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Optimizing FRCM Retrofitting Through FEM: Effects of Matrix Thickness, Mesh Size, and Textile Geometry

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ABSTRACT

In Heritage constructions preservation, compatibility with existing materials, long-term durability, and structural performance are critically required. In this respect, the strengthening or repair of masonry panels using inorganic-based composite systems such as Fabric-Reinforced Cementitious Matrix (FRCM) has become an effective and increasingly adopted strategy. While experimental studies have widely demonstrated their capacity to enhance in-plane resistance and deformation capacity, the comprehensive assessment of damage processes within the strengthened system remains limited.

Accordingly, this study presents a validated numerical investigation of the nonlinear shear response of masonry systems, including descriptions of the experimental models and the corresponding adopted material laws. Parametric analyses were conducted to assess the influence of the matrix thickness, textile mesh size, and their configuration on the ultimate shear capacity and the corresponding failure mode. Results in terms of shear stress and damage distribution indicate that the mechanical compatibility between the matrix and the fabric is crucial for providing an optimal retrofitting design.

1 Introduction

Unreinforced masonry (URM) shear-walls are widely used in existing buildings and Heritage constructions [1–3]. However, they exhibit limited tensile strength and brittle behavior when subjected to in-plane loading, particularly under seismic actions [4, 5]. Shear failure in masonry walls is typically governed by diagonal tension cracking [6], sliding along mortar joints [7], or combined shear–compression mechanisms [8], leading to rapid stiffness degradation and poor energy dissipation [9]. For this reason, significant research efforts have been devoted over the past two decades to developing

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effective and compatible strengthening techniques capable of improving the strength and ductility of URM [10–12]. Among the available retrofitting solutions, FRCM systems have emerged as a promising alternative to traditional Fiber-Reinforced Polymer (FRP) composites [8, 13–17]. Unlike FRP systems, which rely on organic epoxy resins, FRCM employs an open-mesh fiber textile embedded within an inorganic mortar matrix, typically cement-based natural hydraulic lime (NHL) [18, 19], or geopolymer, ensuring improved permeability, fire resistance, and physicochemical compatibility with masonry substrates—features that are particularly relevant in Heritage conservation applications [20–22].

Under in-plane shear loading, FRCM strengthening enhances the mechanical response of URM panels by activating a tensile-resistant mechanism aligned with the principal stress directions. The textile fibers bridge developing cracks and delaying their propagation, while the mortar matrix provides stress transfer and mechanical interlock at the interface. Experimental investigations [23–25] have consistently shown that FRCM-reinforced panels exhibit increased shear strength, improved deformation capacity, and enhanced post-peak residual behavior compared to unreinforced specimens. In this respect, Longo et al. [9] proposed a geopolymer-based inorganic matrix composite as an innovative solution for simultaneous structural and energy retrofitting of existing buildings. The authors' experimental investigations on double-sided retrofitted masonry panels demonstrated that the geopolymer system achieves mechanical performance comparable to conventional lime-based systems, while offering superior thermal insulation. The findings highlight FRCM's potential to enhance both seismic resistance and thermal efficiency of masonry structures.

The effectiveness of FRCM systems under shear depends on several interacting parameters, including the mechanical properties of the textile, mesh geometry, reinforcement ratio, mortar characteristics, composite thickness, and the quality of bond at the fabric-to-matrix interface. For this purpose, analytical and numerical approaches [1, 2, 26–28] have been employed to reduce experimental costs and overcome the limitations associated with extensive laboratory testing, while enabling a deeper understanding of the governing mechanisms and parameter interactions. Accordingly, Calò et al. [27] developed an analytical model specifically aimed at quantifying the mechanical contribution of FRCM systems by introducing the new concept of fabric exploitation factor, a parameter that measures the degree to which the textile tensile capacity is actually mobilized during loading. As highlighted in their work, the effectiveness of an FRCM retrofit does not depend solely on the nominal tensile strength of the fibers, but rather on the portion of that strength that can be activated through the fabric-to-matrix interaction. The exploitation factor, therefore, captures the combined influence of matrix stiffness, bond efficiency, and crack-bridging mechanisms, providing a rational indicator of how much of the textile's theoretical capacity is effectively used before failure. Their results demonstrated that FRCM systems often operate far below full fabric utilization, and that strengthening efficiency is governed by the compatibility between the mortar matrix and the textile. This concept is particularly relevant for the present study, where the numerical results confirm that variations in matrix thickness, mesh size, and textile thickness directly affect the exploitation level of the reinforcement, and thus the global performance of the strengthened masonry panel. In addition, Calò et al. [29] conducted a numerical study on masonry wall retrofitting with inorganic composite systems, including FRCM. Using calibrated FEMs, the authors found that the exploitation factor of the reinforcing fabric strongly depends on the mechanical compatibility with the matrix.

Based on the synthesis presented above, studies focusing on damage mechanisms in masonry systems remain limited. Therefore, the present work aims to complement the finite element results proposed by Calò et al. [29] by addressing previously unexplored aspects through a comprehensive representation of damage initiation and its subsequent evolution. Indeed, the impact of the matrix depth, textile mesh size, and thickness on the ultimate shear capacity and the corresponding damage localization is numerically focused under ABAQUS [30]. The paper is structured as follows: first, the finite element implementation of the proposed model is described, including mesh sensitivity and stability considerations, constitutive material modeling and calibration procedures, as well as loading and boundary conditions. Finally, the numerical results are validated against available reference data. The parametric analysis results demonstrate the synergistic effect of NHL and fabric, leading to a transition from brittle to ductile behavior and a marked reduction in damage propagation and severity, thus providing enhanced energy dissipation capacity and improved structural resilience.

2 FEM Implementation

The experimental model studied by Longo et al. [9] on masonry panels reinforced with various types of materials was simulated. Three short walls made of solid bricks, assembled with mortar joints, were modeled under ABAQUS [30]. The walls have a total height and width of 51 cm, and a thickness of 12 cm. Three simulated wall configurations are considered

in the present study, namely: unreinforced wall (URM), reinforced wall with external matrix bonded on the two sides (NHL), and reinforced wall with a fabric reinforced with a cementitious matrix (FRCM). Figures 1 and 2 show the confrontation between the designed and tested panels by Longo et al. [9] and the generated ones in the present FEM study. Moreover, the bricks and mortars were meshed using eight-node continuous shell elements with reduced integration and bending control, designated SC8R. The alkali-resistant (AR) glass textile was modeled using eight-node 3D solid elements (C3D8R), known for their excellent bending control and reduced integration capabilities.

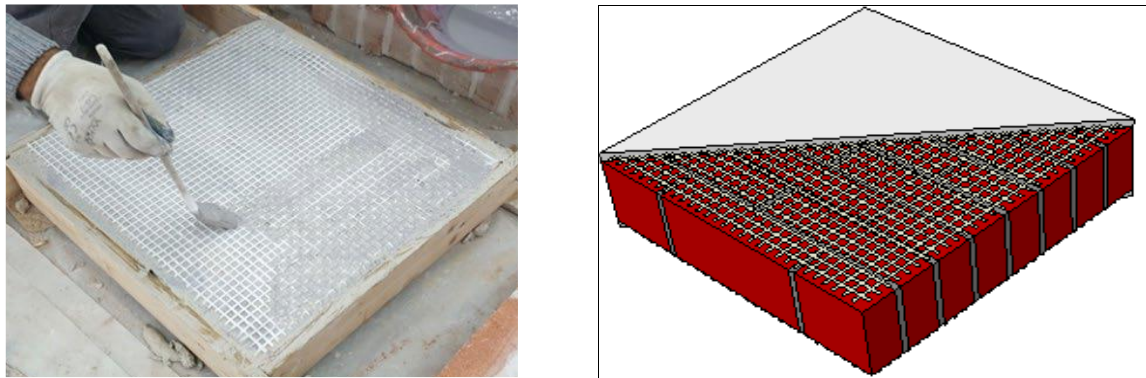


Fig. 1 – 3D views of the simulated FRCM walls tested by Longo et al. [9]

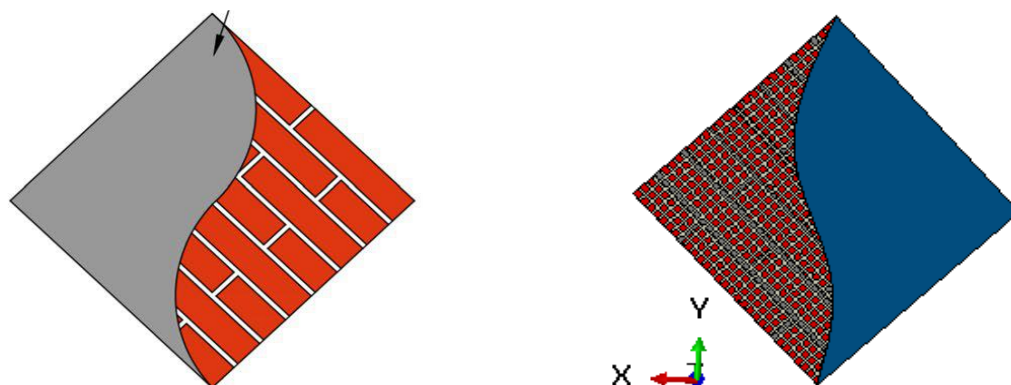


Fig. 2 – FRCM wall under in-plane shear loading: Test [9] versus FEM

Selecting an appropriate mesh size is crucial in finite element simulations, as it affects both the reliability of the results and the computational efficiency of the model. Using a variety of element sizes, a mesh sensitivity was carried out to allow the model to capture refined modeling details while effectively representing the overall behavior. Table 1 recapitulates the strain values corresponding to the ultimate shear load of each simulated mesh size.

Table 1 - Mesh convergence results in terms of strain value

Mesh size (mm)	30	25	20	15	10	8	6	4	2
Shear Strain (‰)	4.30	2.51	2.10	1.18	1.15	1.12	1.10	1.10	1.11

A significant reduction in shear strain is observed when refining the mesh from 30 mm to 15 mm, indicating strong mesh dependency at a coarse discretization. Beyond 15 mm, the strain values stabilize around 1.10‰, demonstrating numerical convergence. Accordingly, a mesh size of 10 mm was adopted to match the 10 mm thickness of the mortar joints, thereby avoiding nodal incompatibility at the brick–mortar interface. This choice ensures geometric consistency while providing sufficiently accurate and mesh-independent results. Furthermore, a friction coefficient of 0.2 was assigned between the brick and the mortar joint to control interfacial slip and provide a more realistic contact interaction. However, Tie constraint and embedded interactions were used for NHL mortar and textile, respectively.

2.1 Materials and BC

The in-plane shear load is applied at the top of the 45°-rotated wall, while the bottom edge remains fully clamped. The loading is imposed through a strain-controlled procedure using the static general step, applied monotonically with an incremental step of 10^{-5} . The analysis is continued until failure, which is identified by excessive damage development in the material model. According to Calo et al [29], two main material numerical models were used in the present study. Concrete damaged plasticity (CDP) for brittle and related materials was used to simulate the experimental behavior of the brick units, joint mortar, and NHL mortar. While composite textiles were modeled as elastic orthotropic materials. More details about the CDP model, measured and predicted values are provided in the cited reference [29]. However, Table 2 provides the predicted tensile and compressive damage level at each load stage of each modeled wall material.

Table 2 - CDP damage parameters of the brick and mortars.

Parameter	Brick	Joint mortar	NHL
Ultimate compressive stress (MPa) [9]	24.06	8.88	9.10
Damage at ultimate compressive stress (%)	18.29	24.12	17.19
Ultimate tensile stress (MPa) [9]	1.61	3.25	3.10
Damage at ultimate tensile stress (%)	10.72	12.58	11.87
Compressive stress at failure (MPa)	2.81	1.75	1.78
Damage at compression failure (%)	71.71	60.79	61.06
Tensile stress at failure (MPa)	0.016	0.0004	0.0035
Damage at tensile failure (%)	98.24	99.6	97.5

The elastic behavior of orthotropic composite materials, such as AR Glass textiles, can be described using the classical constitutive equations for plane stress. The stress–strain relationship in the material’s local coordinates (1,2) can be transformed to the global coordinates (x, y) using a standard coordinate transformation. According to Meddour et al. [31, 32], the generalized Hooke’s law for an orthotropic lamina under plane stress is expressed as:

$$\begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \tau_{12} \end{Bmatrix}_{\{\sigma\}} = \begin{bmatrix} \cos^2 \theta & \sin^2 \theta & 2\sin \theta \cos \theta \\ \sin^2 \theta & \cos^2 \theta & -2\sin \theta \cos \theta \\ -\sin \theta \cos \theta & \sin \theta \cos \theta & \cos^2 \theta - \sin^2 \theta \end{bmatrix} \times \underbrace{\begin{bmatrix} \bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16} \\ \bar{Q}_{12} & \bar{Q}_{22} & \bar{Q}_{26} \\ \bar{Q}_{16} & \bar{Q}_{26} & \bar{Q}_{66} \end{bmatrix}}_{[\bar{Q}]} \times \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix}_{\{\varepsilon\}} \quad (1)$$

Where, σ_x , σ_y , τ_{xy} are the stresses in the global coordinate system and ε_x , ε_y , γ_{xy} are the corresponding strains. θ is the angle between the local fiber direction and the global. $\bar{Q}_{ij}$ are the transformed reduced stiffness coefficients of the lamina, which account for the orthotropic elastic properties in the local axes. This formulation allows capturing both the anisotropic response of individual layers and the influence of layer orientation in a laminated composite. The mechanical properties of the AR Glass textile for defining the stiffness matrix used in this study are summarized in Table 3.

Table 3 - Main elastic and failure parameters of the used AR Glass textile.

Parameter	Young’s modulus (GPa)	Transverse modulus (GPa)	Poisson’s ratio	Trans. tensile stress (MPa)	Long. tensile strength (MPa)	Shear strength (MPa)
Value	108	32.4	0.33	578.7	1929	70
Reference	Measured [9]	Predicted [31]	Measured [9]	Predicted [31]	Measured [9]	Predicted [31]

The global stiffness matrix is evaluated in a tangent form and updated at each load increment to account for material nonlinearity and damage evolution, as used by Djenad et al. [33]. For masonry or mortar modeled using the Concrete Damaged Plasticity (CDP) model, the element stiffness matrix is derived from the degraded tangent constitutive matrix, which depends on the current damage variables in tension and compression, leading to a progressive reduction of stiffness

as cracking and crushing develop. The AR composite is modeled separately using an orthotropic elastic constitutive law, contributing a stable stiffness response unless additional damage criteria are activated. The global stiffness matrix is obtained by assembling the element-level tangent stiffness matrices of all materials, and equilibrium is enforced through an incremental–iterative Newton–Raphson method. As loading progresses, stiffness degradation governed by the CDP formulation directly influences the structural response, enabling accurate simulation of nonlinear behavior and damage accumulation under increasing shear demand.

3 Results interpretation

Predicted results in terms of bearing capacity and damage are highlighted and compared for each considered configuration. The main objective is to emphasize the positive contribution of the FRCM system in terms of structural resilience and ductility. The localization of damage provides valuable insight into the degree of stress exploitation within the fabric and the system’s ability to effectively redistribute stress in strengthened configurations. Accordingly, this section presents both qualitative and quantitative validation of the numerical model, followed by a parametric analysis aimed at identifying and discussing the influence of the main governing parameters.

3.1 FEM Calibration

The validation phase ensures the reliability of the simulation framework through comparison with reference results. In this respect, Table 4 provides the predicted numerical values compared to the test one, while Figure 3 illustrates the comparison between the FEM behavior versus the real experimental one of Longo et al. [9].

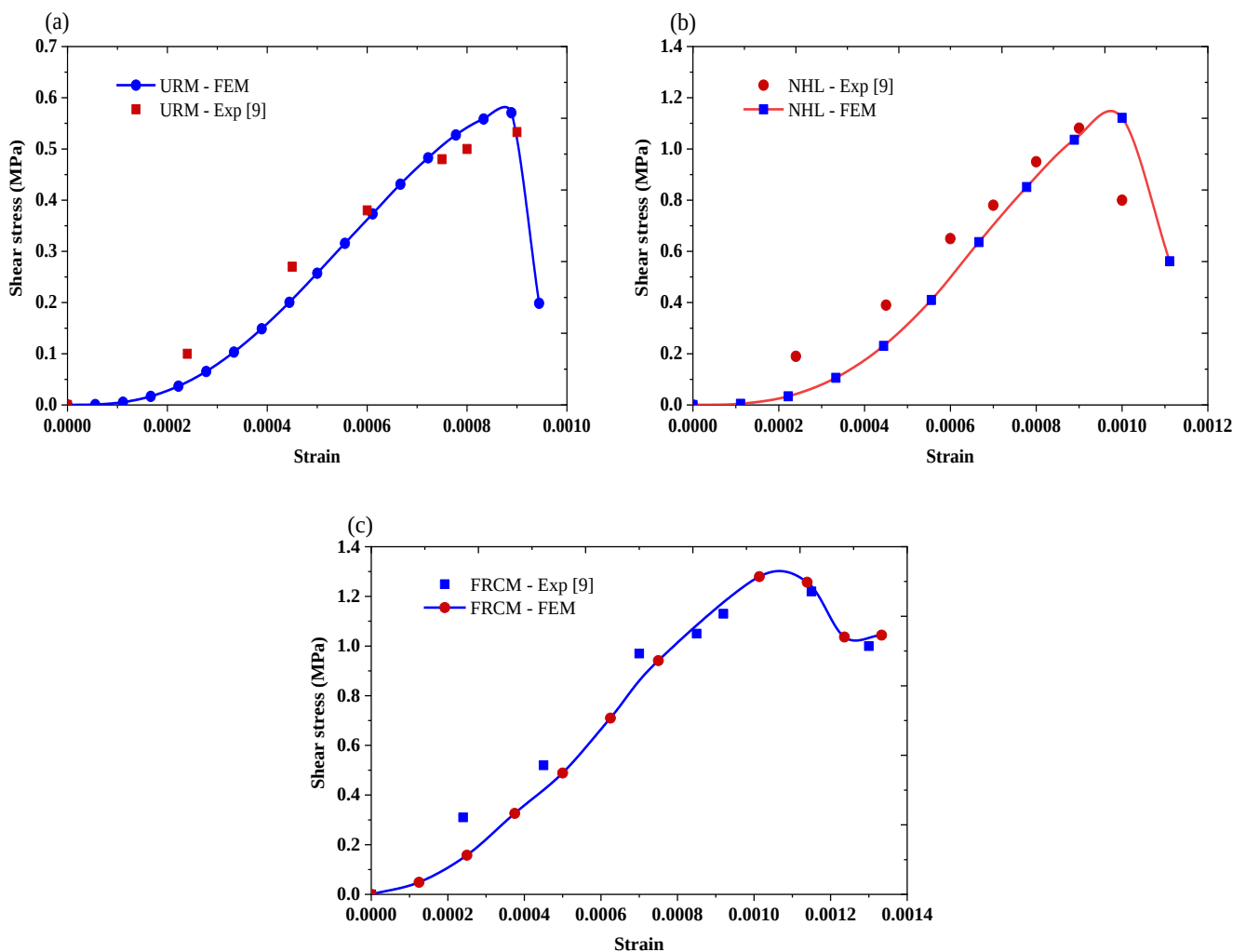


Fig. 3 - Global quantitative behavior comparison between tests [9] and present FEM: a) URM, b) NHL, c) FRCM

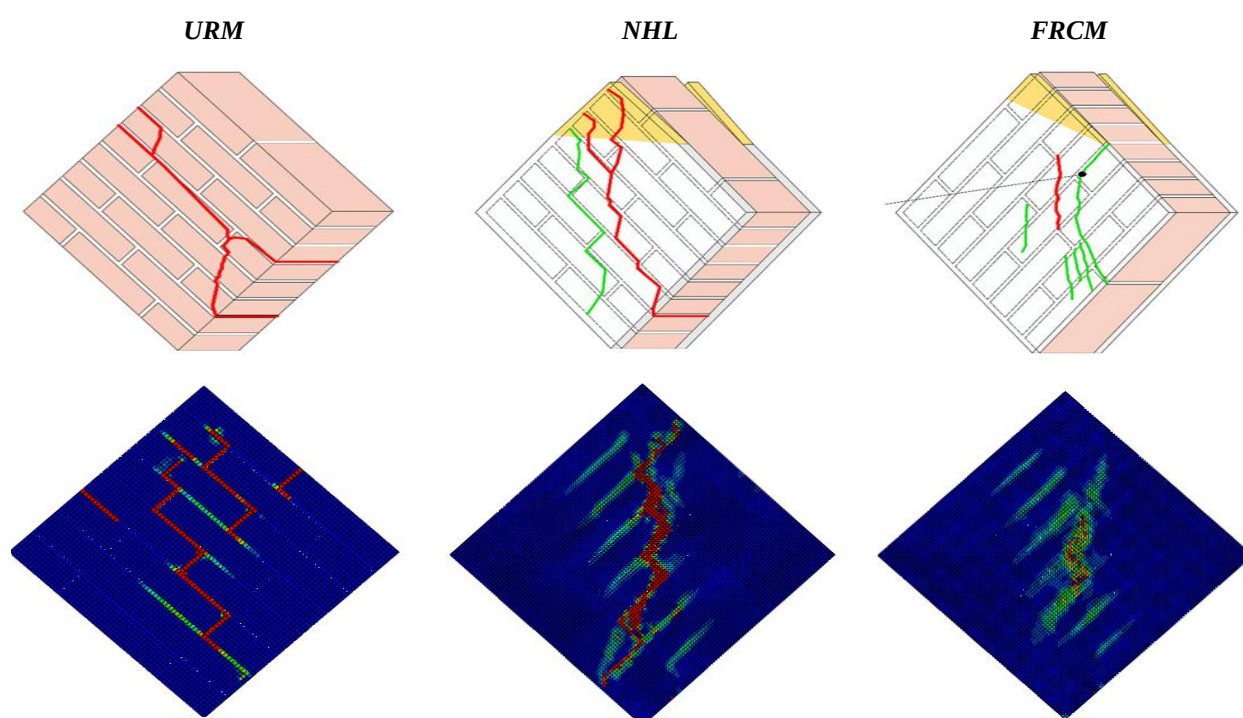
Table 4 – Recapitulation of test results [9] and the present FEM ones.

Wall designation	Exp. [9] peak load (kN)	FEM peak load (kN)	Exp. [9] strain (‰)	FEM. strain (‰)	Exp. [9] shear strength (MPa)	FEM. shear strength (MPa)
URM	46.18	49.39	0.91	0.88	0.533	0.570
NHL	93.53	97.06	0.96	1.1	1.081	1.121
FRCM	105.56	110.77	1.21	1.23	1.22	1.256

For the URM wall, the FEM peak load (49.39 kN) overestimates the experimental value (46.18 kN) by approximately 6.95 %, while the strain error is about 3.3%, and the shear strength is overestimated by nearly 6.9%. These relatively small discrepancies indicate a good agreement, confirming that the model accurately captures the brittle shear response of the unreinforced masonry. For the NHL-strengthened wall, the FEM peak load (97.06 kN) significantly underestimates the experimental value (93.53 kN), leading to a large error of about 4 %, which suggests that the model may underestimate stiffness or bonding efficiency. However, the strain prediction shows an error of about 14.6%, and the shear strength error remains limited to approximately 3.7%, indicating that while the ultimate load capacity is overpredicted, the stress level at failure is reasonably captured.

For the FRCM-strengthened wall, the FEM peak load (110.77 kN) is very close to the experimental value (105.56 kN), with an error of only 4.9%. The strain error is about 1.7%, and the shear strength is overestimated by roughly 3.0%. These relatively low error margins are even smaller than those reported by Calo et al. [28], which numerically obtained peak loads of 50.58, 110.89, and 122.83 kN for the URM, NHL, and FRCM systems, respectively. This is due to the more realistic modelling strategy adopted in the present study, particularly the explicit consideration of the brick–mortar contact interface. This improved representation of interfacial behavior enhances the accuracy of stress transfer mechanisms and damage localization. The results, therefore, demonstrate excellent correlation and confirm that the numerical model reliably reproduces the mechanical response of the strengthened masonry system.

In terms of morphological comparison, Figure 4 illustrates the localization of damage patterns in the studied walls, highlighting both the numerical predictions and the corresponding reference experimental observations [9]. Comparison enables a direct assessment of crack distribution, failure modes, and damage concentration zones, thereby evaluating the model's ability to realistically reproduce the experimentally observed structural response.

**Fig. 4 - Local qualitative behavior comparison between tests [9] and present FEM: a) URM, b) NHL, c) FRCM**

The comparison demonstrates a satisfactory agreement between the experimentally observed failure modes and the predictions from FEMs. As shown in the cartographies, the damage localization, crack development, and overall failure pattern obtained through the numerical model closely match those observed during the experimental tests. This correspondence confirms the model's ability to accurately reproduce the material's nonlinear behavior and failure mechanisms, thereby validating its use for analysis. In order to demonstrate the effect of strengthening, Figure 5 presents a comparison between the studied models in terms of shear load-bearing capacity. When comparing the behavior of the FRCM and NHL walls, some potential differences can be observed, which may be attributed to the FRCM strengthening.

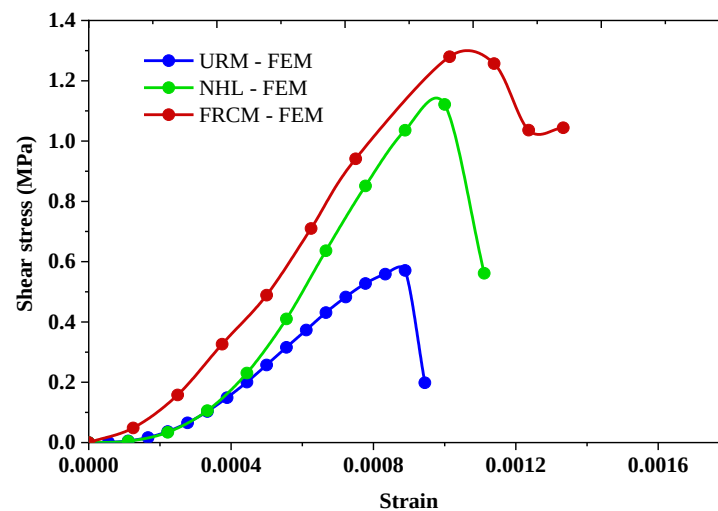


Fig. 5 - Comparison between the systems models in terms of load-bearing capacity

Compared to the URM wall, both strengthening techniques significantly improve load capacity and ductility. The NHL configuration increases the experimental peak load by approximately 48% (from 49.39 kN to 97.06 kN) and shows a slight improvement in ultimate strain, indicating moderate ductility enhancement. In contrast, the FRCM system provides a much higher gain, with an increase of about 124% in peak load (up to 110.77 kN) and a more pronounced rise in ultimate strain (from 0.91‰ to 1.21‰), demonstrating a clear shift toward a more ductile and energy-dissipative response.

3.2 Influence of NHL matrix thickness

The influence of the NHL matrix thickness was investigated by considering three configurations: 10 mm, 15 mm, and 20 mm per side. The comparison was performed using the shear load–shear displacement response in Figure 6. The results indicate that increasing the matrix thickness affects the ultimate shear strength relatively, as all configurations reach almost comparable peak stress values. However, a clear influence is observed on the initial stiffness of the system. The 15 mm and 20 mm configurations exhibit a steeper initial slope in the curves compared to the 10 mm case, reflecting enhanced shear rigidity. This behavior suggests that increasing the matrix thickness mainly improves elastic initial stiffness and deformation control, while having a limited impact on the ultimate load-carrying capacity when a certain thickness is exceeded. While the shear gain with respect to the URM remains relevant.

The damage analysis of the three thickness configurations illustrated in Figure 7 shows very similar localization patterns and crack propagation mechanisms. In all cases, damage concentrates along diagonal shear bands, indicating a dominant brittle shear failure mode. Physically, this can be explained by the fact that the masonry substrate governed overall failure: the NHL overlay, even when thicker, mainly contributes to initial stiffness and load carrying but cannot significantly delay cracking in the weaker masonry units. The transfer of shear stresses through the interface is sufficient to slightly stiffen the response, but the inherent low tensile capacity of the masonry leads to early crack localization. Therefore, while thicker NHL matrices enhance elastic rigidity, they have a negligible influence on the progression of damage and do not change the fundamentally brittle nature of the failure; hence, the need for internal reinforcement.

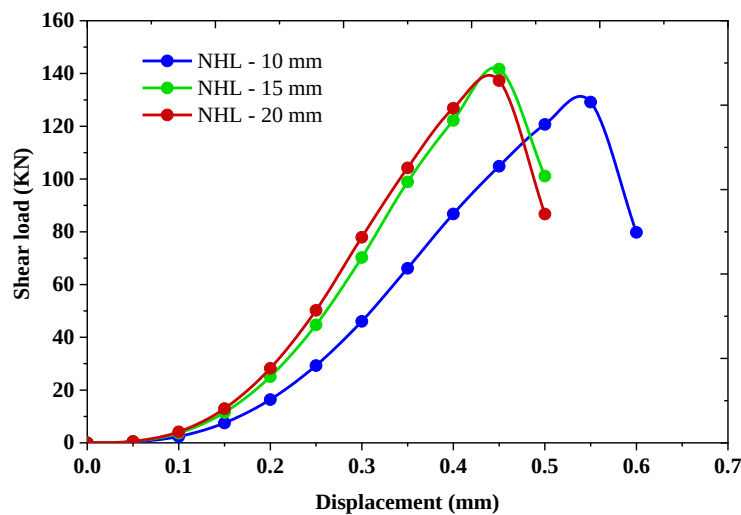


Fig. 6 - Shear stress–time curves of FRCM system according to NHL thickness

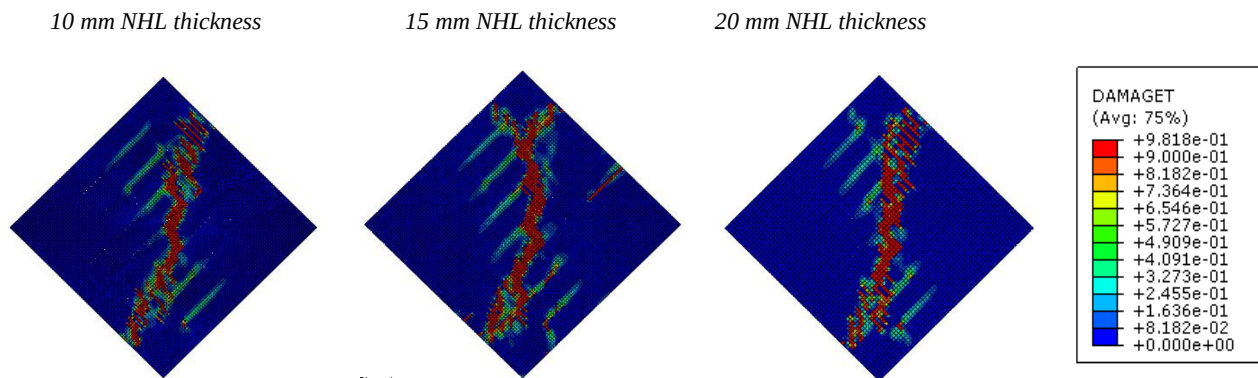


Fig. 7 - Damage localization in the FRCM system according to NHL thickness

3.3 Effect of AR Fabric Mesh Size

The influence of the AR-glass textile mesh size was examined by considering three configurations (i.e. 6×6 mm, 12×12 mm, and 18×18 mm). The numerical results show that the elastic stiffness decreases as the mesh opening increases, while the peak shear strength remains essentially unchanged across all configurations. This behavior cannot be attributed to variations in the intrinsic stiffness of the textile since the material properties are identical in all cases, but rather to the different levels of fiber density and the corresponding interaction mechanisms activated within the composite system. When a finer mesh is used, the textile contains a larger number of fibers per unit area, which enhances the continuity of stress transfer between the matrix and the reinforcement. This denser fiber arrangement promotes a more uniform distribution of tensile stresses along the masonry surface and increases the number of effective cracks-bridging points. As a result, the fabric-to-matrix interaction becomes more efficient, leading to a higher exploitation level of the textile. In parallel, the masonry substrate benefits from this improved confinement: a larger portion of the compressed region is mobilized, and the wall engages a wider area in resisting shear deformation. This combined effect explains the higher initial stiffness and the more distributed cracking observed for the 6×6 mm and 12×12 mm meshes. Conversely, enlarging the mesh opening reduces the number of fibers available to engage with the mortar matrix, thereby diminishing the stress transfer capability and lowering the textile exploitation level. The reduced strengthening effect limits the portion of masonry that actively contributes to resisting shear, leading to a more localized damage pattern and a noticeable reduction in initial stiffness. Nevertheless, the ultimate shear capacity remains governed primarily by the tensile strength of the masonry substrate, which explains why all mesh configurations reach similar peak stress values despite the different stiffness responses.

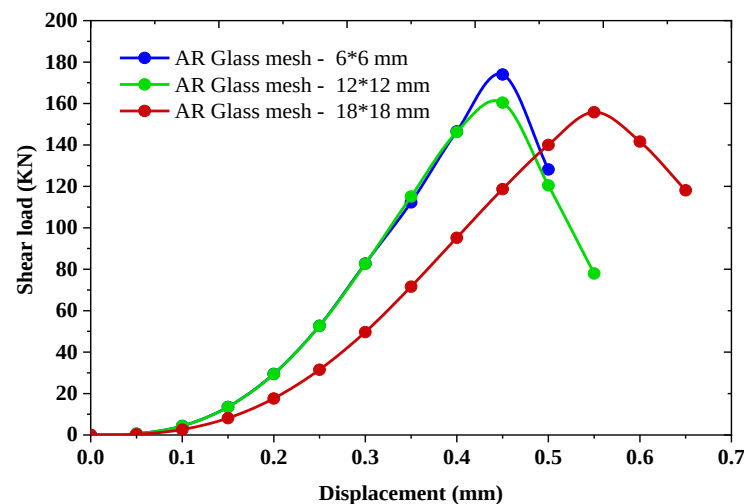


Fig. 8 - Shear stress–time curves of FRCM system according to AR Glass textile mesh size

Damage analysis according to AR fabric mesh sizes highlighted in Figure 9 shows a clear difference between the coarser 18×18 mm configuration. While the 6×6 mm and 12×12 mm meshes exhibit dense and well-distributed cracking along diagonal shear bands, the 18×18 mm mesh shows a significant reduction in damage density, with fewer cracks and smaller damaged zones. Physically, this can be explained by the interaction between the reinforcement and the masonry substrate. In finer meshes, the higher fiber density ensures more continuous stress transfer and confinement, promoting crack formation across a wider area. Conversely, the 18×18 mm mesh, with fewer fibers per unit area, is less able to activate the masonry locally, reducing stress concentration at multiple sites and therefore limiting the propagation of damage. As a result, although the coarser mesh leads to lower overall stiffness, it paradoxically shows less visible damage, because the masonry fails in a more localized manner with fewer cracks, rather than distributed damage over a larger area. This effect is consistent with the curves in Figure 8, where the 18×18 mm mesh shows reduced elastic stiffness but similar peak shear stress, highlighting that mesh size primarily influences stiffness and damage distribution rather than strength.

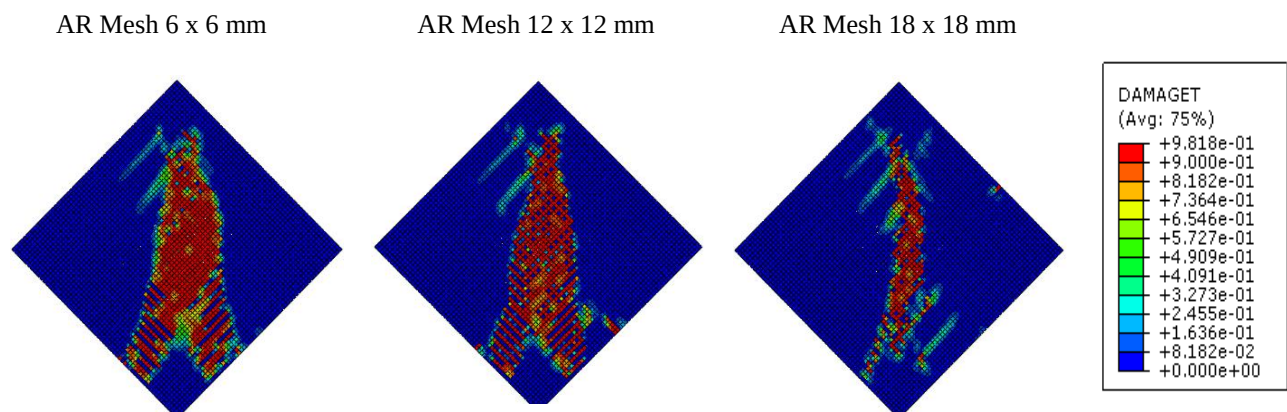


Fig. 9 - Damage localization in the FRCM system according to AR Glass textile mesh size

3.4 Effect of fabric thickness

The influence of fabric thickness was studied for four configurations: 0.055 mm, 0.1 mm, 0.5 mm, and 1 mm. As shown in the shear capacity curves in Figure 10, the two thinner laminates (0.055 mm and 0.1 mm) exhibit brittle behavior, with sudden failure and limited strain capacity. In contrast, the thicker fabric layers (0.5 mm and 1 mm) significantly improve both ductility and load-carrying capacity, showing higher peak shear stress and a more gradual post-peak response. Physically, this improvement occurs because a thicker fabric provides greater cross-sectional areas for stress transfer and more restraint against crack opening, which delays the onset of damage in the masonry and allows progressive mobilization

of the composite system. The increased thickness also enhances the overall tensile and shear stiffness of the wall, contributing to a more gradual and controlled deformation under applied loads.

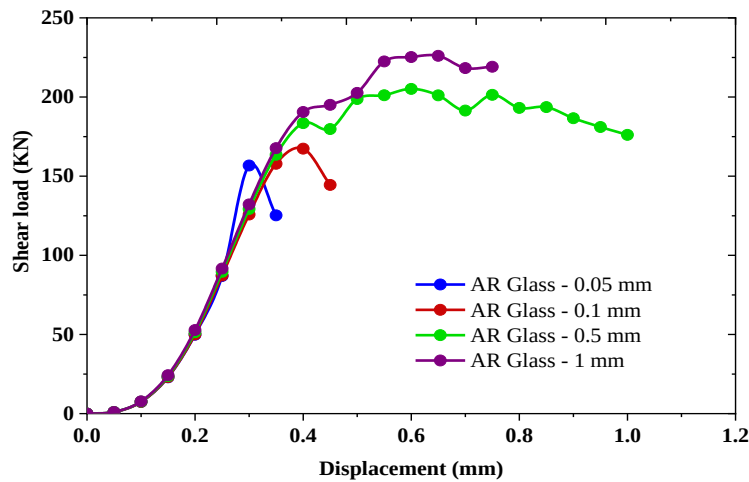


Fig. 10 - Shear stress–time curves of FRCM system according to AR Glass fabric thickness

The damage patterns in Figure 11 further illustrate this effect. For the thin FRP layers, damage is concentrated along narrow shear bands, reflecting poor stress redistribution and localized cracking. With 0.5 mm and 1 mm fabric, damage is much reduced and more evenly distributed across the wall surface. Physically, this occurs because the thicker fabric provides more continuous strengthening, effectively bridging cracks and distributing shear stress over a wider area. This prevents stress concentration at isolated points, reducing the crack propagation level and enabling the masonry to be better exploited before failure. The result is a ductile failure mode with delayed localization, demonstrating that thicker fabric improves both the structural resistance and the damage management of the retrofitted wall.

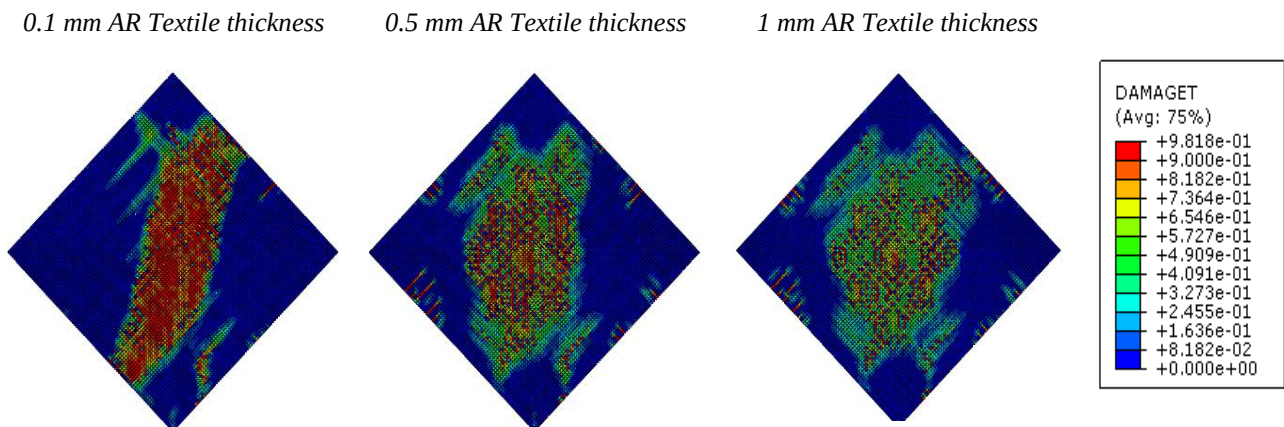


Fig. 11 - Damage localization in the FRCM system according to the AR Glass textile thickness

4 Conclusions and final remark

This work presented a comprehensive numerical investigation of the in-plane shear response of masonry walls strengthened with FRCM systems, combining an NHL mortar matrix and AR-glass textile. A validated finite element framework was developed to reproduce the nonlinear behavior of masonry, including stiffness degradation, cracking, and damage evolution. The study addressed three main research objectives: (i) validation of the FEM model against reference available experimental results, (ii) detailed analysis of damage initiation and propagation in strengthened and un-strengthened walls, and (iii) parametric assessment of key reinforcement variables, namely matrix thickness, textile mesh size, and textile thickness. Based on the numerical evidence, the following conclusions can be drawn. The FEM predictions showed satisfactory agreement with experimental data, with peak load discrepancies below 7.5% for URM and below 3%

for FRCM-strengthened walls. The model accurately reproduced both global shear response and local damage patterns, confirming its suitability for parametric exploration. NHL overlays improved shear capacity by approximately 48%, but with limited influence on ductility. In contrast, FRCM retrofitting increased peak load by 124% and significantly enhanced deformation capacity, demonstrating a clear transition from brittle to more ductile behavior. Increasing the matrix thickness from 10 mm to 20 mm produced a noticeable increase in initial stiffness but a limited variation in ultimate shear strength gain. Damage patterns remained governed by the masonry substrate, indicating that matrix thickness primarily affects elastic rigidity rather than failure mechanisms. Finer meshes (6×6 mm and 12×12 mm) provided higher initial stiffness due to improved stress transfer and strengthening. The coarser 18×18 mm mesh reduced stiffness and produced more localized damage, although ultimate strength remained similar across all configurations, confirming that mesh size affects stiffness and crack distribution rather than peak capacity. Textile thickness had the strongest impact on structural performance. Thin layers (0.055–0.1 mm) exhibited brittle-like behavior with concentrated damage, whereas thicker textiles (0.5–1 mm) significantly improved ductility, increased peak shear stress, and promoted more uniform damage distribution. This highlights the role of the textile cross-section in delaying crack opening and enhancing load redistribution. Reinforced walls exhibited more diffuse and controlled damage patterns compared to URM specimens. Thicker textiles enabled a more efficient exploitation of the masonry substrate by distributing stresses over wider regions, reducing localization and delaying failure. The numerical trends align with the analytical framework proposed by Calò et al. [27], where the effectiveness of FRCM systems is governed by the *exploitation factor*, assumed as the degree to which the textile tensile capacity is mobilized. The parametric results confirm that matrix–fabric compatibility, textile geometry, and textile thickness directly influence this exploitation level.

Despite the robustness of the results, further experimental and numerical investigations are required to confirm or refine the observed trends, particularly regarding long-term behavior, interface mechanics, environmental effects, and multi-axial loading conditions. These aspects remain essential to fully validate the proposed conclusions and to optimize FRCM design strategies for practical engineering applications.

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