



**Politecnico
di Torino**

ScuDo
Scuola di Dottorato - Doctoral School
WHAT YOU ARE, TAKES YOU FAR

Doctoral Dissertation

Doctoral Program in Civil and Environmental Engineering (37th cycle)

**Mechanical and durability
performances of Natural TRM
composites**

Experimental investigation and analytical modelling

By

Mattia Baldassari

Supervisor(s):

Prof. Pietro Cornetti, Supervisor

Prof. Alessia Monaco, Supervisor

Doctoral Examination Committee:

Prof. Francesco Focacci , Referee, University of E-Campus

Prof. Gabriele Milani, Referee, Politecnico di Milano

Politecnico di Torino

2026

Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

Mattia Baldassari

2026

* This dissertation is presented in partial fulfillment of the requirements for **Ph.D. degree** in the Graduate School of Politecnico di Torino (ScuDo).

Mechanical and durability performances of Natural TRM composites

Mattia Baldassari

Textile-Reinforced Mortar (TRM) systems have emerged as effective and compatible solutions for the strengthening of existing masonry structures, offering advantages in terms of vapour permeability, fire resistance, and mechanical compatibility with historical substrates. In parallel, growing environmental awareness has accelerated interest in Natural TRMs (NTRMs), which replace synthetic fibres with bio-based reinforcements such as flax. However, the mechanical behaviour of NTRMs, particularly in tension, and their long-term durability in alkaline environments typical of cement-based matrices, remain insufficiently characterised. This research addresses these critical gaps by combining a comprehensive experimental campaign with advanced analytical modelling.

The study investigates two natural TRM systems: a flax-reinforced TRM and a basalt-reinforced TRM. An extensive experimental programme was carried out to characterise yarns, textiles, and TRM coupons under reference and accelerated ageing conditions (water and alkaline solution at 23 °C and 40 °C). Mechanical tests demonstrated that flax fibres exhibit a pronounced nonlinear tensile response, governed by fibre untwisting and filament alignment, while basalt fibres behave essentially linearly until failure. After alkaline conditioning, flax fibres and TRMs showed substantial strength reductions, especially at 40 °C, whereas basalt experienced moderate yet measurable degradation. TRM tensile tests confirmed pseudo-ductile behaviour but revealed significant stress drops at crack initiation in natural systems, reflecting limited fibre–matrix bond capacity and nonlinear fibre activation.

Based on these results, a modelling framework was developed to capture the tensile behaviour of NTRMs, extending existing cohesive-zone and trilinear models by explicitly incorporating textile inelasticity, progressive damage, and durability effects. A parameter-driven approach was proposed to simulate fibre strength decay, the decrease in the stress-transferring effectiveness at the interface, and deterioration of the cross-section due to alkaline attack. The model successfully reproduced multi-cracking, stiffness evolution, and strength decay trends observed in both flax and basalt TRMs, with good agreement, particularly for specimens aged up to 3000 h.

The outcomes demonstrate that the tensile behaviour of NTRMs cannot be accurately modelled under linear-elastic fibre assumptions; the alkaline exposure leads to significant deterioration in natural fibres, strongly influenced by temperature; and modelling durability as a loss of effective resisting area provides a physically consistent representation of degradation mechanisms. The study also highlights the role of textile geometry, multilayer effects, and testing configuration in the exploitation efficiency of natural fibres.

This work provides a new insight into the mechanics of natural-fibre TRMs, with a validated experimental dataset and a durability-aware analytical model. The results support the future development of reliable design criteria and durability mitigation strategies for sustainable strengthening systems in conservation engineering.