

Strengthening of unreinforced masonry: a systematic review of mechanical performance gains and limitations of reinforcement systems

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Reforço de alvenarias não armadas: uma revisão sistemática dos ganhos mecânicos e das limitações dos sistemas de reforço

RESUMO

Objetivo - Analisar de forma sistemática as técnicas de reforço aplicadas à alvenaria não armada, com foco nos ganhos de resistência mecânica, especialmente à compressão e ao cisalhamento, bem como nas limitações associadas aos diferentes sistemas de reforço investigados na literatura científica.

Metodologia - Foi conduzida uma Revisão Sistemática da Literatura, estruturada a partir de protocolo de busca definido, critérios claros de inclusão e exclusão e aplicação do método PRISMA para seleção dos estudos. Os artigos selecionados foram analisados quanto ao tipo de alvenaria, técnica de reforço empregada, configuração experimental, ganhos percentuais de resistência e limitações relatadas.

Originalidade/relevância - O estudo aborda uma lacuna relevante na literatura ao sistematizar, de forma comparativa, os ganhos mecânicos e as limitações dos principais sistemas de reforço aplicados à alvenaria não armada, contribuindo para uma avaliação crítica integrada do desempenho estrutural e da aplicabilidade dessas técnicas.

Resultados - Os resultados indicam que os maiores ganhos de resistência ocorrem, predominantemente, em solicitações de cisalhamento no plano, especialmente em sistemas baseados em argamassas reforçadas com têxteis ou fibras, como TRM e FRCM, com incrementos frequentemente superiores a duzentos por cento. Os ganhos em resistência à compressão mostraram-se mais moderados e associados, sobretudo, a mecanismos de confinamento. As limitações mais recorrentes envolvem variabilidade de desempenho, falhas prematuras na interface reforço-substrato, incompatibilidades químicas e restrições de aplicação em edificações históricas.

Contribuições teóricas/metodológicas - A pesquisa consolida um panorama comparativo dos sistemas de reforço, relacionando desempenho mecânico e limitações técnicas, além de evidenciar a necessidade de modelos de dimensionamento mais adequados para sistemas com matrizes inorgânicas.

Contribuições sociais e ambientais - Os achados subsidiam a escolha de soluções de reforço mais compatíveis com edificações existentes e patrimônio histórico, favorecendo intervenções mais seguras, duráveis e alinhadas a princípios de sustentabilidade e conservação do ambiente construído.

PALAVRAS-CHAVE: Alvenaria não armada. Reforço estrutural. Resistência ao cisalhamento. Resistência mecânica. Revisão sistemática da literatura.

Strengthening of unreinforced masonry: a systematic review of mechanical performance gains and limitations of reinforcement systems

ABSTRACT

Objective – To systematically analyze reinforcement techniques applied to unreinforced masonry, focusing on gains in mechanical strength, particularly compressive and shear resistance, as well as on the limitations associated with the different reinforcement systems reported in the scientific literature.

Methodology – A Systematic Literature Review was conducted based on a predefined search protocol, clear inclusion and exclusion criteria, and the application of the PRISMA method for study selection. The selected articles were analyzed according to masonry type, reinforcement technique, experimental configuration, percentage gains in strength, and reported limitations

Originality/Relevance – This study addresses a relevant gap in the literature by providing a comparative and integrated synthesis of mechanical performance gains and technical limitations of the main reinforcement systems applied to unreinforced masonry, supporting a critical assessment of their structural effectiveness and practical applicability.

Results – The results indicate that the highest strength gains are predominantly associated with in-plane shear loading, especially for systems based on textile- or fiber-reinforced mortars, such as TRM and FRCM, with increases frequently exceeding two hundred percent. Gains in compressive strength were generally more moderate and mainly related to confinement mechanisms. The most recurrent limitations include performance variability, premature failure at the reinforcement-substrate interface, chemical incompatibility, and restrictions on application in historic masonry.

Theoretical/Methodological Contributions – The study consolidates a comparative framework relating mechanical performance and technical limitations of reinforcement systems and highlights the need for more suitable design models for systems based on inorganic matrices.

Social and Environmental Contributions – The findings support the selection of reinforcement solutions that are more compatible with existing and historic buildings, contributing to safer, more durable interventions aligned with sustainability and built heritage conservation principles.

KEYWORDS: Unreinforced masonry. Structural strengthening. Shear strength. Systematic literature review

Refuerzo de albañilerías no armadas: una revisión sistemática de los incrementos de desempeño mecánico y las limitaciones de los sistemas de refuerzo

RESUMEN

Objetivo – Analizar de forma sistemática las técnicas de refuerzo aplicadas a la albañilería no armada, con énfasis en los incrementos de resistencia mecánica, especialmente a compresión y cortante, así como en las limitaciones asociadas a los distintos sistemas de refuerzo descritos en la literatura científica.

Metodología – Se llevó a cabo una Revisión Sistemática de la Literatura, estructurada a partir de un protocolo de búsqueda definido, criterios claros de inclusión y exclusión y la aplicación del método PRISMA para la selección de los estudios. Los artículos seleccionados fueron analizados según el tipo de albañilería, la técnica de refuerzo empleada, la configuración experimental, los incrementos porcentuales de resistencia y las limitaciones reportadas.

Originalidad/Relevancia – El estudio aborda un vacío relevante en la literatura al sistematizar de manera comparativa los incrementos de desempeño mecánico y las limitaciones técnicas de los principales sistemas de refuerzo aplicados a la albañilería no armada, permitiendo una evaluación crítica integrada de su eficacia estructural y aplicabilidad práctica.

Resultados – Los resultados indican que los mayores incrementos de resistencia se asocian predominantemente a sollicitaciones de cortante en el plano, especialmente en sistemas basados en morteros reforzados con textiles o fibras, como TRM y FRCM, con incrementos que frecuentemente superan el doscientos por ciento. Los aumentos de resistencia a compresión fueron más moderados y se relacionaron principalmente con mecanismos de confinamiento. Las limitaciones más recurrentes incluyen variabilidad del desempeño, fallas prematuras en la interfaz refuerzo–sustrato, incompatibilidades químicas y restricciones de aplicación en edificaciones históricas.

Contribuciones Teóricas/Metodológicas – La investigación consolida un marco comparativo que relaciona desempeño mecánico y limitaciones técnicas de los sistemas de refuerzo, además de evidenciar la necesidad de modelos de dimensionamiento más adecuados para sistemas con matrices inorgánicas.

Contribuciones Sociales y Ambientales – Los hallazgos respaldan la selección de soluciones de refuerzo más compatibles con edificaciones existentes y patrimoniales, promoviendo intervenciones más seguras, duraderas y alineadas con principios de sostenibilidad y conservación del patrimonio construido.

PALABRAS CLAVE: Albañilería no armada. Refuerzo estructural. Resistencia al cortante. Revisión sistemática de la literatura.

1 INTRODUCTION

Unreinforced masonry (URM) structures account for a significant proportion of historical and contemporary buildings worldwide. Recognized for their constructive efficiency, simplicity, and cost-effectiveness, these systems are widely employed in residential, commercial, and industrial buildings. Nevertheless, their structural vulnerability particularly under seismic events and accidental loads in high-risk regions highlights a critical limitation of masonry: its inherently low tensile and shear strength (Lourenço, 2022; Preciado et al., 2020; Gonem, 2021). Despite their high compressive performance, masonry structures are especially prone to failures induced by tensile and shear stresses, which frequently lead to diagonal cracking, excessive displacements, and premature collapses, particularly under seismic actions, extreme winds, or differential settlements (Mezrea et al., 2021; Habieb et al., 2023; Kafodya et al., 2019).

In response to these vulnerabilities, a wide range of structural strengthening strategies has been proposed and investigated with the aim of enhancing shear resistance, improving ductility, and mitigating the risk of partial or total structural collapse (Yardim & Lalaj, 2016; Ismail & Ingham, 2016; Gattesco & Boem, 2015; Bitar et al., 2020). Among the most extensively studied solutions are fiber-reinforced polymers (FRP), textile-reinforced mortars (TRM), and sustainable materials, including natural fibers and metallic meshes. The use of composite materials such as FRP and TRM has gained prominence due to their effectiveness in improving structural resilience and preventing progressive failures. FRP materials, characterized by high tensile strength and low self-weight, are particularly suitable for interventions requiring the preservation of visual and architectural integrity, such as in historic buildings; however, technical challenges such as high cost and limited fire resistance remain relevant concerns. Conversely, TRM systems have emerged as a preferred alternative in heritage contexts, as they exhibit mechanical compatibility with traditional substrates and offer potential reversibility (Kouris & Triantafillou, 2018; Carozzi et al., 2018; Dong et al., 2021; Thomoglou et al., 2023; Rao & Pavan, 2015).

Although the international literature addresses a broad spectrum of strengthening systems for unreinforced masonry, gaps persist regarding the applicability of these methods to building typologies of high practical relevance, such as the so-called *box-type buildings* (“prédios do tipo caixa”) found in the Recife Metropolitan Region (RMR), Brazil. These buildings, named after their geometry and distinctive structural behavior, were widely constructed during the 1970s and 1980s in the Greater Recife area and have been associated with a series of severe accidents, including at least 18 collapses resulting in dozens of fatalities between 1977 and 2023 (Folha de Pernambuco, 2025). Available technical studies and forensic reports indicate that these collapses stem from design deficiencies, low-quality materials, construction flaws, lack of systematic maintenance, and environmental influences, thereby evidencing the inherent fragilities of load-bearing masonry systems without adequate reinforcement (Mélo, 2007).

Furthermore, the assessment of the structural performance of these buildings cannot be dissociated from the urban context in which they are embedded, as urban morphology, spatial configuration, and infrastructure availability directly influence quality of life, building usage, and the degradation processes of the built environment (Castro et al., 2024). In this sense, understanding structural vulnerabilities must be integrated into a broader reading of the urban

territory, encompassing spatial, social, and environmental dimensions. From this expanded perspective, the evaluation of vulnerable buildings—such as box-type structures—requires analytical tools that go beyond isolated approaches, incorporating systemic methodologies capable of supporting urban planning and the management of the built environment. The measurement of urban sustainability through integrated indicator systems has proven essential for capturing the complexity of urban phenomena, particularly in small and medium-sized cities, by enabling the combined assessment of social, environmental, economic, and institutional dimensions associated with urban performance (Silva et al., 2024).

Accordingly, the central motivation of this study lies in the need to critically examine, from a global perspective, how different strengthening systems investigated internationally can provide insights into improving the performance of vulnerable unreinforced masonry, such as that found in box-type buildings in the Recife Metropolitan Region. The regional contextualization of collapse events, combined with accumulated international knowledge and the incorporation of urban and systemic approaches, justifies the development of a systematic literature review that integrates both the mechanical benefits and the limitations of the strengthening techniques examined, with the aim of informing safer, more sustainable engineering practices tailored to historically problematic construction contexts.

2 OBJECTIVES

This Systematic Literature Review aims to investigate and compare the main strengthening systems applied to unreinforced masonry, with emphasis on the assessment of mechanical strength gains—particularly in compression and shear—as well as on the critical analysis of the limitations associated with each technique, considering their contribution to improving structural performance and resistance to collapse mechanisms under seismic actions.

3 METHODOLOGY

This Systematic Literature Review was conducted in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), ensuring transparency, traceability, and reproducibility of the adopted methodological procedures (Page et al., 2021). The review framework and the definition of the research strategy followed the PICO method (Population, Intervention, Comparison, Outcomes), which is widely used in systematic reviews to organize and delimit the scope of analysis. The population considered comprised unreinforced masonry (URM) structures, while the intervention encompassed the different structural strengthening techniques applied to this construction system. The comparison was established through the analysis of results reported for distinct strengthening methods, considering their effects on structural performance. The evaluated outcomes included gains in mechanical strength particularly in compression and shear as well as aspects related to efficiency, methodological accuracy, relative costs, and structural impacts associated with the interventions, thereby enabling a comprehensive overview of the available evidence in the literature.

The search strategy was developed using Boolean operators, combining relevant terms across consolidated scientific databases, namely: Scielo, Scopus, Web of Science, Engineering Village, and ScienceDirect. The keywords employed were: (“unreinforced masonry” OR “URM” OR “brick masonry” OR “stone masonry” OR “masonry”) AND (“structural reinforcement” OR “repair” OR “innovative reinforcement”) AND (“mechanical behavior” OR “structural performance” OR “compressive strength”). The results were restricted to articles published in English within the last ten years, with the aim of capturing recent and representative studies on masonry strengthening and structural performance, with particular emphasis on innovative solutions and practical applications.

3.1 INCLUSION AND EXCLUSION CRITERIA

The selection of studies included in this Systematic Literature Review considered academic articles published between 2014 and January 2025, available in full text and written in English, which directly addressed strengthening methodologies applied to unreinforced masonry (URM). Priority was given to studies presenting quantitative data derived from experimental testing, enabling an objective assessment of the mechanical strength gains resulting from the application of strengthening techniques. The inclusion and exclusion criteria were defined to ensure the methodological consistency of the analyzed sample and the relevance of the selected studies to the research objectives.

Table 1 - Systematically summarizes the criteria adopted in this review.

Criterion	Description
Inclusion Criteria (IC)	C-I01: Studies specifically addressing the strengthening of unreinforced masonry (URM) C-I02: Studies presenting quantitative data and experimental testing C-I03: Exclusion within scope — opinions, editorials, and literature reviews that do not present new quantitative data
Exclusion Criteria (EC)	C-E01: Studies that do not address masonry strengthening C-E02: Studies focused on reinforced masonry C-E03: Articles without quantitative data or experimental testing C-E04: Strengthening interventions focused on columns, beams, or vaults C-E05: Articles whose main subject is unrelated to the strengthening of unreinforced masonry

Source: Prepared by the authors.

3.2 DATA EXTRACTION

The identified references were systematically organized and imported into the START bibliographic software, which was used as a supporting tool for the selection, screening, and management of the analyzed studies. The screening process was conducted in two complementary stages: initially, titles and abstracts were evaluated in order to identify potentially relevant studies; subsequently, full-text reading of the selected articles was performed to confirm their eligibility based on the previously established criteria. The search and final selection of references were completed in January 2025. For each study included in the

review, information considered essential for the systematic analysis was extracted. These data comprised bibliographic aspects such as authors’ institutional affiliations, year of publication, and journal, allowing for the temporal and geographical characterization of the scientific output. The study rationale was also recorded in order to identify the motivation and primary focus of the research with respect to strengthening techniques applied to unreinforced masonry.

In addition, technical information related to the materials used in the strengthening systems, the type of technique applied, and the masonry typology analyzed was collected. Whenever available, quantitative data associated with mechanical strength gains were extracted, as well as information on advantages and limitations reported by the authors. The data extraction framework was structured based on predefined questions, presented in Table 2, ensuring consistency and standardization in the treatment of information throughout the review.

Table 2 – Research Questions and Data Extracted in the Systematic Literature Review

Code	Research Question	Extracted Data
P1	What bibliometric results were identified?	Year of publication, country, authors’ affiliation, scientific journal
P2	What are the main scopes of the selected articles?	Type of unreinforced masonry, strengthening technique, structural context
P3	Which studies reported gains in compressive or shear strength?	Percentage gains in mechanical strength obtained from experimental testing
P4	What limitations were identified in the analyzed strengthening systems?	Technical, constructability, durability, and compatibility limitations
P5	How do mechanical strength gains relate to the technical limitations of the different strengthening systems analyzed?	Comparative analysis between mechanical performance and limitations of the strengthening systems

Source: Prepared by the authors.

4 RESULTS

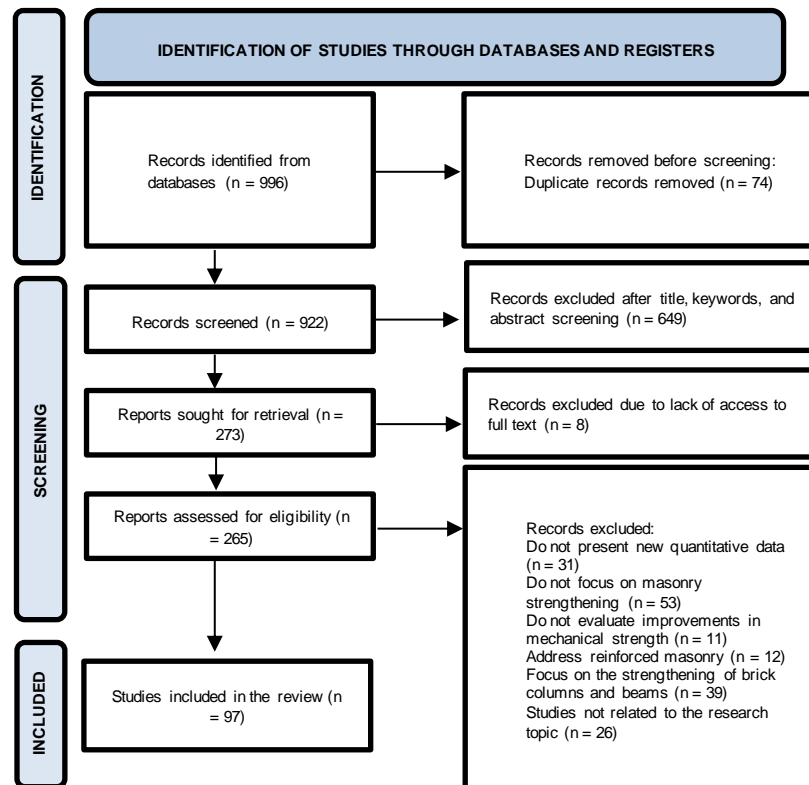
The results presented in this chapter derive from the systematic analysis of the selected studies, in accordance with the established methodological criteria. The organization of the findings follows the structure of the defined research questions, initially addressing the bibliometric results, followed by the characterization of the scope of the analyzed articles. Subsequently, studies reporting gains in compressive and shear strength in unreinforced masonry are presented, as well as the main limitations associated with the investigated strengthening systems. Finally, a comparative analysis between the obtained gains and the identified technical limitations is carried out, providing an integrated perspective on the performance and applicability of the different strengthening methods.

P1 – WHAT BIBLIOMETRIC RESULTS WERE IDENTIFIED?

Figure 1 presents the PRISMA flow diagram, which synthesizes the process of identification, screening, eligibility, and inclusion of the studies considered in this systematic

review. This procedure enabled the rigorous selection of 97 articles through the exclusion of duplicate records and studies that did not meet the criteria related to scope, methodology, or the availability of quantitative data, thereby ensuring transparency, traceability, and methodological consistency throughout the selection process.

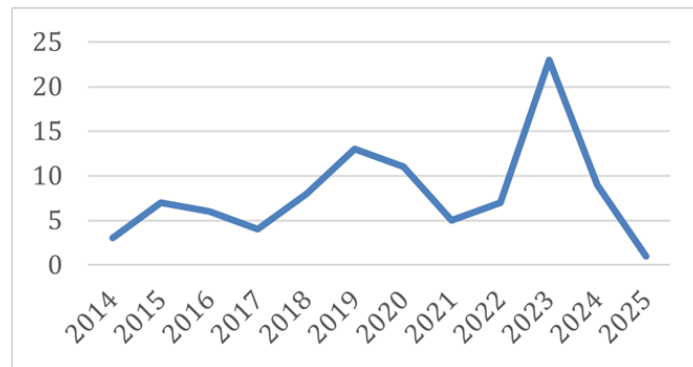
Figure 1 – PRISMA Protocol



Source: Prepared by the authors.

The temporal analysis of publications, presented in Figure 2a, indicates that studies on unreinforced masonry strengthening have been predominantly concentrated over the last decade. A progressive increase in scientific output is observed from 2018 onward, culminating in a peak in 2023, with the highest number of published articles. This trend reflects the recent consolidation of the topic within the academic community, associated with advancements in structural rehabilitation techniques and the growing demand for safety and durability in existing buildings. The geographical distribution of the articles reveals the predominance of countries with a well-established research tradition in masonry and structural engineering. Italy stands out as the main hub of scientific production, followed by China, Iran, and Spain. The presence of studies across different continents highlights the global nature of the topic and reinforces the need for strengthening solutions adaptable to diverse construction contexts, particularly in regions exposed to seismic actions or accelerated building degradation.

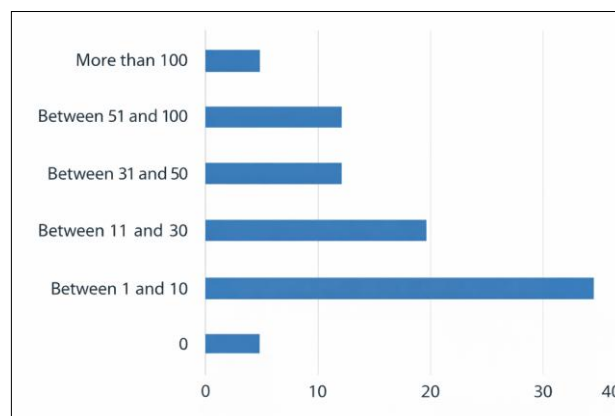
Figure 2 – Temporal Analysis of Publications



Source: Prepared by the authors.

With regard to scientific journals, most publications are concentrated in well-established outlets within the fields of civil engineering, construction materials, and structural engineering. The journal *Construction and Building Materials* stands out as the primary dissemination venue, followed by *Journal of Building Engineering*, *Engineering Structures*, and *Structures*. This concentration indicates that the topic of unreinforced masonry strengthening is addressed in a transversal manner, encompassing experimental, analytical, and applied research approaches. Finally, the analysis of the most cited authors, presented in Figure 3, highlights the influence of researchers who have made significant contributions to advancing knowledge in this field. Studies developed by Corradi et al. (2014), with 136 citations, Marcari et al. (2017), with 131 citations, and Ismail and Ingham (2016), with 129 citations, exhibit high scientific impact. These figures reflect the relevance of investigations focused on understanding the mechanical behavior of strengthened masonry and on the development of efficient reinforcement systems compatible with existing buildings.

Figure 3 – Most Cited Articles among the Selected Studies



Source: Prepared by the authors.

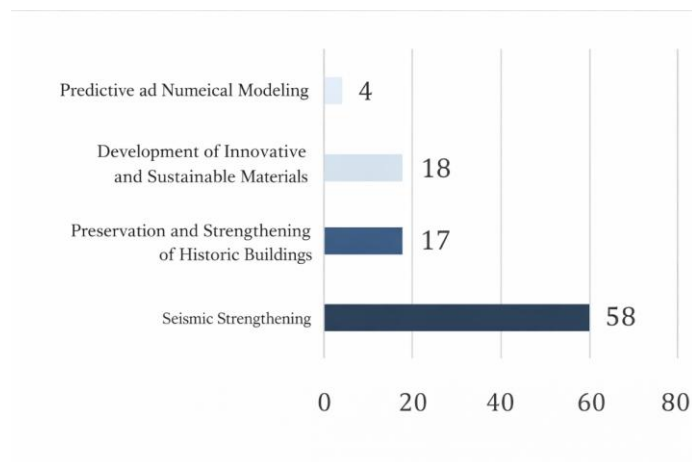
P2 – WHAT ARE THE MAIN SCOPES OF THE SELECTED ARTICLES?

The quantitative analysis of the articles included in this Systematic Literature Review reveals that research motivations are organized into well-defined thematic groups, as presented in Figure 4. The predominant group corresponds to seismic strengthening, accounting for the majority of the analyzed studies. These works primarily aim to improve the structural

performance of unreinforced masonry walls, with emphasis on increasing shear strength, enhancing durability, and improving energy dissipation capacity in regions subjected to severe seismic actions. Another significant body of research is related to the preservation and strengthening of historic buildings, focusing on achieving a balance between increased load-bearing capacity and the preservation of original architectural features. These studies prioritize minimally invasive strengthening solutions, aligned with heritage conservation principles and the maintenance of the aesthetic integrity of existing structures. The group dedicated to the development of innovative and sustainable materials includes investigations seeking reinforcement alternatives with lower environmental impact while maintaining adequate mechanical performance. These studies reflect the growing concern for sustainability in structural engineering, highlighting the use of natural fibers and reinforcement systems based on inorganic matrices or materials with a reduced environmental footprint.

To a lesser extent, studies related to numerical and predictive modeling focus on the development of computational tools capable of simulating the structural behavior of strengthened masonry. These approaches enable more accurate preliminary analyses and contribute to the optimization of structural interventions, reducing uncertainties associated with the performance of strengthening systems. Overall, the identified thematic groups demonstrate the breadth and relevance of research on unreinforced masonry strengthening, encompassing practical applications, innovative approaches, and advanced structural analysis methodologies.

Figure 4 - Main Thematic Groups of the Selected Articles



Source: Prepared by the authors.

P3 – WHICH STUDIES REPORTED GAINS IN COMPRESSIVE OR SHEAR STRENGTH?

In order to address Research Question P3, **Table 3** synthesizes the studies that reported quantitative gains in compressive and shear strength of unreinforced masonry subjected to different strengthening techniques. A comparative framework is presented, including the strengthening technique group employed, the predominant masonry typology analyzed, the type of loading condition evaluated, the typical percentage gain ranges observed, the main mechanisms responsible for improving structural performance, and the representative authors for each approach. This systematization enables the identification of recurring trends, typical efficiency levels, and behavioral differences associated with both the strengthening system and the base masonry material.

Table 3 – Synthesis of the Main Mechanical Strength and Shear Gains in Strengthened Unreinforced Masonry

Strengthening Technique Group	Predominant Masonry Typology	Type of Loading Evaluated	Typical Gain Range (%)	Main Improvement Mechanisms	Authors	Relevant Remarks
TRM / FRCM (mineral textiles and fibers)	Clay brick, stone, tuff	In-plane shear	130% to 440%	Surface confinement, diagonal crack control, and stress redistribution	Almeida et al. (2015); Angiolilli et al. (2021, 2023); Cassese et al. (2021)	Performance dependent on matrix–substrate compatibility; reduced gains in adobe masonry
TRM / FRCM with basalt textile (BTRM)	Clay brick, tuff stone, adobe	In-plane shear	30% to 440%	High tensile strength of the textile and good matrix adhesion	Cassese et al. (2021); Marcari et al. (2017)	High variability associated with base material strength
FRM (high-ductility fiber-reinforced mortar)	Masonry prisms	In-plane shear	Up to 620%	Increased matrix ductility and delayed brittle failure	Joo Ha Lee (2022)	Elevated results associated with specific testing conditions
FRM applied out-of-plane	Schist masonry	Out-of-plane bending	Up to 900%	Increased load-bearing capacity and peak load	Colombo et al. (2016)	Application focused on out-of-plane loading
TRC (textile-reinforced concrete)	Masonry prisms	Axial compression	Up to 85%	Partial confinement and improved global stability	Anuhya et al. (2019)	Moderate gains compared to shear performance
Embedded steel reinforcement (meshes and connectors)	Clay and concrete blocks	Compressão axial	130% to 148%	Internal confinement and increased stiffness	Oliveira et al. (2018); Sandoval et al. (2021)	More invasive technique
Hybrid systems (Reticolatus)	Rubble stone and pebble masonry	In-plane shear	17% to 112%	Structural stitching and direct load transfer	Borri et al. (2014)	Enhanced gains when combined with jacketing
Transverse metallic confinement	Rubble stone masonry	Compression and shear	45% to 152%	Restriction of lateral expansion and improved cohesion	Pinho et al. (2017); Spinella et al. (2014)	High applicability in historic buildings
NSM (Near-Surface Mounted) with FRP	Clay blocks	In-plane shear	28% to 325%	Efficient mechanical anchorage and localized reinforcement	Jafari et al. (2018); Soleymani et al. (2023)	Sensitive to detailing and workmanship
Unbonded external reinforcement	URM (unspecified)	In-plane shear	Up to 119%	Introduction of prestressing forces	Hung et al. (2024)	Recent technique, still underexplored
Organic FRP (GFRP)	Solid brick with lime mortar	In-plane shear	Up to 755%	High tensile strength and good interaction with compatible substrate	Demaj et al. (2023)	Results associated with traditional lime mortars

Source: Prepared by the authors.

The analysis of the studies compiled in Table 3 demonstrates that techniques based on textile- or fiber-reinforced mortars provide the highest and most consistent gains in shear strength for unreinforced masonry. TRM and FRCM systems stand out recurrently, with strength increments varying significantly depending on the type of textile, the matrix used, and the masonry typology. In clay brick and stone masonry, these systems frequently achieve gains exceeding 200%, reaching particularly high values in configurations with basalt textiles, which indicates high efficiency in controlling diagonal cracking and mobilizing shear resistance. However, the performance of these systems is not uniform across all masonry typologies. In adobe masonry, for instance, the reported gains are considerably more modest, highlighting the direct influence of the substrate's low mechanical strength and its limited stress-transfer capacity between the reinforcement matrix and the base material. This behavior underscores the need for compatibility between the strengthening technique and the substrate, particularly in vernacular constructions or masonry with low mechanical performance.

High-ductility fiber-reinforced mortar systems exhibited the highest localized increases in shear strength, with gains exceeding 600% in masonry prisms. These results indicate that increased matrix ductility plays a fundamental role in delaying brittle failure and promoting stress redistribution under in-plane loading. Nevertheless, such elevated values should be interpreted with caution, considering the specific testing conditions, specimen scale, and structural representativeness of the analyzed models. With regard to compressive strength, the observed gains tend to be more moderate when compared to shear results. Techniques based on embedded steel reinforcement, transverse confinement, and hybrid systems showed relevant improvements, generally associated with increased confinement capacity and enhanced global stability of the masonry. These systems demonstrated consistent performance in both masonry prisms and stone masonry, proving suitable for interventions in existing buildings where the application of continuous external reinforcement is constrained by construction or heritage-related limitations.

Methods based on metallic confinement and prestressed systems presented variable yet significant gains in both compression and shear. The variability of the results is associated with factors such as masonry geometry, material integrity, and the efficiency of anchorage of confinement elements. Even so, these systems are particularly relevant for applications in historic buildings due to their reversibility and reduced visual impact. Overall, the results indicate that the highest percentage gains are predominantly associated with shear loading, especially in continuous or semi-continuous external strengthening systems, whereas compressive gains tend to be more limited and strongly dependent on confinement mechanisms. Accordingly, Table 3 highlights that the selection of the strengthening technique should consider not only the desired level of improvement, but also the masonry typology, the prevailing loading condition, and the constructional, functional, and heritage-related constraints of the building.

P4 – WHAT LIMITATIONS WERE IDENTIFIED IN THE ANALYZED STRENGTHENING SYSTEMS?

In order to address Research Question P4, Table 4 summarizes the main limitations and challenges reported for the strengthening systems analyzed, as described in the selected studies. The limitations were organized by strengthening technique group, highlighting aspects related to mechanical behavior, durability, substrate compatibility, execution conditions, and applicability to existing buildings, with particular emphasis on unreinforced masonry and historic constructions.

Table 4 – Synthesis of the Limitations of Strengthening Systems in Unreinforced Masonry

Strengthening Technique	Main Limitations	Nature of the Limitation	Authors
FRP with epoxy matrix	Irreversibility, incompatibility with historic masonry, brittle debonding failure	Compatibility and mechanical behavior	Corradi et al. (2014); De Santis et al. (2019)
TRM / FRCM	Performance variability and fiber slippage failure	Execution and interface behavior	Corradi et al. (2014); Bertolesi et al. (2020); Jafarian et al. (2024)
Steel reinforcement	Increased mass, corrosion risk, and brittle behavior	Structural dynamics and durability	Messali et al. (2017); Borri et al. (2014); Ranjan et al. (2023)
NSM	Dependence on epoxy adhesives and asymmetric structural behavior	Execution and global mechanical response	Al-Jaberi and Myers (2015); Jafarian et al. (2024)
Natural fibers	Low durability and limited mechanical strength	Material properties and durability	Ferrara et al. (2020); Cassese et al. (2021)
Injection and repair techniques	Ineffectiveness in non-injectable historic masonry	Compatibility	Rogiros Illampas et al. (2017)

Source: Prepared by the authors.

The analysis of the selected studies demonstrates that no strengthening technique is free from limitations, which are strongly conditioned by substrate compatibility, application method, and the structural context of the building. For FRP systems based on epoxy matrices, the main constraints are associated with the irreversibility of the intervention, chemical incompatibility with historic masonry, and the environmental sensitivity of the adhesive. These factors limit their applicability in heritage conservation scenarios and in environments subject to thermal variations or high humidity.

TRM and FRCM systems, although widely recognized for their compatibility with historic substrates, present limitations related to performance variability and the occurrence of premature failures due to fiber slippage or debonding at the matrix–substrate interface. Additionally, the reliance on predominantly manual installation procedures and uncertainties regarding the actual effectiveness of mechanical connectors introduce challenges in terms of standardization, repeatability of results, and structural design, particularly when applied over large surface areas. In the case of steel-based strengthening systems, the main limitations arise from the increase in structural mass and stiffness, which may result in adverse effects under seismic actions. Susceptibility to corrosion and the potential for brittle behavior under certain

failure modes are also critical factors, especially in aggressive environments or long-term interventions. Near-Surface Mounted (NSM) techniques share some of the constraints of FRP systems, particularly when epoxy adhesives are used, and may exhibit asymmetric structural behavior when applied unilaterally. Solutions based on natural fibers are characterized by limitations related to durability and mechanical resistance, particularly when used within alkaline cementitious matrices. This restricts their application to specific contexts or requires the use of alternative matrices to ensure adequate long-term performance. Finally, traditional repair methods, such as grout injection, may prove ineffective or even detrimental in certain types of historic masonry, reinforcing the need for a careful assessment of compatibility between the intervention technique and the base material. Overall, the findings indicate that the limitations of strengthening systems are not exclusively linked to mechanical performance, but also to constructability, environmental exposure, and heritage considerations. These results highlight the importance of an integrated approach in selecting intervention techniques for unreinforced masonry, simultaneously considering structural efficiency, durability, compatibility, and the specific application context.

P5 – HOW DO MECHANICAL STRENGTH GAINS RELATE TO THE TECHNICAL LIMITATIONS OF THE DIFFERENT STRENGTHENING SYSTEMS ANALYZED?

The analysis of the selected studies indicates that strengthening systems for unreinforced masonry exhibit a trade-off relationship between the level of mechanical improvement achieved and the technical limitations associated with their application. In general, techniques capable of providing higher strength gains tend to impose greater constraints in terms of constructability, durability, and reversibility, whereas solutions with moderate gains are typically more suitable for rehabilitation and heritage preservation contexts. In this regard, fiber-reinforced polymer (FRP) systems stand out for their significant strength enhancements; however, their application is frequently constrained by limitations related to hygrothermal behavior, intervention irreversibility, and incompatibility with historic masonry (ElMalyh et al., 2020; Bernat-Masó et al., 2019). These aspects restrict their use in existing buildings, particularly where the preservation of the physico-chemical integrity of the substrate is required.

Conversely, TRM and FRCM systems present a more balanced relationship between structural performance and technical compatibility. Although they do not consistently achieve the maximum gains observed in polymer-based systems, these solutions combine relevant mechanical improvements with greater vapor permeability and improved substrate interaction, which explains their recurrent adoption in historic buildings (Babaeidarabad et al., 2014; Ismail & Ingham, 2016; Torres et al., 2021). Intermediate techniques, such as Near-Surface Mounted (NSM) systems and metallic confinement, occupy a compromise position between efficiency and invasiveness. These methods provide consistent mechanical gains with reduced visual impact; however, their effectiveness is strongly dependent on execution quality and substrate conditions, and they may be associated with localized risks, such as damage to masonry units. Solutions based on natural fibers and high-ductility materials demonstrate that more limited mechanical gains may be offset by benefits related to sustainability and improved post-peak

behavior. Nevertheless, concerns regarding durability and long-term stability still constrain their application to specific or experimental contexts (Menna et al., 2015; Ferrara et al., 2020).

Highly invasive systems, such as precast panel solutions, illustrate that the highest strength gains are often achieved at the expense of substantial modifications to the original structural system, increased mass, and elevated construction costs. Such interventions are therefore recommended only in scenarios where structural risk justifies their magnitude (Xu et al., 2022). The integrated findings of this analysis indicate that, in the context of box-type buildings in the Recife Metropolitan Region, the most suitable strengthening systems are those that balance mechanical strength gains with technical limitations, avoiding excessively invasive or behaviorally incompatible solutions. In this scenario, systems based on inorganic matrices—such as TRM and FRCM—controlled metallic confinement strategies, and NSM reinforcement techniques emerge as particularly appropriate. These systems demonstrate the capacity to promote significant shear strength increases and improvements in post-peak behavior, combined with greater constructability compatibility, reduced visual impact, and feasibility for application in existing buildings. In contrast, solutions that prioritize maximum strength gains—such as polymer-based systems with epoxy matrices or highly invasive structural interventions—tend to present substantial restrictions regarding durability, execution, and substrate compatibility, making them less suitable for this specific building typology.

Accordingly, the results of this Systematic Literature Review reinforce that the selection of strengthening systems should prioritize techniques that reconcile mechanical performance, constructability, and compatibility with unreinforced masonry, rather than exclusively maximizing strength enhancement.

CONCLUSION

This Systematic Literature Review critically analyzed the main strengthening systems applied to unreinforced masonry, highlighting recent advances in research and the growing relevance of the topic within the context of structural rehabilitation. The results indicate that the most significant mechanical strength gains are predominantly associated with shear loading conditions, achieved through different external strengthening strategies. It was observed that techniques associated with high strength gains—such as polymer-based systems and highly invasive solutions—present relevant technical limitations related to durability, constructability compatibility, and reversibility, which restrict their application in existing buildings. In contrast, systems based on inorganic matrices, such as TRM and FRCM, as well as Near-Surface Mounted (NSM) reinforcement and controlled confinement strategies, demonstrated a more balanced relationship between mechanical performance and technical limitations, showing greater suitability for interventions in unreinforced masonry.

The integrated analysis reinforces that there is no universally superior solution; rather, the selection of a strengthening system depends on the masonry typology, the predominant loading condition, and the construction constraints of the building. In the context of box-type buildings in the Recife Metropolitan Region, the findings of this review indicate that techniques with greater constructability compatibility and lower levels of invasiveness tend to be more

technically appropriate, provided they are supported by adequate structural diagnosis and compatible design criteria.

REFERENCES

ALJABERI, Z.; MYERS, J. J. Influence of Near-Surface Mounted (NSM) FRP with cementitious material on the Out-of-Plane Behavior of Reinforced Masonry Walls. **8th International Structural Engineering and Construction Conference** 1 jan. 2015. DOI: 10.13140/RG.2.1.1348.9363

ALMEIDA, J. A. P. P.; PEREIRA, E. B.; BARROS, J. A. O. Assessment of overlay masonry strengthening system under in-plane monotonic and cyclic loading using the diagonal tensile test. **Construction and Building Materials**, v. 94, p. 851–865, 24 jul. 2015. DOI: 10.1016/j.conbuildmat.2015.07.040

ANGIOLILLI, M. et al. Fiber Reinforced Cementitious Matrix (FRCM) for strengthening historical stone masonry structures: Experiments and computations. **Engineering Structures**, v. 224, p. 111102, dez. 2020. DOI: 10.1016/j.engstruct.2020.111102

ANGIOLILLI, M.; GREGORI, A.; CATTARI, S. Performance of Fiber Reinforced Mortar coating for irregular stone masonry: Experimental and analytical investigations. **Construction and Building Materials**, v. 294, p. 123508, ago. 2021. DOI: 10.1016/j.conbuildmat.2021.123508

BABAEIDARABAD, R. et al. Seismic retrofit of URM-infilled RC frames by the steel-jacketed hybrid walls. **Engineering Structures**, v. 291, p. 116438, set. 2023. DOI: 10.1016/j.engstruct.2023.116438

BERNAT-MASÓ, E.; GIL, L. Assessing the performance of CFRP strengthening on masonry walls using experimental modal analysis. **Engineering Structures**, v. 193, p. 184–193, 17 maio 2019. DOI: 10.1016/j.engstruct.2019.05.036

BERTOLESI, E. et al. Effectiveness of textile reinforced mortar (TRM) materials in preventing seismic-induced damage in a U-shaped masonry structure submitted to pseudo-dynamic excitations. **Construction and Building Materials**, v. 248, p. 118532, jul. 2020. DOI: 10.1016/j.conbuildmat.2020.118532

BITAR, R. et al. Strengthening unreinforced masonry walls using natural hemp fibers. **Journal of Building Engineering**, v. 30, p. 101253, jul. 2020. DOI: 10.1016/j.jobbe.2020.101253

BORRI, A. et al. Masonry wall panels with GFRP and steel-cord strengthening subjected to cyclic shear: An experimental study. **Construction and Building Materials**, v. 56, p. 63–73, abr. 2014. DOI: 10.1016/j.conbuildmat.2014.01.056

ANUHYA, C. L. et al. Compression behaviour of brick masonry strengthened with Textile Reinforced Concrete (TRC) – A preliminary study. **IOP Conference Series Materials Science and Engineering**, v. 577, n. 1, p. 012053–012053, 1 nov. 2019. DOI: 10.1088/1757-899X/577/1/012053

CAROZZI, F. G. et al. Ancient masonry arches and vaults strengthened with TRM, SRG and FRP composites: Experimental evaluation. **Composite Structures**, v. 187, p. 466–480, mar. 2018. DOI: 10.1016/j.compstruct.2017.12.075

CASSESE, P. et al. In-plane shear behaviour of adobe masonry wallets strengthened with textile reinforced mortar. **Construction and building materials**, v. 306, p. 124832–124832, 1 nov. 2021. DOI: 10.1016/j.conbuildmat.2021.124832

CASTRO, A. A. B. DA C. et al. Morphological Aspects and Quality of Urban Life. **Revista Nacional de Gerenciamento de Cidades**, v. 12, n. 85, 27 jun. 2024. DOI: 10.17271/23188472128520244213

COLOMBO, M. et al. Fibre reinforced mortar application for out-of-plane strengthening of schist walls. **Construction and Building Materials**, v. 121, p. 185–197, set. 2016. DOI: 10.1016/j.conbuildmat.2016.05.158

CORRADI, M. et al. Shear strengthening of wall panels through jacketing with cement mortar reinforced by GFRP grids. **Composites Part B: Engineering**, v. 64, p. 33–42, ago. 2014. DOI: 10.1016/j.compositesb.2014.03.022

DE SANTIS, S. et al. Out-of-plane seismic retrofitting of masonry walls with Textile Reinforced Mortar composites. **Bulletin of Earthquake Engineering**, v. 17, n. 11, p. 6265–6300, 9 set. 2019. DOI: 10.1007/s10518-019-00701-5

DE SANTIS, S. et al. Seismic performance of masonry walls retrofitted with steel reinforced grout. **Earthquake Engineering & Structural Dynamics**, v. 45, n. 2, p. 229–251, 16 set. 2015. DOI: 10.1002/eqe.2625

DEMAJ, A. et al. Shear performance of brick masonry walls reinforced with twisted steel bars. **Structures**, v. 58, p. 105579, dez. 2023. DOI: 10.1016/j.istruc.2023.105579

DINÇ-ŞENGÖNÜL, B. et al. Behavior of grout injected solid stone masonry walls under in-plane loading. **Structures**, v. 58, p. 105411, dez. 2023. DOI: 10.1016/j.istruc.2023.105411

DONG, Z. et al. Strengthening of unreinforced masonry walls against out-of-plane loads using carbon textile reinforced mortar optimized by short PVA fibers. **Engineering Structures**, v. 227, p. 111433–111433, 1 nov. 2020. DOI: 10.1016/j.engstruct.2020.111433

ELMALYH, S. et al. Shear Strength of Unreinforced Masonry Walls Retrofitted with CFRP. **Advances in Science, Technology and Engineering Systems Journal**, v. 5, n. 2, p. 351–359, 2020. DOI: 10.25046/aj050246

FERRARA, G. et al. Shear capacity of masonry walls externally strengthened using Flax-TRM composite systems: experimental tests and comparative assessment. **Construction and Building Materials**, v. 261, p. 120490, nov. 2020. DOI: 10.1016/j.conbuildmat.2020.120490

FOLHA DE PERNAMBUCO. *Prédios tipo caixa e desabamentos no Recife*. Disponível em: <https://www.folhape.com.br/noticias/predios-caixao-desabamento/409450>. Acesso em: 9 jan. 2025.

GATTESCO, N.; BOEM, I. Experimental and analytical study to evaluate the effectiveness of an in-plane reinforcement for masonry walls using GFRP meshes. **Construction and Building Materials**, v. 88, p. 94–104, jul. 2015. DOI: 10.1016/j.conbuildmat.2015.04.014

GONEN, S. et al. Stochastic discontinuum analysis of unreinforced masonry walls: Lateral capacity and performance assessments. **Engineering Structures**, v. 238, p. 112175, jul. 2021. DOI: 10.1016/j.engstruct.2021.112175

HABIEB, A. B. et al. Seismic Retrofitting of Indonesian Masonry Using Bamboo Strips: An Experimental Study. **Buildings**, v. 13, n. 4, p. 854, 24 mar. 2023. DOI: 10.3390/buildings13040854

HUNG, C.-C. et al. Comparative studies on in-plane shear behavior of masonry wallettes retrofitted with mortar, UHPC, and ECC ferrocement: Shotcrete and prefabricated panels. **Case Studies in Construction Materials**, v. 21, p. e03801–e03801, 27 set. 2024. DOI: 10.1016/j.cscm.2024.e03801

ISMAIL, N.; INGHAM, J. M. In-plane and out-of-plane testing of unreinforced masonry walls strengthened using polymer textile reinforced mortar. **Engineering Structures**, v. 118, p. 167–177, jul. 2016. DOI: 10.1016/j.engstruct.2016.03.041

JAFARI, A. et al. Effect of the FRP sheet's arrays and NSM FRP bars on in-plane behavior of URM walls. **Journal of Building Engineering**, v. 20, p. 679–695, 20 set. 2018. DOI: 10.1016/j.jobe.2018.09.018

JAFARIAN, S. et al. Performance of low-carbon textile-reinforced mortar: Out-of-plane response of strengthened masonry walls. **Construction and Building Materials**, v. 415, p. 134904, fev. 2024. DOI: 10.1016/j.conbuildmat.2024.134904

JOO HA LEE. Compressive and Shear Behavior of Masonry Reinforced with Ultra-Rapid-Hardening Fiber-Reinforced Mortar (URH-FRM). **Materials**, v. 15, n. 24, p. 8825–8825, 10 dez. 2022. DOI: 10.3390/ma15248825

KAFODYA, I.; OKONTA, F.; KLOUKINAS, P. Role of fiber inclusion in adobe masonry construction. **Journal of Building Engineering**, v. 26, p. 100904, nov. 2019. DOI: 10.1016/j.jobe.2019.100904

KOURIS, L. A. S.; TRIANTAFILLOU, T. C. State-of-the-art on strengthening of masonry structures with textile reinforced mortar (TRM). **Construction and Building Materials**, v. 188, p. 1221–1233, nov. 2018. DOI: 10.1016/j.conbuildmat.2018.08.039

LOURENÇO, P. B. Monuments and Historic Buildings: Monuments and Historic Buildings: Earthquakes and Structural Engineering. **World Congress on Civil, Structural, and Environmental Engineering**, abr. 2022. DOI: 10.11159/icsect22.002

MARCARI, G.; BASILI, M.; VESTRONI, F. Experimental investigation of tuff masonry panels reinforced with surface bonded basalt textile-reinforced mortar. **Composites Part B: Engineering**, v. 108, p. 131–142, jan. 2017. DOI: 10.1016/j.compositesb.2016.09.094

MÉLO, Mauro José Araújo Campelo de. Análise de laudos emitidos sobre "prédios tipo caixa" da região metropolitana de Recife : causas apontadas para os desabamentos e interdições. 2007. 167 f. Dissertação (Mestrado em Engenharia Civil) - **Universidade Católica de Pernambuco**, Recife, 2007.

MESSALI, F.; METELLI, G.; PLIZZARI, G. Experimental results on the retrofitting of hollow brick masonry walls with reinforced high performance mortar coatings. **Construction and Building Materials**, v. 141, p. 619–630, jun. 2017. DOI: 10.1016/j.conbuildmat.2017.03.112

MEZREA, P. E. et al. Diagonal tensile tests on historical brick masonry wallets strengthened with fabric reinforced cementitious mortar. **Structures**, v. 33, p. 935–946, out. 2021. DOI: 10.1016/j.istruc.2021.04.076

MIRABI BANADAKI, H.; ESLAMI, A.; RONAGH, H. Near-surface-mounted retrofitting of damaged/undamaged adobe walls using steel bars: Analytical evaluation of experimental results. **Structures**, v. 28, p. 2111–2121, dez. 2020. DOI: 10.1016/j.istruc.2020.10.020

OLIVEIRA, R. A. et al. Structural performance of unreinforced masonry elements made with concrete and horizontally perforated ceramic blocks – Laboratory tests. **Construction and Building Materials**, v. 182, p. 20–34, set. 2018. DOI: 10.1016/j.conbuildmat.2018.06.092

PAGE, M. J. et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. **British Medical Journal**, v. 372, n. 71, 2021.

PINHO, F. F. S.; LÚCIO, V. J. G.; BAIÃO, M. F. C. Experimental analysis of rubble stone masonry walls strengthened by transverse confinement under compression and compression-shear loadings. **International Journal of Architectural Heritage**, v. 12, n. 1, p. 91–113, 20 nov. 2017. DOI: 10.1080/15583058.2017.1377314

PRECIADO, A. et al. Seismic damage and retrofitting identification in unreinforced masonry Churches and bell towers by the september 19, 2017 (Mw = 7.1) Puebla-Morelos earthquake. **Engineering Failure Analysis**, v. 118, p. 104924, dez. 2020. DOI: 10.1016/j.engfailanal.2020.104924

RANJAN, N. et al. Exploring applicability of recycled nylon fiber reinforced mortar in joints and plaster to enhance the bond strength, in-plane and out-of-plane capacity of masonry structures. **Journal of Building Engineering**, v. 72, p. 106744, ago. 2023. DOI: 10.1016/j.job.2023.106744

RAO, K. S. N.; PAVAN, G. S. FRP-Confined Clay Brick Masonry Assemblages under Axial Compression: Experimental and Analytical Investigations. **Journal of Composites for Construction**, v. 19, n. 4, p. 04014068, ago. 2015. DOI: 10.1061/(ASCE)CC.1943-5614.0000525

ROGIROS ILLAMPAS et al. Validation of the repair effectiveness of clay-based grout injections by lateral load testing of an adobe model building. **Construction and Building Materials**, v. 153, p. 174–184, 17 jul. 2017. DOI: 10.1016/j.conbuildmat.2017.07.054

SANDOVAL, O. J. et al. Performance of unreinforced masonry panels strengthened with mortar overlays reinforced with welded wire mesh and transverse connectors. **Construction and Building Materials**, v. 267, p. 121054–121054, 14 out. 2020. DOI: 10.1016/j.conbuildmat.2020.121054

SILVA, L. F. C. DA et al. Sistema de Indicadores de Sustentabilidade Urbana para Pequenas Cidades. **Revista Nacional de Gerenciamento de Cidades**, v. 12, n. 87, 26 dez. 2024. DOI: 10.17271/23188472128720245181

SOLEYMANI, A. et al. In-plane shear strengthening of traditional unreinforced masonry walls with near surface mounted GFRP bars. **Construction and Building Materials**, v. 367, p. 130362, fev. 2023. DOI: 10.1016/j.conbuildmat.2023.130362

SPINELLA, N.; COLAJANNI, P.; RECUPERO, A. Experimental in situ behaviour of unreinforced masonry elements retrofitted by pre-tensioned stainless steel ribbons. **Construction and Building Materials**, v. 73, p. 740–753, 1 dez. 2014. DOI: 10.1016/j.conbuildmat.2014.09.116

THOMOGLU, A. K.; JAGADESH; VOUTETAKI, M. E. Review of Out-of-Plane Strengthening Techniques of Unreinforced Masonry Walls. **Fibers**, v. 11, n. 9, p. 78–78, 19 set. 2023. DOI: 10.3390/fib11090078

TORRES, B. et al. Textile reinforced mortars (TRM) for repairing and retrofitting masonry walls subjected to in-plane cyclic loads. An experimental approach. **Engineering Structures**, v. 231, p. 111742, mar. 2021. DOI: 10.1016/j.engstruct.2020.111742

XU, W. et al. Experimental and numerical investigation on the seismic performance of masonry walls reinforced by PC panels. **Journal of Building Engineering**, v. 58, p. 105049–105049, 6 ago. 2022. DOI: 10.1016/j.job.2022.105049

YARDIM, Y.; LALAJ, O. Shear strengthening of unreinforced masonry wall with different fiber reinforced mortar jacketing. **Construction and Building Materials**, v. 102, p. 149–154, jan. 2016. DOI: 10.1016/j.conbuildmat.2015.10.095

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20

DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, **Isaac Sérgio Araújo de Brito, Emilia Rahnemay Kohlman Rabbani; Victor Marcelo Estolano de Lima; Tiago Ancelmo de C. Pires** declaro(amos) que o manuscrito intitulado **“Reforço de alvenarias não armadas: uma revisão sistemática dos ganhos mecânicos e das limitações dos sistemas de reforço”**:

1. **Vínculos Financeiros:** Não possui/possui vínculos financeiros que possam influenciar os resultados ou interpretação do trabalho. Este trabalho foi financiado pela FACEPE - Fundação de Amparo à Ciência e Tecnologia de Pernambuco.
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