Construction and Building Materials 50 (2014) 226–236

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Experimental assessment of Textile Reinforced Sprayed Mortar strengthening system for brickwork wallettes

Ernest Bernat-Maso [a,*], Christian Escrig [a], Chrysl A. Aranha [b], Lluís Gil [a]

[a] Department of Strength of Materials and Engineering Structures, Technical University of Catalonia, Colom 11, 08222 Terrassa, Spain
[b] ISISE, Department of Civil Engineering, University of Minho, Guimares, Portugal

HIGHLIGHTS

- Sprayed application of the mortar of Textile Reinforced Mortar (TRM).
- Study of the influence of mortar type and fibre grid type.
- Influence of the application technique and the strengthening configuration.
- Bending tests on wallettes strengthened with Textile Reinforced Sprayed Mortar.
- TRSM performance is comparable to that of manual application (TRM).

ARTICLE INFO

Article history:
Received 3 June 2013
Received in revised form 5 September 2013
Accepted 24 September 2013
Available online 17 October 2013

Keywords:
Textile Reinforced Mortar
Strengthening
Masonry
Experimental test
Application technique

ABSTRACT

This work explores the feasibility of strengthening masonry with Textile Reinforced Mortar (TRM) by projecting it to save application time. Nineteen tests on masonry samples strengthened with TRM have been carried out to assess this new application method. Different mortars and fibre grids were considered for studying their influence and applicability with this new technique. Three points bending tests have been performed on the specimens to compare the flexural strength between cases with manually applied mortar (TRM) and sprayed application (TRSM) of the mortar layer. It was noticed that the strengthening mortar has a significant influence on the failure mode. Results show a remarkable (between 2 and 6 times more) productivity increase when using TRSM and a load-bearing capacity rise for the cases with larger grid spacing and projectable mortar when using TRSM instead of TRM. Greater ductility values were also observed for the TRSM cases in comparison with the analogue TRM cases (same grid and mortar).

1. Introduction

Unreinforced masonry has been extensively used as a construction material in the building industry, especially for residential buildings. Most of these buildings are still in service and some require strengthening interventions in order to adapt the structure for a new use or to fulfil the requirements of current structural codes. The low shear and tensile strength of this material are the limiting properties for this adaptation. Unreinforced masonry structures are designed to withstand compressive loads and strengthening them is necessary to bear tensile forces.

Among the innovative masonry strengthening methods studied by other research, it is worth mentioning the Fibre Reinforced Polymers (FRPs) because of their wide use. This solution has proven to be effective on concrete structures but showed significant drawbacks when applied on masonry because of the use of organic resins as part of the FRP strengthening [1]. The most important issues are the hygrometric and mechanical incompatibilities between the masonry and the resin, the loss of strength of epoxy resins above the glass transition temperature and the toxicity of the materials. This situation led to the proposal of several alternatives. The most significant ones are the Engineering Cementitious Concrete (ECC) presented by Maalej et al. [2] who strengthened masonry panels against out-of-plane loads with promising results (blast protection) and the Textile Reinforced Mortar (TRM) initially developed for strengthening concrete structures (see [3,4]) but successfully adapted for its application on masonry (see [5,6]). Nowadays, TRM is the most studied strengthening solution for masonry but as the application technique is by hand and is time-consuming, the system needs to be improved in order to become a competitive alternative. It has to be highlighted that TRM has been deeply analysed as a strengthening solution: Ortlepp et al. [7] presented a methodology for the mechanical characterisation of TRM, Harajli et al. [8] showed its performance against cyclic bending loads and Papanicolau et al. [6] compared the TRM system with the FRP solution. For all these cases the application of TRM was by hand.

* Corresponding author. Tel.: +34 937398728; fax: +34 937398994.
E-mail address: ernest.bernat@upc.edu (E. Bernat-Maso).

0950-0618/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.conbuildmat.2013.09.031

To improve the TRM strengthening system, the projection of concrete (shotcrete) was considered as the technological base to develop an industrialised hybrid method consisting of placing a textile grid embedded inside a layer of projected concrete. This technique was efficiently used for the first time when strengthening a concrete structure at the University of Applied Sciences in Schweinfurt, Germany [9]. However, adapting this system for masonry structures has not been considered yet and the use of mortar instead of concrete needs to be studied too.

For this reason, the original work presented herein is focused on comparing the performance of manual and mechanical application of TRM. Several masonry samples have been built and manually strengthened with different commercial TRM systems, whereas other samples have been strengthened by projecting a plastering mortar on different fibre grids previously attached to the masonry surface. This system, which could be called Textile Reinforced Sprayed Mortar (TRSM), is fully described. It has to be remarked that the mortars developed to be applied in TRM strengthening systems cannot be projected because of the size of the sand. Hence, a plastering mortar (with lower bonding, compressive and flexural strength) was used for projecting purposes.

All samples were tested under bending and the influence of different strengthening parameters (grid geometry and material, number of grids and strengthening of one or two sides) has been analysed for the TRSM cases. In addition, some of the TRSM samples have been used for performing a comparative study with TRM cases (manual application).

The possibility of adapting the existing commercial TRM solutions to be applied by projection is discussed and the comparison between the two application modes (TRM and TRSM) is presented showing that the type of the mortar is an important variable to be taken into account in the analysis.

The economic analysis of implementing the TRSM technology is out of the scope of the present paper which is focused on the technical aspects of this new way of applying the TRM strengthening.

To sum up, the main aim of the present work is to prove the feasibility of using TRSM as a suitable and quicker strengthening method for masonry structures in comparison with the original TRM solution.

2. Procedure

To achieve the main aim of the research three experimental groups were defined. The strengthened samples are summarised in Table 1. The codification of these samples was ABC-XY-Z where A represents the application process of the TRM, *M* for hand application and *S for* sprayed application; the second letter represents the material the strengthening grid was made of, *G* for glass, *C* for carbon, *S* for steel and *B* for basalt; C represents the type of mortar, *M* for a cementitious-based mortar which is specifically designed for TRM, *R* for a lime-based mortar which is also specifically designed for TRM application, *X* for a pozzolana-based mortar also designed for TRM systems and *O* for a projectable plastering mortar; the number *X* represents the number of strengthened sides and *Y* the number of fibre grids installed per side; finally, the number *Z* shows the repetition order of analogue samples.

- In the first group three masonry specimens were fabricated as control samples for comparison purposes with the rest of the tests. They were masonry prisms stacked with ten bricks each. It was considered unnecessary to include the data acquired from these tests in Table 1 because the specimens were unreinforced and thus, failed under their own weight when placed in horizontal position.
- The second group consisted of nine specimens strengthened with Textile Reinforced Mortar (TRM) applied by hand. The studied parameters by comparing them might be the type of strengthening mortar and the fibre grid material. The mortars used for these cases were commercial mortars only. Each one of these mortars has been specifically designed to work with a specific textile (material and fibre grid geometry). These specimens consisted of masonry prisms of ten bricks each (except one case of nine bricks, labelled as MGR-11-1 in Table 1).
- The third group of samples was fabricated and tested in order to analyse the feasibility of the Textile Reinforced Sprayed Mortar (TRSM) system and to compare its performance with that obtained using TRM. For this part of the project, ten masonry specimens made by stacking nine bricks each in a prism were fabricated. The mortar used for embedding the fibre grid in it was developed for plastering works in contrast with the mortars of the second group. Hence, this fact is also considered as a study variable. Summarising, the parameters studied with the samples of this group were the type of textile grid, the number of layers of reinforcement and the number of reinforced sides.

2.1. Properties of component materials

To construct the specimens, solid clay bricks of size 280 mm × 132 mm × 45 mm were used. The water absorption capacity of

Table 1
Characterisation of the strengthened specimens.

Application method	Grid	Overlaying mortar	No. of reinforced sides	No. of grids per layer	Mortar thickness (mm)	No. of rovings	Designation
Hand	Glass	M	1	1	10.5	10	MGM-11-1
Hand	Glass	M	1	1	9.0	10	MGM-11-2
Hand	Glass	M	1	1	11.5	11	MGM-11-3
Hand	Glass	R	1	1	11.0	10	MGR-11-1
Hand	Glass	R	1	1	13.5	10	MGR-11-2
Hand	Glass	R	1	1	10.5	11	MGR-11-3
Hand	Carbon	X	1	1	11.0	29	MCX-11-1
Hand	Carbon	X	1	1	10.0	29	MCX-11-2
Hand	Carbon	X	1	1	5.0	30	MCX-11-3
Hand	Glass	O	1	1	7.0	11	MGO-11-1
Hand	Carbon	O	1	1	1.0	27	MCO-11-1
Hand	Steel	O	1	1	6.0	42	MSO-11-1
Sprayed	Glass	O	1	1	2.5	11	SGO-11-1
Sprayed	Carbon	O	1	1	2.0	27	SCO-11-1
Sprayed	Steel	O	1	1	2.0	42	SSO-11-1
Sprayed	Basalt	O	1	1	0.5	17	SBO-11-1
Sprayed	Basalt	O	1	2	1.0	17	SBO-12-1
Sprayed	Glass	O	1	2	4.0	11	SGO-12-1
Sprayed	Glass	O	2	1	4.0	11	SGO-21-1