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Short note

Flexible repointing of historical facing-masonry column-type specimens with basalt fibers: A first insight

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ABSTRACT

The strengthening of facing-masonry columns represents a current challenge since from the past for architects and engineers. A typical past solution involves the use of a continuous or punctual jacketing of the column by metal profiles. Nowadays strips of composite materials have been substituting these last ones, but even if the column is surely strengthened, the aesthetic result can be unsatisfactory. To this end, an innovative solution has been recently proposed: the use of the reinforcement into the mortar joints (repointing). This permits to hide the reinforcement so as to completely preserve the aesthetic appearance. In general, high resistant materials have been tested till now but never reaching their final strength. This way, in this paper flexible basalt fiber ropes having low mechanical strength have been placed into the mortar joints to reinforce facing-masonry column-type specimens. The first results seem to be promising in enhancing their compressive strength without compromising their aesthetical appearance and, although preliminary, they encourage further in-depth analyses.

1. Introduction

The strengthening of facing-masonry columns represents a current key issue since from the past for architects and engineers [1]. Externally hooping the masonry columns with different techniques was the most common intervention in the past and it is still used now. First confinement techniques involved metal jacketing. This reinforcement is particularly effective but has some drawbacks, such as cost-effective, time-consuming and adds mass to the structures. Since the last few years, Fiber-Reinforced Polymers (FRP) [2–4] offers an interesting alternative, because they are easy to handle, flexible and so quick to install, have a high strength-to-weight ratio and add practically no mass. On the other hand, it is worth noting that their high strength is often not achieved unless the lateral strain in the confined column is very high [1]. This means that, even if the premature local failure of FRPs, due to local stress concentrations, is avoided, the masonry fails before they reach their maximum contribute. Besides, FRPs can have higher costs, lower resistance to fire loads and have to be carefully applied, especially in continuous jacketing, if masonry columns are subject to moisture problems from the ground due to the poor transpiration of the generally used epoxy resins. A promising way to solve these drawbacks seems to be the use of Fiber-Reinforced Cementitious Matrix (FRCM) [5,6], but this technique needs to be applied continuously along the column.

In this way, all the previous techniques seem to be unsatisfactory for their aesthetic results when applied on facing-masonry columns belonging to the Architectural Heritage [7]. To this end, an innovative solution has been recently proposed: the use of the reinforcement into the mortar joints (repointing). This permits to hide the reinforcement so as to completely preserve the aesthetic appearance. Despite of the available literature on the application of repointing technique on masonry walls or panels [8–11], studies on its application on masonry columns are anyhow very limited [12,13] or carried out by also using holes drilled through the member cross-section [14]. Besides, in these very few experiences, mechanically pretensioned high resistant materials have been applied and tested but never reaching their final strength. This way, in this paper flexible basalt fiber ropes having low mechanical strength have been used only into the mortar joints (with no drilled holes) to reinforce facing-masonry column-type specimens. Besides, they had no mechanical pretension. These ropes were successfully used for strengthening masonry walls in previous studies [15–19]. Two types of mortar were investigated to bond the basalt rope to the masonry joint and as finishing: a hydraulic lime-based and an epoxy-based mortar.

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Table 1
Average mechanical characteristics and relative coefficient of variation values (CoV) of the used materials.

Masonry specimens							
Mortar				Bricks			
f_{bm}	CoV	f_{cm}	CoV	f_{cm}	CoV	E_{30-60}	CoV
1.98 Mpa	0.19	5.16 Mpa	0.30	79.89 Mpa	0.20	2047 Mpa	0.27
Strengthening materials							
Basalt fibres rope[a]							
F_{fu}	CoV	ΔL_{Fmax}	CoV	ε_{fu}	CoV	f_u	CoV
3163.30 N	0.14	26.32 mm	0.18	0.053	0.18	251.86 Mpa	0.14
$E_{1st\ Branch}$		CoV		$E_{2nd\ Branch}$		SD	
3224.77 Mpa		0.30		6527.77 Mpa		0.12	
Hydraulic mortar							
f_{bm}		CoV		f_{cm}		CoV	
3.23 Mpa		0.08		31.10 Mpa		0.04	

f_{bm}: bending strength; f_{cm}: compressive strength; E_{30-60}: Young's modulus between 30% and 60% of compressive strength; F_{fu}: ultimate tensile load; ΔL_{Fmax}: ultimate elongation; ε_{fu}: ultimate strain; f_u: tensile strength related to the nominal cross-section of the rope (ϕ4 mm). Following [24], also the elastic modulus of the two branches of the bi-linear law that better fit the two part of the stress–strain curve of ropes are reported with standard deviation.

[a] These results come from tensile tests reported in [24] merged with other three new tensile tests on three specimens of the same basalt rope.

2. Materials and methods

2.1. Brick and mortar for unreinforced specimens

The lime mortar, chosen with the aim at reproducing a common historical mortar having weak mechanical characteristics, had the following proportions by weight, lime:sand:water 1:0.83:0.28. It was tested according to UNI EN 1015-11 [20] and UNI EN 998-2 [21] standards. Tests were performed after more than 60 days.

Common load-bearing bricks ($24 \times 11 \times 5.5\,cm^3$) were used. Their compressive strength was assessed according to UNI EN 771-1 [22] and UNI EN 772-1 [23] standards.

Results are shown in Table 1.

2.2. Strengthening materials

The same 4-mm diameter basalt fibers ropes reported in [24] were used. Three tensile tests were carried out on them following [24]. Results are reported in Table 1.

Two different mortars were investigated to bond the rope: a hydraulic lime-based mortar and an epoxy-based one. The first one is a commercial ready-to-use fine texture mortar made by hydraulic binders, used for structural reinforcement. It was tested as the previous lime one. The water percentage (30% of the dry powder weight) recommended by the producer was used. Table 1 reports the results.

The second one is a commercial two-component solvent-free epoxy adhesive mortar. The main properties are reported in Table 2.

Table 2
Characteristics of the epoxy-based mortar (from manufacturer).

Characteristics	Value
Number of components	2 (A + B)
Workability time	30 minutes
Complete hardening a 25 °C	7 days
Minimum application temperature	+5 °C
Limit of operative temperature	−30/+90 °C
Consistency (A + B)	Tixotropic product
Dry residue (A + B) UNI 8309	> 98%
Compression strength 1 day ASTM D695-02a	> 26 MPa
Compression strength 7 days ASTM D695-02a	> 38 MPa
Flexural strength 1 day ASTM D790	> 21 MPa
Flexural strength 7 days ASTM D790	> 23 MPa
Concrete adhesion	> 3 (support's break) MPa

2.3. Experimental program

Nine square section small scale masonry column-type specimens was tested by compression:

- 3 specimens with no reinforcement: 1NC, 2NC, 3NC;
- 3 specimens repointed by basalt fibers ropes and the hydraulic mortar: 1CM, 2CM, 3CM;
- 3 specimens repointed by basalt fibers ropes and the epoxy mortar: 1CR, 2CR, 3CR.

Fig. 1 reports the nominal dimensions of the specimens. The horizontality of each course was checked in both directions as well as its verticality. A layer of mortar was placed at the bottom of each specimen, so as to avoid local asperities and have the square base flat.

Prisms of polystyrene with designed thickness of 2.5 cm were placed in the external joints of the reinforced specimens. This has been done with the aim of avoiding to remove the mortar from the joints for the application of the repointing technique, so as to save time, and avoiding eventual damages to the specimens.

Compression tests started after more than 60 days from their construction for preventing seasoning from influencing results [25].

Two LVDTs were used for measuring vertical displacements, while one LVDT measured horizontal displacements. This last one was placed in the middle high by paying attention at crossing a vertical mortar joint. Average lowerings of the specimens, their vertical strains and their elastic modulus were calculated. Horizontal strains of the specimens were calculated too.

Compression stress was obtained as the ratio between the applied force and the nominal cross-section area. The Young's modulus was evaluated by considering the mean value between the strains coming from the two vertical transducers. Compression tests were carried out in load control with a constant load gradient using a common hydraulic press with a maximum load capacity of 3000 kN and 0.1% of tolerance. Attention was paid at having a flat and regular surface on the top of each specimen. Thus, each specimen was capped by a gypsum layer.

2.4. Description of the strengthening technique

Each horizontal joint was reinforced (Fig. 1). Before inserting the basalt fibers rope, each pre-setting horizontal mortar joint was first cleaned and prepared by a layer of hydraulic or epoxy-based mortar to provide a smoother surface and to facilitate the insertion