EFFECTIVENESS OF BASALT FIBRE-REINFORCED CEMENTITIOUS SYSTEMS IN CONFINING MASONRY MEMBERS: AN EXPERIMENTAL INVESTIGATION

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31st Cycle of the PhD Course in
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Keywords: masonry, strengthening and repair, basalt fibre-reinforced polymers (BFRPs), basalt fibre-reinforced cementitious matrices (BFRCMs), confinement, RC columns, digital image correlation (DIC), laboratory tests

Introduction

The use of composites based on fibre-reinforced polymers (FRPs) to strengthen masonry columns has become a common practice in the last decades. FRPs, however, exhibit some shortcomings when applied to masonry substrates, due to the organic nature of their matrix. For this reason, increasing attention is paid today to composites based on fibre-reinforced cementitious matrices (FRCMs) [1], in which the polymeric matrix is replaced with an inorganic matrix (such as cementitious mortars). Cementitious matrices guarantee higher breathability and compatibility with the substrate, less sensitivity to debonding at the interfaces, and higher resistance to fire and high temperatures. Moreover, due to the increasing demand for new materials not only mechanically efficient but also sustainable, composites reinforced with basalt fibres are becoming very appealing for strengthening masonry structures.

Several works have been devoted to the application of composites to confine masonry, but only a few are about basalt fibres [2]. Additionally, the small number of studies currently available on the confinement of masonry by means of FRCMs are mainly focused on the efficiency of this system in enhancing the mechanical performance of strengthened members. In fact, few indications are available on the modelling of the compressive behaviour of FRCM-confined masonry [3] and few equations have been formulated to predict structural strength [4]. Last but not least, comparisons on the performance of BFRP and BFRCM systems are still missing in the literature, a necessary step to quantify the effectiveness of cement-based composites in improving the performance of masonry columns.

The aim of this study is the comparative evaluation of the effectiveness of BFRP and BFRCM systems in increasing the load carrying capacity and the ductility of confined masonry columns. Two are the main objectives: to assess the performance of basalt textile as a new material for strengthening applications; and to understand whether composites made with cementitious matrices and reinforced with basalt fibres are a valid alternative to FRPs for strengthening masonry columns.

Experimental programme

In this framework, a detailed experimental investigation is performed by testing BFRP- and BFRCM-confined clay-brick masonry cylinders in compression. A total of twenty-six cylinders were obtained by coring two different assembly schemes (Figure 1), in order to investigate the influence of the number of vertical joints (one or three) in the masonry. Specimens were strengthened by using either one or two layers of BFRP or BFRCM. Unconfined cylinders were also tested as control specimens.

An investigation on the mechanical properties of the constituent materials of the masonry and of the composite, as well as a detailed characterization of the tensile behaviour of BFRCM were performed as a preliminary step. Digital Image Correlation – DIC was used in the tests.

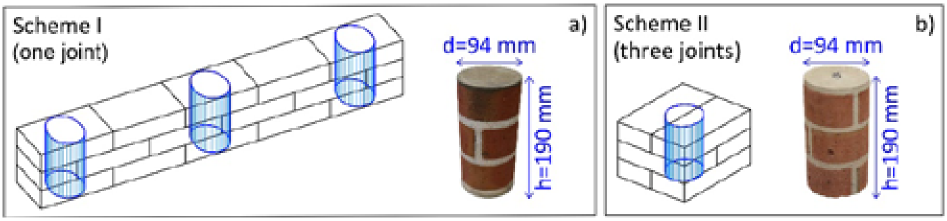

Figure 1. Brick assembly schemes: (a) Scheme I, and (b) Scheme II.

Test results

The stress-strain curves of unconfined and BFRP/BFRCM-confined cylinders are plotted in Figure 2. In Table 1 the average peak axial stress (f_{m0}-f_{mc}), the axial strain at the peak stress (ε_{m0}-ε_{mc}) and the ultimate axial strain (ε_{mu}-ε_{mcu}) are reported, along with the COV values.

Unconfined cylinders exhibit a brittle behaviour, characterized by a steep softening after the peak, while the response of confined specimens is more ductile and has a gentler softening. The average peak stresses for the unconfined cylinders were 25.2 MPa and 19.9 MPa for Scheme I and Scheme II, respectively. In the latter case, the detrimental effect of the vertical mortar joints was sizeable indeed. In general, both strengthening systems improve the bearing capacity of the masonry, with the peak stress increasing with the increase of the reinforcing layers. In particular, the strength gain due to the addition of a second layer was more pronounced in BFRP-confined cylinders. The effectiveness of the confinement was higher for Scheme II (weaker masonry involving three vertical joints), in both BFRP and BFRCM-confined specimens. The number of the joints, however, had a stronger effect in the case of BFRCM-confined cylinders. In the case of Scheme I, considering the cylinders confined with one layer (Fig. 2a), the strength increase with respect to unconfined specimens was comparable in both BFRCM and BFRP-confined cylinders (27% and 29%, respectively), while two layers of BFRP (68% increase) were more effective than two layers of BFRCM (38% increase), see Fig. 2b. BFRP wraps, however, induced a more brittle behaviour with respect to BFRCM (Figs. 2a,b). In fact, the stress-strain curves of BFRP-confined specimens (Scheme I) show a steep softening. On the contrary, BFRCM-wrapped specimens exhibit a more ductile softening, with larger residual strains. Regarding Scheme II, the strength increments yielded by BFRCM are larger than those yielded by BFRP (66% vs 38% for one layer, and 85% vs 71% for two layers, see Figs. 2c,d).

For Scheme II, the two strengthening systems produce comparable peak-strain increments with respect to unconfined specimens, with the BFRP system yielding slightly better results when one layer is used (45% vs 49%) and the BFRCM system yielding slightly better results when two layers are used (75% vs 69%). For Scheme I, BFRCM- wrapping is more effective than BFRP-wrapping with one layer (increments of 59% and 17%, respectively), while with two layers the strain gains are comparable (72% vs 82%).

Considering the average ratio between the ultimate and peak strains in confined cylinders, the best results are achieved in the weaker masonry (Scheme II), for both BFRCM- and BFRP-systems, with gains of 52% and 45% respectively (one reinforcing layer), and gains of 41% and 62% (two reinforcing layers). For Scheme I, similar increments are achieved with one layer of BFRCM (29%) and BFRP (33%), while two layers are more effective using BFRCM than BFRP (37% vs 20%).

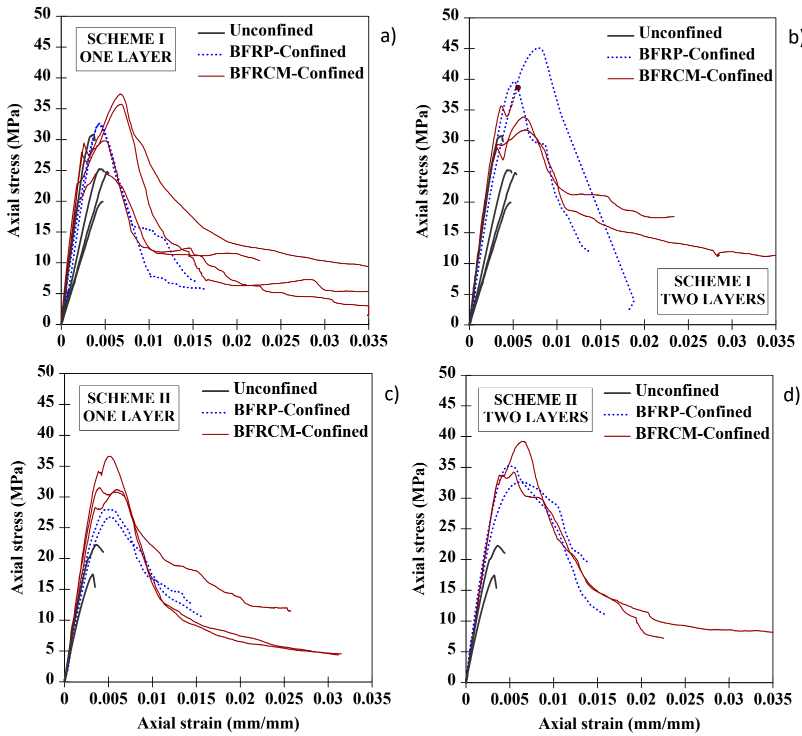

Figure 2. Stress-strain curves on cylinders: (a,b) Scheme I reinforced with one and two layers; and (c,d) Scheme II reinforced with one and two layers.

Table 1. Average results for unconfined and confined cylinders (COV values in brackets).

	Assembly	Confinement	f_{m0}-f_{mc}	ε_{m0}-ε_{mc}	ε_{mu}-ε_{mcu}
	Scheme I	Unconfined	25.19 (17.60 %)	0.0036 (12.41 %)	0.0038 (15.91 %)
	Scheme II	Unconfined	19.85 (17.14 %)	0.0034 (8.88 %)	0.0038 (13.56 %)
FRCM	**Scheme I**	1 layer	32.04 (17.40 %)	0.0058 (21.27 %)	0.0074 (13.37 %)
		2 layers	34.78 (10.35 %)	0.0062 (2.75 %)	0.0085 (6.76 %)
	Scheme II	1 layer	32.98 (9.60 %)	0.0050 (18.78 %)	0.0075 (7.07 %)
		2 layers	36.73 (9.58 %)	0.0060 (12.16 %)	0.0085 (8.90 %)
FRP	**Scheme I**	1 layer	32.56 (0.35 %)	0.0042 (7.08 %)	0.0056 (1.23 %)
		2 layers	42.36 (9.08 %)	0.0065 (31.47 %)	0.0078 (24.73 %)
	Scheme II	1 layer	27.33 (3.21 %)	0.0051 (4.54 %)	0.0074 (1.58 %)
		2 layers	33.95 (5.45 %)	0.0058 (17.90 %)	0.0094 (21.80 %)

The experimental data are instrumental in formulating analytical expressions (not reported here) for the prediction of strength-related parameters in BFRP/BFRCM-confined masonry.

Concluding remarks and outlook

Both basalt fibre-reinforced polymers and basalt fibre-reinforced cementitious matrices significantly increase the performance of masonry cylinders, but BFRCMs are particularly promising for the strengthening of masonry structures. The good performance of this system - compared with the more consolidated retrofitting technique based on BFRP - demonstrates the validity of cement-based systems as an alternative to polymer-based systems, with numerous advantages in masonry strengthening.

The influence that other parameters (type of masonry, shape of cross-section, type of cementitious matrix) may have on the effectiveness of BFRCM strengthening systems requires further studies, inclusive of tests on large-scale columns necessary to understand possible scale effects.

References

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Supervisors of the thesis: *Professor Livia La Mendola and Dr. Giovanni Munafò*