the strategic role of durability within the context of sustainable construction. The partial replacement of cement and aggregates with industrial and agricultural by-products contributes not only to reducing environmental impact but also to consolidating practices based on the circular economy. Such strategies point toward the need for more integrated approaches that reconcile technical performance, longevity, and environmental responsibility (Garg and Shivastava, 2023; Abadel et al., 2023).

## 5. CONCLUSIONS

This study aimed to develop a systematic review on the theme of "Durability in rendering mortars" to understand the developments in this field over recent years. Based on the information gathered, the following conclusions can be highlighted:

Regarding the performance of rendering mortars, mechanical properties, especially compressive strength are widely investigated. The limitation of focusing predominantly on this property restricts the assessment of the actual performance of mortars within construction systems. Properties such as modulus of elasticity and bond strength, which are essential for predicting deformation and cracking, remain under-explored, indicating the need for more comprehensive research that considers the full set of mechanical parameters.

Concerning durability, a predominance of tests focused on water absorption and carbonation resistance is observed, highlighting the relevance of these parameters in evaluating mortar performance against degradation processes. However, the lack of standardization in testing methods still represents a challenge for comparing different studies.

The move toward sustainability has driven the use of alternative materials, which demonstrate the potential to improve mechanical performance and reduce environmental impacts. The integration of environmental criteria through tools such as Life Cycle Assessment (LCA) reinforces the importance of understanding durability not only as a technical characteristic but also as an essential component of sustainability in the construction industry. Thus, mortar development must be based on multidisciplinary approaches capable of balancing mechanical performance, durability, and environmental responsibility, promoting more efficient and sustainable materials for the construction sector.

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