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

ISSN 2318-8472, v. 13, n. 89, 2025

Methodologies for reconstruction of the binder aggregate ratio of historical mortars: a systematic literature review

Micael Justino
Mestrando, UPE, Brasil
micael.justino@upe.br
https://orcid.org/0000-0001-9798-5915

Yeda Póvoas
Professora Doutora, UPE, Brasil
yvp@poli.br
https://orcid.org/0000-0003-1907-415X

Raphael Britto
Mestrando, UPE, Brasil
rbml@poli.br
https://orcid.org/0000-0003-3172-6878

Submissão: 30/06/2025
Aceite: 20/08/2025
JUSTINO , Micael; PÓVOAS, Yeda; BRITTO, Raphael. Metodologias para reconstrução do traço de argamassas de edificações antigas: uma revisão sistemática da literatura. **Revista Nacional de Gerenciamento de Cidades**, *[S. l.]*, v. 13, n. 89, 2025. DOI: 10.17271/23188472138920256154. Disponível em: https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/6154.

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

ISSN 2318-8472, v. 13, n. 89, 2025

Metodologias para reconstrução do traço de argamassas de edificações antigas: uma revisão sistemática da literatura

RESUMO

Objetivo - realizar um levantamento de alcance global a respeito dos métodos utilizados para caracterizar a composição estrutural das argamassas de edificações históricas, bem como os tipos de análises necessárias para esse fim.

Metodologia - o seguinte trabalho seguiu a metodologia de uma revisão sistemática. As bases foram selecionadas, Scopus, Science direct e Engeneering village com intuito de abranger publicações tanto de áreas especificas como do geral.

Originalidade/relevância – o levantamento das pesquisas, proposto por esse trabalho, visa trazer clareza quanto aos métodos mais eficazes na obtenção do traço de argamassas antigas, contribuindo nas restaurações de edifícios históricos com uma certeza maior em relação a compatibilidade das argamassas.

Resultados – os resultados apontam para os métodos de ataque ácido, DRX e TGA como os mais utilizados por apresentarem claramente a composição do material. Outro resultado importante está na identificação dos traços mais comuns de argamassas históricas sendo 1:3, 1:1,5 e 1:2.

Contribuições teóricas/metodológicas – por indicar os métodos mais eficientes na caracterização de argamassas antigas, os resultados dessa pesquisa podem trazer segurança quanto a elaboração de parâmetros usados na restauração do patrimônio histórico.

Contribuições sociais e ambientais – o restauro de edificações antigas requer minucioso cuidado devido a possuíeis incompatibilidade entre os materiais e por isso a busca pelo melhor método de caracterizar as argamassas pode ser custosa e por vezes demorada. Os resultados dessa pesquisa podem impactar essa busca economizando recursos e tempo, uma vez que possui alcance global e abrange uma extensa faixa temporal.

PALAVRAS-CHAVE: Restauração. Argamassas históricas. Reconstrução de traço.

Methodologies for reconstruction of the binder aggregate ratio of historical mortars: a systematic literature review

ABSTRACT

Objective –To conduct a global scope review regarding the methods used to characterize the structural composition of mortars in historical buildings, as well as the types of analysis necessary for this purpose.

Methodology – This work followed the methodology of a systematic review. The Scopus, Science Direct, and Engineering Village databases were selected to cover publications from both specific and general areas.

Originality/Relevance – The survey of research proposed by this work aims to bring clarity to the most effective methods for obtaining the composition of old mortars, contributing to the restoration of historical buildings with greater certainty regarding the compatibility of mortars.

Results – The results point to acid attack, XRD, and TGA methods as the most used because they clearly present the material's composition. Another important result is the identification of the most common compositions of historical mortars, being 1:3, 1:1.5, and 1:2.

Theoretical/Methodological Contributions – By indicating the most efficient methods for characterizing ancient mortars, the results of this research can bring security regarding the elaboration of parameters used in the restoration of historical heritage.

Social and Environmental Contributions –The restoration of ancient buildings requires meticulous care due to possible incompatibility between materials, and therefore the search for the best method to characterize mortars can be costly and time-consuming. The results of this research can impact this search by saving resources and time, given its global scope and extensive time frame.

KEYWORDS: Restoration. Historical mortars. Reconstruction of the binder aggregate ratio.

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

ISSN 2318-8472, v. 13, n. 89, 2025

Metodologías para determinar la proporción ligante árido en morteros históricos: una revisión sistemática de la literatura

RESUMEN

Objetivo – Realizar un levantamiento de alcance global sobre los métodos utilizados para caracterizar la composición estructural de las argamasas de edificaciones históricas, así como los tipos de análisis necesarios para este fin.

Metodología – El siguiente trabajo siguió la metodología de una revisión sistemática. Las bases seleccionadas fueron Scopus, Science Direct y Engineering Village con el fin de abarcar publicaciones tanto de áreas específicas como generales.

Originalidad/Relevancia – el levantamiento de las investigaciones propuesto por este trabajo tiene como objetivo traer claridad sobre los métodos más eficaces para obtener la composición de argamasas antiguas, contribuyendo a las restauraciones de edificios históricos con una mayor certeza en relación con la compatibilidad de las argamasas.

Resultados – los resultados apuntan a los métodos de ataque ácido, DRX y TGA como los más utilizados por presentar claramente la composición del material. Otro resultado importante es la identificación de las composiciones más comunes de argamasas históricas siendo 1:3, 1:1,5 y 1:2.

Contribuciones Teóricas/Metodológicas – al indicar los métodos más eficientes en la caracterización de argamasas antiguas, los resultados de esta investigación pueden brindar seguridad en cuanto a la elaboración de parámetros utilizados en la restauración del patrimonio histórico.

Contribuciones Sociales y Ambientales – la restauración de edificaciones antiguas requiere un cuidado minucioso debido a posibles incompatibilidades entre los materiales, y por lo tanto la búsqueda del mejor método para caracterizar las argamasas puede ser costosa y a veces demorada. Los resultados de esta investigación pueden impactar en esta búsqueda ahorrando recursos y tiempo, ya que tiene un alcance global y abarca una amplia franja temporal.

PALABRAS CLAVE: Restauración. Morteros históricos. Determinación de la proporción ligante árido

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

ISSN 2318-8472, v. 13, n. 89, 2025

1. INTRODUCTION

Resilient to time and cultural change, historical buildings require constant interventions and repairs. According to Loureiro (2020c), plaster mortars—because they are more exposed to weathering and mechanical impacts—represent the portion of the structure most in need of maintenance. Affonso and Azambuja (2024) emphasize the importance of rendering mortars in the overall performance of buildings and highlight their significant consumption in traditional Brazilian constructions. Xu (2018) notes that these mortars are essentially composed of a mixture of inert materials and binders with cementitious properties, such as lime, which has been used for thousands of years. However, Borsoi (2019) draws attention to the lack of standardization among these compounds, noting that mortar composition may vary according to its intended function.

> With the improvement of human habitation standards, the performance requirements of mortars have inevitably increased. Consequently, researchers have developed organic–inorganic composite mortars with distinct functions and properties (Lou, 2023, p. 1).

Despite the high heterogeneity in mortar composition, Silva *et al.* (2024) affirm that restoration mortars are indispensable for the conservation of historical heritage, as they are formulated to meet specific aesthetic and functional compatibility requirements between old and new materials. According to Loureiro (2020b), the use of Portland cement, for instance, can lead to cracks, staining, and even efflorescence. Pacheco-Torgal (2012) and Barbero-Barrera *et al.* (2014) point out that such effects occur because Portland cement exhibits low permeability, a high modulus of elasticity, and the presence of salts—characteristics incompatible with lime-based mortars.

Another important aspect concerns the cultural and historical value of cities, which must be preserved for future generations. Therefore, any modification that might compromise the authenticity of a building should be avoided.

To achieve this compatibility, the restoration of historical structures demands a scientific and multidisciplinary approach that encompasses both structural and historical perspectives. Yildizlar (2020) emphasizes that, for safe and technically sound restoration, it is essential to determine the properties of the materials used in conservation work, their compatibility with existing materials, and their long-term effects.

> In restoration projects, mortars and renders must be designed and applied to match those used in the original construction, which requires a deep understanding not only of the nature of the binder and aggregates but also of the formulation and microstructure of the mortar. (Yildizlar, 2020, p. 3)

Given these considerations, Qian (2022) stresses the need for analyses that determine the composition of materials in historical buildings as an initial step for restoration or rehabilitation, since these materials have a significant impact on the mechanical and physical characteristics of structures.

ISSN 2318-8472, v. 13, n. 89, 2025

The present study aims to conduct a comprehensive global review of the methods used to determine the mass proportions of mortars in historical buildings, as well as the types of analyses required for this purpose. This investigation seeks to shed light on the evolution of these methodologies over time, contributing to the identification of possible gaps in a process that has

2. METHODOLOGY

A systematic literature review is an organized and reproducible method used to identify, evaluate, and summarize the body of knowledge produced on a specific topic (Fink, 2019). The present study followed the methodological guidelines of the PRISMA framework—*Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (Liberati *et al.*, 2009). The databases were selected with the intent of encompassing both specialized and general publications.

To ensure a broad scope, Scopus was chosen because, according to Elsevier, it covers more than 240 disciplines. ScienceDirect was also included, as it provides access to over one million open-access articles. To target a more specialized range of publications in engineering, architecture, and construction, the Engineering Village database was added.

For defining the search strings, the PICo strategy was applied, which aims to extract from the research questions their essential elements: *Population (P)*, *Interest (I)*, and *Context (Co)*. Table 1 presents the components of the PICo framework. The search strings used were: "architecture OR construction AND heritage OR 'historic masonry' OR 'historic mortars' AND 'characterization AND mortars'," adapted as necessary for each database. The Boolean operator OR was used to connect terms within the same category or synonyms, while AND was used to combine different categories. Searches were restricted to the title and abstract fields to ensure greater precision in retrieving relevant studies.

Table 1- PICo Framework Elements of the Study

Critérios	Descrição
Population	Arquitetura, Construção, Reabilitação, Reforma
Interest	Historical buildings, Historical conservation, Historical mortars, Historical masonry
Context	Characterization, Characterization and analysis of mortars, Characterization and analysis of historical mortars, Microscopy of historical mortars

Source: The authors.

The selected keywords were intended to direct the review toward studies presenting methodologies capable of reconstructing the mix proportions of mortars that compose the structures of historical buildings. Accordingly, Table 2 lists the guiding research questions addressed in this study.

ISSN 2318-8472, v. 13, n. 89, 2025

Table 2 – Research Questions

Reference	Research Question	Rationale
Q 1	What methodologies are used for characterization?	Identifying the methods applied allows for understanding which ones provide the most accurate analytical results.
Q 2	What types of mix proportions were found?	Understanding whether there are common proportions among historical mortar mixes.
Q 3	Are there methodological differences over time?	Determining whether techniques have been added or removed throughout the years.

Fonte: Os autores

3. RESULTS AND DISCUSSION

3.1 DATABASE FILTERS

Within the databases themselves, the following filters were applied, in this order: limitation to the subject areas *Engineering, Materials Science, Earth and Planetary Science, Environmental Science, Computer Science, Physics, Chemistry, Energy, Chemical Engineering,* and *Multidisciplinary*; limitation to documents written in *English, Spanish, Portuguese,* and *Italian*; and limitation to *articles* and *conference papers* only. After applying these filters offered by each platform, the number of remaining studies was reduced to 557 articles in Scopus, 712 in Engineering Village, and 507 in ScienceDirect. Table 3 presents the total number of articles retrieved from each database.

Table 3- Resultado da pesquisa nas bases de dados

Database	Search Results
Scopus	685
Engeneering village	768
Web of science	625

Source: Authors.

3.2 FILTROS PESSOAIS

A total of 2,078 articles remained after unifying the search results from all databases. The next step involved applying manual analytical filters, including: removal of duplicate titles; removal of duplicate DOIs; and exclusion by title—specifically discarding studies that mentioned mortars without using keywords such as *Restoration, Chemometric, Investigation, Analysis, Characterization, Assessment, Detection,* or *Estimation*. After these steps, 122 articles remained for abstract screening.

Regarding the exclusion criteria based on abstracts, studies that did not propose any form of mortar analysis—particularly those not addressing the chemical, mineralogical, or microscopic composition—were excluded, as well as those that did not present the mixing proportions as a result. At the end of this stage, 47 articles remained for full reading and analysis.

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

ISSN 2318-8472, v. 13, n. 89, 2025

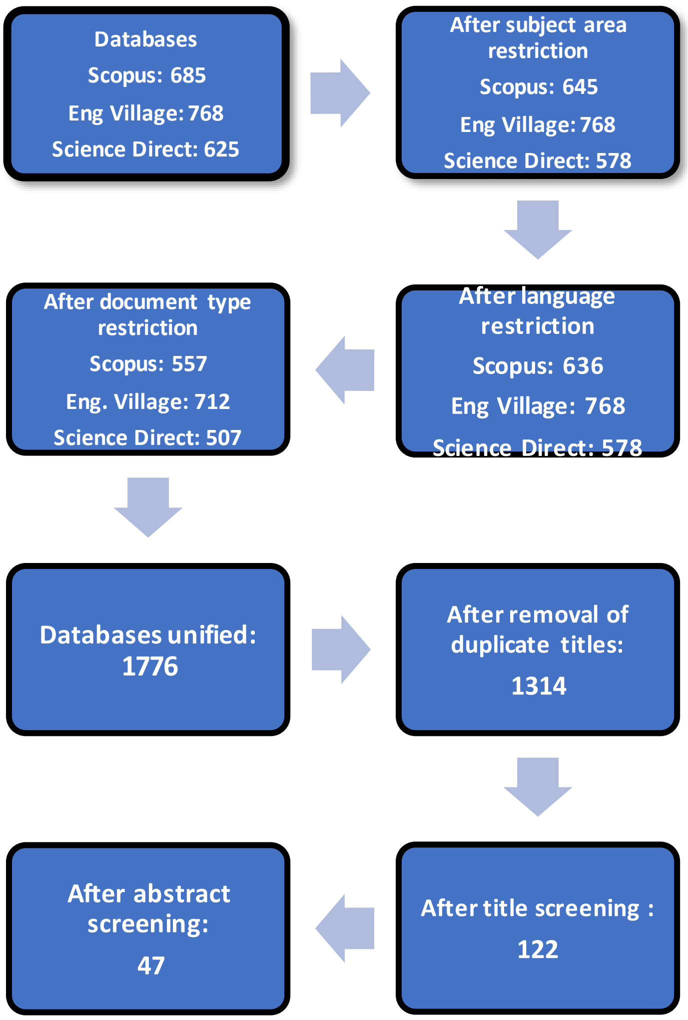
Table 4 presents the criteria used to select titles and articles, based on the combination of the terms *mortar* or *historical mortar* with the selected keywords. Figure 1 shows the flowchart illustrating the number of studies obtained at each selection phase.

Table 4 - Critério para inclusão - combinações necessárias para escolha

Palavra principal	Combinação para Título	Palavra principal	Combinação para Resumo
Mortar Or Historical mortar	Restoration	Mortar Or Historical mortars	Compositions
	Chemometric		Granulometric distributions
	Investigation		Binder/aggregate ratios
	Analysis		Mineralogical characterization
	Characterization		Chemical characterization
	Assessment		Original composition
	Detection		
	Estimation		

Source: Authors.

Figure 1: Research Flowchart



Source: The authors.

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

ISSN 2318-8472, v. 13, n. 89, 2025

3.3 DISCUSSION

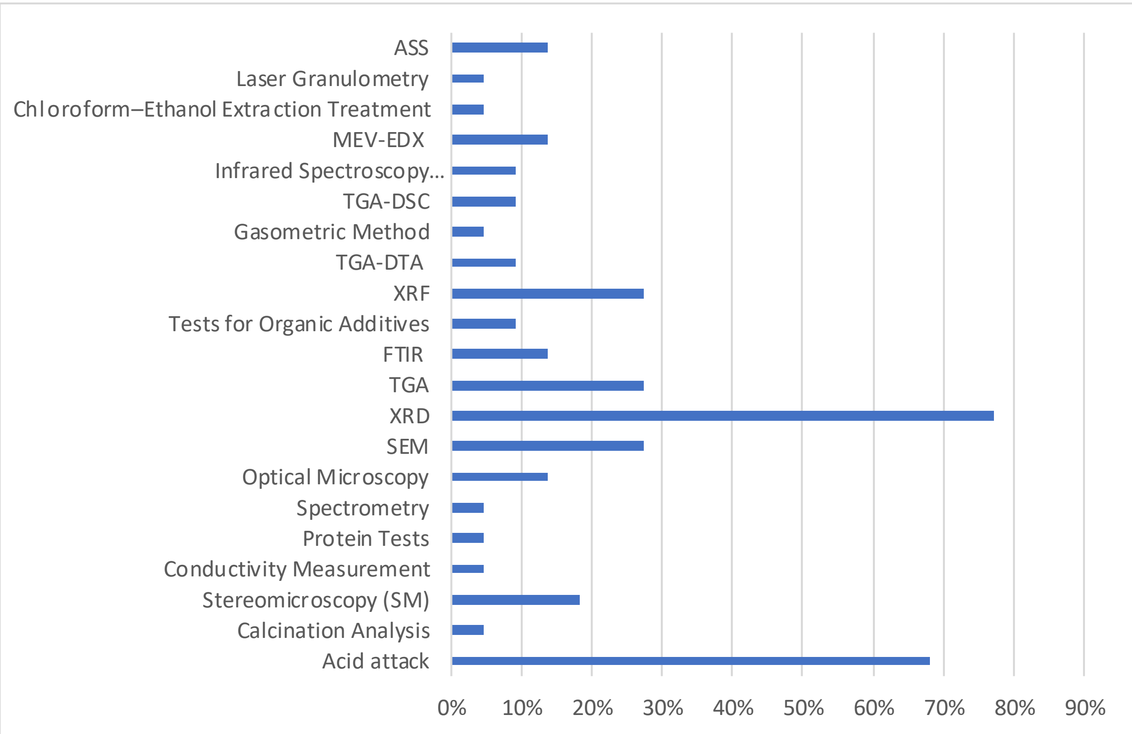
Once the refinement of the selected studies was completed using the PRISMA method, it was possible to take a more analytical look at the literature and identify a wide range of physical and chemical techniques applicable to the characterization of ancient mortars (Santos Silva, 2010). However, the present study focuses solely on identifying techniques aimed at determining the mix proportions of mortars. Figure 2 displays the methods found in the selected studies, as well as the percentage of occurrence in the systematic literature review (SLR).

Among the most frequent methods are X-ray diffraction (XRD) and acid attack (wet chemical method), which appeared in 78% and 69% of the analyzed papers, respectively. The frequent use of XRD can be attributed to several factors, such as its non-destructive nature, high precision, and ability to rapidly identify mineralogical phases—allowing, for example, the identification of the binder within a mortar.

Conversely, the acid attack is a destructive method based on a simple chemical principle: solubility. The soluble fraction corresponds to the binder, while the insoluble portion represents the aggregate. By calculating the difference in mass between these fractions, it becomes possible to reconstruct the original mix proportion.

Other techniques, such as X-ray fluorescence (XRF), thermogravimetric analysis (TGA), and scanning electron microscopy (SEM), were also identified in a significant portion of the studies reviewed.

Figure 2 – Use of analytical methods in the selected studies.



Source: The authors.

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

ISSN 2318-8472, v. 13, n. 89, 2025

The use of these methods—along with, in some cases, their combination—produces results presented through analyses of different natures. However, it is important to emphasize the need for clarity regarding the specific objectives that each method can achieve, even before its application. Accordingly, based on the data obtained from the selected studies, Table 5 presents the relationship between these methods—whether used individually or in combination—and their respective objectives.

Table 5 - Analytical Methods and Their Respective Objectives

Methods	Objective
Acid attack	Determine the proportions of aggregates that do not react with the binder.
Calcination analysis	Verify the pozzolanic activity of the rendering mortar.
Stereomicroscopy	Characterize the aggregates.
Conductivity test	Determine the portions of water-soluble salts.
Protein test	Identify possible organic additives.
Spectrometry	Analyze the soluble components (binders).
Optical microscopy	Obtain petrographic parameters such as binder/aggregate ratio and aggregate size.
Scanning Electron Microscopy (SEM)	Analyze the chemical composition and provide detailed microstructural images.
X-ray Diffraction (XRD)	Identify mineral phases, even at low concentrations.
Thermogravimetric Analysis (TGA)	Show mass variation over time and allow chemical composition analysis.
Fourier Transform Infrared Spectroscopy (FTIR)	Chemically characterize the sample.
Organic additive tests (potassium iodide for starch, protein test, Benedict's reagent for sugars)	Detect the presence of organic components.
X-ray Fluorescence (XRF)	Detect the elemental composition.
Thermogravimetry with Differential Thermal Analysis (TGA-DTA)	Analyze mass loss as a function of temperature, identifying variation rates.
Gasometric method	Estimate the binder weight fraction.
Thermogravimetry with Differential Scanning Calorimetry (TGA-DSC)	Analyze mass loss as a function of enthalpy energy.
Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM-EDX)	Corroborate previous analyses by identifying elements through energy-dispersive X-ray detection.
Chloroform–ethanol extraction treatment	Detect organic components.
Laser granulometry	Not specified.

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

ISSN 2318-8472, v. 13, n. 89, 2025

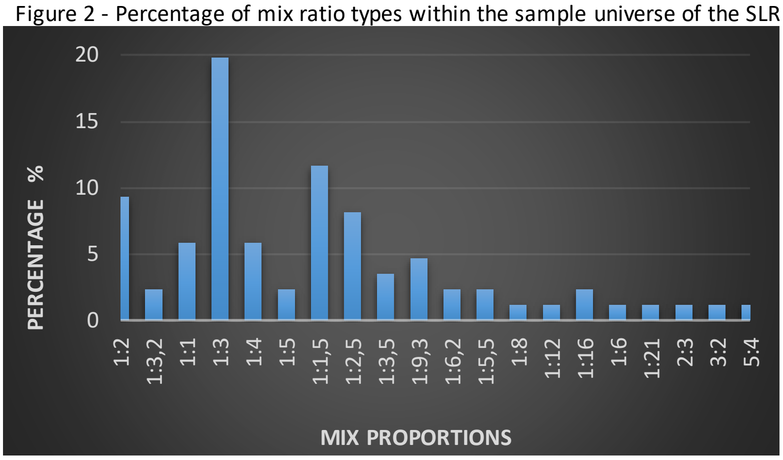
Methods	Objective
Atomic Absorption Spectroscopy (AAS)	Quantify the binder oxide through the Cementation Index (CI); as the hydraulic character increases, the CI rises.

Source: The authors

Regarding the mix proportions, each analyzed study tended to propose more than one mass ratio, since each sample produced distinct results. Thus, Figure 3 presents the types of mix ratios identified and their frequency among the samples analyzed in the selected studies.

The results reveal a wide variety of mix proportions. However, it can be observed that the 1:3 ratio appears most frequently—present in nearly 20% of the samples—indicating that this proportion was commonly used in mortar formulations throughout history. Other ratios also appear with notable frequencies: 1:1.5 (2.3%), 1:2.5 (8.14%), 1:2 (9.3%), 1:1 (5.8%), and 1:4 (5%).

Figure 2 - Percentage of mix ratio types within the sample universe of the SLR.



Fonte: Os autores.

Table 6 presents the articles selected after applying the PRISMA refinement, as well as key characteristics of each study, including the year, country, and method chosen for sample analysis in each work.

Tabela 6 - the articles selected after the PRISMA.

Nr.	Autores/ Referencias	Ano	País	Método utilizado
1	Luxán, M.P.; Dorrego, F.; Laborde, A.	1995	Espanha	TGA[1]
2	Moropoulou, A.; Bakolas, A.; Bisbikou, K.	1995	Grécia	TGA-DTA[2]; XRD[3]

[1] Thermogravimetric Analysis (TGA)
[2] Thermogravimetric and Differential Thermal Analysis (TGA-DTA)
[3] X-Ray Diffraction (XRD)

ISSN 2318-8472, v. 13, n. 89, 2025

Nr.	Autores/ Referencias	Ano	País	Método utilizado
3	Moropoulou A.; Bakolas A.; Bisbikou K.	2000	Grécia	SEM-EDX[4]; XRD[3]; Optical Microscopy; TGA[1]; FTIR[5]
4	Callebaut, K. *et al*.	2001	Belgica	XRD[3]; SEM-EDX[4]; Petrographic Microscopy
5	De Luxán M.P.; Dorrego F.	2004	Espanha	Acid Attack; Sieving
6	Rampazzi, L. *et al*.	2006	Itália	Acid Attack; Optical Microscopy; Sieving
7	Stefanidou M.A.; Papayianni I.	2007	Grécia	-------------
8	Gleize, P.J.P.; Motta, E.V.; Silva, D.A. et *al*.	2009	Brasil	FTIR[5]; ASS[6]; XRD[3]; TGA[1]; Acid Attack
9	Mertens, G. *et al*.	2009	Bélgica	Fluorescence Microscopy; Acid Attack
10	Cizer, Ö.; Schueremans, L.; Serre, G.;	2010	Bélgica	XRD[3]; TGA[1]; Acid Attack
11	Sanjurjo-Sánchez, *et al*.	2010	Espanha	XRD[3]; AAN [7]
12	Schueremans, L.; *et al*.	2011	Bélgica	SEM; XRF[8]; Acid Attack
13	Kramar, S.; *et al*.	2011	Eslovênia	Optical Microscopy ; XRD[3];FTIR[5]; SEM-EDS[9];
14	Bartz, W.; Rogó, J.; Rogal, R.;	2012	Polônia	Optical Microscopy; SEM; Acid Attack; *ASS*[6]; XRD[3]; Sieving; EI[10]; TGA – DTA[2]
15	Sagin, E. U.; *et al*.	2012	Turquia	XRD[3]; FTIR[5]; SEM-EDS[9]; LIBS[11]
16	Pineda, P.; Robador, M.D.; Perez-Rodriguez, J.L.	2013	Espanha	SEM; XRD[2];FTIR[4]; SEM-EDX[4]; TGA – DTA[2]
17	Martínez, I.; *et al*.	2013	Espanha	Mercury Intrusion Porosimetry; XRD[3]; SEM-EDX[4]

[4] Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX)
[5] Fourier Transform Infrared Spectroscopy
[6] Atomic Absorption Spectrometry
[7] Análise de ativação de neutrons
[8] X-ray Fluorescence
[9] Energy Dispersive Spectroscopy
[10] Infrared Spectroscopy
[11] Laser-Induced Breakdown Spectroscopy

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

ISSN 2318-8472, v. 13, n. 89, 2025

Nr.	Autores/ Referencias	Ano	País	Método utilizado
18	Carasek, H.; Japiassú, P.; Cascudo, O.;	2014	Portugal	DRX[3]; TGA-DTA[2]; Optical Microscopy ; SEM; Acid Attack ; ASS[6]
19	Meng, C. L.; *et al.*	2015	China	XRD[3]; SEM-EDS[9]
20	Liu, X.; Ma, X.; Zhang, B.	2016	China	XRD[3]; TGA-DSC[12]; Gasometric Method; Acid Attack
21	Leone, G.; *et al.*	2016	Itália	XRF[8]; Petrographic Microscopy; TGA – DTA[2]
22	Lopez-Arcea; P.; *et al.*	2016	França	SEM-EDS[9]; XRD[3]; Ion Chromatography
23	Ulukaya S.; Yoruç A.B.H.; Yüzer N.; et *al.*	2017	Turquia	XRD[3]; TGA[1]; FTIR[5]; XRF[8]; Acid Attack
24	Laycock, E. A.; Pirrie, D.; Clegg, F.; *et al.*	2019	Reino Unido	Acid Attack ; Sieving; XRF[8]; XRD[2]; FTIR[4]
25	Borsoi, G.; Santos Silva, A. Menezes, P.; *et al.*	2019	Portugal	XRD[2]; TGA-DTA[2]; Acid Attack ; SEM;
26	Guerra, F.; Lopes, W; Cazarolli, J. C.	2019	Brasil	XRD[2]; XRF[8]; TGA[1]; Acid Attack
27	Durán-Suárez J.A.; Sáez-Pérez M.P.	2019	Etiopia	XRD[2]; XRF[5]; Optical Microscopy; SEM
28	Ipekci, E.; Sagın, E. U.; Böke, H.	2019	Turquia	XRD[2]; XRF[5]; SEM - EDS[9]; TGA – DTA[6]
29	Yildizlar B.; Sayin B.; Akcay C.	2020	Turquia	Acid Attack ; Sieving; Calcination Analysis; Optical Microscopy; Conductivity; Protein Tests
30	Vidovszky, I.; Pintér, F.	2020	Hungria	Optical Microscopy e SEM
31	Loureiro, A. M. S.; Paz, S. P. A.; Veiga, M. R.; *et al.*	2020	Brasil	XRD[3]; DSC[13]
32	Loureiro, A. M. S.; Da Paz, S. P. A.; Do Rosário, V.M.;	2020	Brasil	Acid Attack; Sieving; Petrographic Microscopy ; DRX[3]; TGA-DSC[12]; MEV-EDX[4]; FRX[8]
33	Loureiro, A. M. S.; Paz, S. P. A.; Angélica, R. S.	2020	Brasil	Acid Attack ; XRD[3]; XRF[5]; XRD[3]-DSC[13];
34	Sena da Fonseca, B; Ferreira Pinto, A.P.; Vaz Silva, D.	2020	Portugal	DRX[3]; Acid Attack

[12] Thermogravimetry coupled with Differential Scanning Calorimetry
[13] Differential Scanning Calorimetry

ISSN 2318-8472, v. 13, n. 89, 2025

Nr.	Autores/ Referencias	Ano	País	Método utilizado
35	Parracha J.L.; *et al*.	2020	Portugal	TGA – DTA[2]; Optical Microscopy; XRD[3]; FRX[8]; Acid Attack
36	Santhanam, K. ; et *al*.	2021	Índia	XRD[3]; XRF[8]; MEV; FTIR[5]; Acid Attack
37	Asaad Al-Omari, Suhail Khattab	2021	Iraque	XRD[3]; Ion Chromatography ; SEM
38	Qian, K.; Song, Y.; Lai, J.; *et al*.	2022	China	FTIR[5]; XRD[3]; SEM-EDX[4]; Acid Attack
39	Santhanam, K.; Ramadoss, R.	2022	Índia	XRD[3]; FXR[8], SEM-EDX[4] , TGA – DTA[2]
40	Gomes de Oliveira; *et al*.	2022	Brasil	Acid Attack ; TGA – DTA[2]; XRD[3]
41	Mechling, Jean-Michel; Baquet, M..	2022	França	XRF[8]; XRD[3]; TGA – DTA[2]
42	Paloma Pineda, *et al*.	2022	Espanha	XRD[2]; XRF[8]; TGA-DSC[12]
43	Luo L.; *et al*.	2023	Mianmar	Optical Microscopy; SEM; XRD[3]; TGA[1]; FTIR[5]; Tests for Organic Additives
44	Tirelli, Giulia; *et al*.	2023	Itália	Optical Microscopy;
45	Maljaee H.; Silva A.S.; Velosa A.	2023	Portugal	XRD[3]; XRF[5]; Petrographic Analysis
46	Calandra S.; *et al*.	2023	Itália	XRD[3]; SEM
47	Talib, Hussnain; *et al*.	2023	Paquistão	Acid Attack; XRD[2]; XRF[5] ; TGA – DTA[2]

4. CONCLUSIONS

The analysis of the selected articles demonstrates that the methods used for the characterization of historical mortars are diverse and, when combined, have the potential to provide more information than merely the mass proportions considered in the present study. Accordingly, several conclusions can be drawn regarding these methods:

a) The efficiency of the methods is evidenced by their consistent use in studies over the years. This continuity fosters familiarity with the procedures, thereby increasing confidence that the intended objectives will be achieved.

b) X-ray diffraction (XRD) and acid attack are methodologies that fall within this reliable category. Regarding possible outcomes, both methods are capable of revealing the microstructure of the mortar and estimating its mix proportions, as well as its basic composition, allowing differentiation between lime- and cement-based pastes.

ISSN 2318-8472, v. 13, n. 89, 2025

c) An important consideration is the identification of potential organic additives, since throughout history various cultures have incorporated additional components into the mix to achieve different functions. Consequently, some tests for organic additives, chloroform–ethanol extraction treatment, or even an *EI* may be necessary.

Concerning the analyses, the study highlights the importance of conducting chemical and mineralogical analyses to elucidate both the mineral components and the base composition of the mixture. This prevents incompatibilities during restoration, which could otherwise lead to structural and cultural damage to the building.

The conclusions presented in this study aim to fill gaps regarding the most efficient methods for characterizing historical mortar mix ratios. The review brings to light the most effective techniques and their main functionalities in reconstructing mortar formulations. Another important point clarified by this systematic review concerns the necessary analyses to ensure safe and accurate characterization, avoiding unnecessary procedures or errors in method selection.

For future research, an investigation of the accuracy of each method and analysis employed is proposed. This could be performed by comparing reconstructed mix ratios from samples extracted from historical buildings with those determined in the laboratory. With the proportions from both sets of mortars, an analysis of variance (ANOVA) could be conducted to determine whether significant differences exist between the results.

REFERÊNCIAS

AFFONSO, S. B. A.; AZAMBUJA, M. D. A. Avaliação tecnológica de argamassa de revestimento produzida com vermiculita expandida. **Revista Nacional de Gerenciamento de Cidades**, v. 12, n. 87, 2024.

BARBERO-BARRERA, M. M.; *et al*. Lime render layers: An overview of their Properties**. Journal of Cultural Heritage.** v. 15, p. 326-330, 2014.

BARTZ, W.; et *al*. Characterization of historical lime plasters by combined non-destructive and destructive tests: the case of the sgraffito in bożnów. **Construction And Building Materials**, v. 30, p. 439-446, 2012.

BORSOI, G. *et al*. Analytical characterization of ancient mortars from the archaeological roman site of Pisões (Beja, Portugal). **Construction and Building Materials**, v. 204, p. 597-608, 2019.

CALANDRA, S. *et al*. Mortar Characterization of Historical Masonry Damaged by Riverbank Failure: The Case of Lungarno Torrigiani (Florence). **Heritage**, v. 6, n. 5, p. 3820-3834, 2023.

CALLEBAUT, K. *et al*. Nineteenth century hydraulic restoration mortars in the Saint Michael's Church (Leuven, Belgium): Natural hydraulic lime or cement?. **Cement and Concrete Research**, v. 31, n. 3, p. 397-403, 2001.

CARASEK, H.; *et al*. Bond between 19th Century lime mortars and glazed ceramic tiles. **Construction And Building Materials**, v. 59, p. 85-98, 2014.

CIZER, Ö.; et. *al*. Assessment of the Compatibility of Repair Mortars in Restoration Projects. **Advanced Materials Research**, v. 133-134, p. 1071-1076, 2010.

DA FONSECA, B. S.; PINTO, AP F.; SILVA, D. V.. Compositional and textural characterization of historical bedding mortars from rubble stone masonries: Contribution for the design of compatible repair mortars. **Construction and Building Materials**, v. 247, p. 118627, 2020.

DE LUXAN, M. P.; DORREGO, F. Characterization and selection of mortars in the restoration of the kings portal (Benavente, Zamora). **Materiales de Construcción,** v. 54, n. 273, p. 35-44, 2004.

ISSN 2318-8472, v. 13, n. 89, 2025

DE OLIVEIRA, L. M. G. *et al*. Investigation of the mortars and clay bricks of a luso-brazilian historic structure from XVIII century: The Nosso Senhor do Bonfim Church. **Journal of Building Engineering**, v. 45, p. 103592, 2022.

DURÁN-SUÁREZ, J. A.; SÁEZ-PÉREZ, M. P.. Characterization of classical construction materials used in ethiopian architecture for the restoration of their historic and artistic heritage. **International Journal of Architectural Heritage**, 2019.

FINK, A. **Conducting Research Literature Reviews: From the Internet to Paper**. Los Angeles: Sage, 2019.

G. BORSOI, et *al.* Analytical characterization of ancient mortars from the archaeological roman site of Pisões (Beja, Portugal). **Construction and Building Materials**, v. 204, p. 597-608, 2019.

GLEIZE, P.J.P.; *et al*. Characterization of historical mortars from Santa Catarina (Brazil). **Cement And Concrete Composites**, v. 31, p. 342-346, 2009.

GUERRA, F. L. *et al*. Biodeterioration of mortar coating in historical buildings: Microclimatic characterization, material, and fungal community. **Building and Environment**, v. 155, p. 195-209, 2019.

ILVA, A.S.; ADRIANO, P.; MAGALHÃES, A. Characterization of historical mortars from Alentejo's religious buildings. **International Journal of Architectural Heritage**. v. 4, p. 138-154, 2010.

IPEKCI, E.; SAĞIN, E. U.; BÖKE, H.. Interior plastering of Ottoman bath buildings. **Case Studies in Construction Materials**, v. 11, p. e00295, 2019.

KRAMAR, S. *et al*. Mineralogical and microstructural studies of mortars from the bath complex of the Roman villa rustica near Mošnje (Slovenia). **Materials Characterization**, v. 62, n. 11, p. 1042-1057, 2011.

LAYCOCK, et *al*. An investigation to establish the source of the Roman lime mortars used in Wallsend, UK. **Construction And Building Materials**. v. 196, p. 611-625, 2019.

LEONE, G. *et al*. Characterization of archaeological mortars from Herculaneum. **Thermochimica Acta**, v. 624, p. 86-94, 2016.

LIBERATI, A. et *al.* The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions. **Annals of Internal Medicine**, v. 151, n. 4, 2009.

LIU, X.; MA, X.; Z, B. Analytical Investigations of Traditional Masonry Mortars from Ancient City Walls Built during Ming and Qing Dynasties in China. **International Journal Of Architectural Heritage**, v. 10, p. 663-673, 2015.

LÓPEZ-ARCE, P. *et al*. Physico-chemical stone-mortar compatibility of commercial stone-repair mortars of historic buildings from Paris. **Construction and Building Materials**, v. 124, p. 424-441, 2016.

LOU, L.; et *al.* A thorough detection of the mortar materials for Buddhist buildings in Bagan, Myanmar. **European Physical Journal Plus.** v. 138, 2023.

LOUREIRO, A. M. S.; *et al*. Assessment of compatibility between historic mortars and lime-metakaolin restoration mortars made from amazon industrial waste. **Applied Clay Science**, v. 198, p. 105843, 2020a.

LOUREIRO, A. M. S.; *et al*. Investigation of historical mortars from Belém do Pará, Northern Brazil. **Construction And Building Materials**, v. 233, p. 117284, 2020b.

LOUREIRO, A. M. S.; PAZ, S. P. A.; ANGÉLICA, R. S. How to estimate the binder:aggregate ratio from lime-based historic mortars for restoration?. **Frontiers in Materials**, v. 7, 2020c.

LUXÁN, M.P.; DORREGO, F.; LABORDE, A. Ancient gypsum mortars from St. Engracia (Zaragoza, Spain): characterization. identification of additives and treatments. **Cement And Concrete Research**, v. 25, p. 1755-1765, 1995.

MALJAEE, H.; SILVA, A. S.; VELOSA, A.. Characterization of mortar from Casa Barbot (Portugal), a case study from the beginning of the 20th century. **Buildings**, v. 13, n. 1, p. 232, 2023.

MARTÍNEZ, I. *et al*. Physico-chemical material characterization of historic unreinforced masonry buildings: The first step for a suitable intervention. **Construction and Building Materials**, v. 40, p. 352-360, 2013.

ISSN 2318-8472, v. 13, n. 89, 2025

MECHLING, Jean-Michel; BAQUET, M.. Physicochemical characterisation of the mortars from Notre-Dame de Paris cathedral–Preliminary findings and reconstitution of the fresh mix. **Journal of Cultural Heritage**, v. 65, p. 57-67, 2024.

MENG, C. L. *et al.* Chemical and microscopic study of masonry mortar in ancient pagodas in East China. **International Journal of Architectural Heritage**, v. 9, n. 8, p. 942-948, 2015.

MERTENS, G. *et al*. Quantitative composition of ancient mortars from the Notre Dame Cathedral in Tournai (Belgium). **Materials characterization**, v. 60, n. 7, p. 580-585, 2009.

MOROPOULOU, A.; BAKOLAS, A.; BISBIKOU, K.. Characterization of ancient, byzantine and later historic mortars by thermal and X-ray diffraction techniques. **Thermochimica Acta**, v. 269-270, p. 779-795,1995.

MOROPOULOU, A.; BAKOLAS, A.; BISBIKOU, K.. Investigation of the technology of historic mortars. **Journal of Cultural Heritage**, v. 1, n. 1, p. 45-58, 2000.

PACHECO-TORGAL, F.P.; FARIA, J.; JALALI, S. Some considerations about the use of lime–cement mortars for building conservation purposes in Portugal: A reprehensible option or a lesser evil?. **Construction and Building Materials**. v. 30, p. 488-494, 2012.

PARRACHA, João Luís *et al*. Mineralogical and microstructural characterisation of rammed earth and earthen mortars from 12th century Paderne Castle. **Journal of Cultural Heritage**, v. 42, p. 226-239, 2020.

PINEDA, P. *et al*. Pore structure and interdisciplinary analyses in Roman mortars: Building techniques and durability factors identification. **Construction and Building Materials**, v. 317, p. 125821, 2022.

PINEDA, P.; ROBADOR, M. D.; PEREZ-RODRIGUEZ, J. L. Characterization and repair measures of the medieval building materials of a Hispanic–Islamic construction. **Construction and Building Materials**, v. 41, p. 612-633, 2013.

QIAN, K.; et *al*. Characterization of historical mortar from ancient city walls of Xindeng in Fuyang, China. **Construction And Building Materials**, v. 315, p. 125780, 2022.

RAMPAZZI, L.; POZZI, A.; Sansonetti. A.;Toniolo, L.; Giussani, B..A chemometric approach to the characterisation of historical mortars. **Cement and Concrete Research**. v. 36, p. 1108-1114, 2006.

SAĞIN, E. U. *et al*. Determination of $CaCO_3$ and SiO_2 content in the binders of historic lime mortars. **Materials and Structures**, v. 45, p. 841-849, 2012.

SANJURJO-SÁNCHEZ, J. *et al*. Chemical and mineralogical characterization of historic mortars from the Santa Eulalia de Bóveda temple, NW Spain. **Journal of Archaeological Science**, v. 37, n. 9, p. 2346-2351, 2010.

SANTHANAM, K.; *et al*. Characterisation on ancient mortar of Chettinadu house at Kanadukathan, Karaikudi, Tamil Nadu, India. **Materials Today**: **Proceedings,** v. 43, p. 1147-1153, 2021.

SCHUEREMANS, L. *et al*. Characterization of repair mortars for the assessment of their compatibility in restoration projects: Research and practice. **Construction and building materials**, v. 25, n. 12, p. 4338-4350, 2011.

ScienceDirect: A plataforma de literatura acadêmica revisada por pares da Elsevier. **Elsevier**, 2023. Disponível em: https://www.elsevier.com/pt-br/products/sciencedirect. Acesso em: 17 nov. 2023.

Scopus Conteúdo. **Elsevier**, 2023. Disponível em: https://www.elsevier.com/pt-br/products/scopus/content. Acesso em: 17 nov. 2023.

SILVA, J. K. S. DA; *et al*.. Argamassas de Restauro: Uma revisão dos desafios e inovações na preservação do patrimônio construído. **Revista Nacional de Gerenciamento de Cidades**, v. 12, n. 87, 2024.

STEFANIDOU, M.A.; PAPAYIANNI, I. Analysis of the old mortars and proposals for the conservation of the archeological site of Logos-Edessa. In: 10th International Conference on Studies, Repairs and Maintenance of Heritage Architecture. **STREMAH 2007**. República Checa, 2007. Disponível em: https://www.witpress.com/Secure/elibrary/papers/STR07/STR07024FU1.pdf Acesso em: 30 Out. 2023.

TALIB, H. *et al*. Scanning through multidisciplinary techniques and recreation of historic mortar: Case study of Rohtas Fort. **Case Studies in Construction Materials**, v. 18, p. e02052, 2023.

ISSN 2318-8472, v. 13, n. 89, 2025

TIRELLI, G.; et *al*. A Chronology of Ancient Earthquake Damage in the Modena Cathedral (Italy): integrated dating of mortars (14c, pollen record) and bricks. **International Journal Of Architectural Heritage**. v. 17, p. 326-342, 2021.

ULUKAYA, S. Material Characterization of Byzantine Period Brick Masonry Walls Revealed in Istanbul (Turkey). **Periodica Polytechnica Civil Engineering**, v. 61, p. 209–215, 2017.

VIDOVSZKY, I.; PINTÉR, F. An Investigation of the Application and Material Characteristics of Early 20th-Century Portland Cement-Based Structures from the Historical Campus of the Budapest University of Technology and Economics. **International Journal Of Architectural Heritage**, v. 14, p. 358-375, 2018.

XU, L., **Study on the comprehensive analysis method of traditional mortar materials-taking the hall of mental cultivation of the palace museum as na example**. Tese de Doutorado. Master Dissertation Zhejiang University 2018

YILDIZLAR, B.; SAYIN, B.; AKCAY, C. A Case Study on the Restoration of A Historical Masonry Building Based on Field Studies and Laboratory Analyses. **International Journal of Architectural Heritage**. v. 14, p. 1341-1359, 2020.

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

ISSN 2318-8472, v. 13, n. 89, 2025

DECLARAÇÕES

CONTRIBUIÇÃO DE CADA AUTOR

O autor Micael Justino foi o responsável pela idéia central do estudo, por isso é considerado o autor principal, e auxiliado pela professora Dra Yeda Póvoas decidiu os objetivos e a metodologia que usaria. Após as escolhas das bases de dados o autor princial contou com auxílio do Raphael Britto para criação dos filtros de base. Os dois autores também desenvolveram filtros mais específicos para que se chegassem aos artigos selecionados ao final do estudo.

De posse dos artigos o autor Micael Justino iniciou a leitura total dos trabalhos, pontuando as características mais importantes. O autror Raphael Britto foi responsável por organizar esses dados em tabelas e graficos. Cada elemento gráfico passou pela análise da Professora Dra Yeda Póvoas. Que por sua vez analisou meticulosamente as etapas da metodologia.

A primeira versão do manuscrito foi feita pelo autor Micael Justino, a ediçao grafica pelo autor Raphael Britto e as devidas correções e adaptações pela professora Dra Yeda Póvoas, sendo responsável pela revisão crítica do trabalho.

Por fim, coube a professora Dra Yeda Póvoas a supervisão da pesquisa coordenando o trabalho e garantindo a qualidade geral do estudo.

DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, Micael Justino, Yeda Póvoas e Raphael Britto, declaramos que o manuscrito intitulado "**Metodologias para reconstrução do traço de argamassas de edificações antigas uma revisão sistemática da literatura**":

1. **Vínculos Financeiros**: Não possui/possui vínculos financeiros que possam influenciar os resultados ou interpretação do trabalho. (Detalhe aqui, se aplicável: "Este trabalho foi financiado por [Nome da Instituição ou Entidade]"; ou "Nenhuma instituição ou entidade financiadora esteve envolvida no desenvolvimento deste estudo").
2. **Relações Profissionais**: Não possui/possui relações profissionais que possam impactar na análise, interpretação ou apresentação dos resultados. (Detalhe aqui, se aplicável: "Eu/Nós mantemos vínculo empregatício com [Nome da Instituição]"; ou "Nenhuma relação profissional relevante ao conteúdo deste manuscrito foi estabelecida").
3. **Conflitos Pessoais**: Não possui/possui conflitos de interesse pessoais relacionados ao conteúdo do manuscrito que poderia influenciar a objetividade do estudo.