NANOCOMPOSITE CLAY BRICKS FOR SMART MASONRY STRUCTURES

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Introduction

Multifunctional structural materials are a topic of growing significance in Civil and Mechanical Engineering due to many promising applications. Advancements in the field of nanotechnologies have led to new additives and techniques capable of transforming traditional materials into multifunctional materials, also termed smart materials. An attractive application for these materials is that of construction materials doped with carbon nanoinclusions useful for structural health monitoring (SHM). SHM is used to evaluate the condition of structures, ideally through simple and fast identification mechanisms, providing insights on imminent or initial damage and variations in structural behavior. Carbon-based additives have shown promise at realizing construction materials with self-sensing capabilities due to their superior mechanical and electrical properties [1]. Their addition to cementitious materials is already a topic of interest in the scientific literature [2], but their application to clay-based materials appears still limited [3]. Particular issues related to the realization of nanomodified clay materials are the critical addition of the nanofillers and the effect of high temperatures on nanoparticles and electrodes from the production process. The presence of carbon inclusions produces conductive and piezoresistive capabilities in the matrices they are dispersed in. Their self-sensing capabilities are given by the correlation between the variation of electrical characteristics, such as electrical resistance, and the variation in the applied strains.

This paper aims at investigating the sensing performance of clay bricks doped with different types of carbon nanoinclusions, and analyzes the opportunities and limitations related to their fabrication and application to masonry structures.

Materials and Experimental Setup

Nanomodified clay bricks filled with 0.2% of three different carbon nanofillers with respect to the weight of the clay were prepared. The nanofillers were: Arkema Graphistrength C100 multi-walled carbon nanotubes (MWCNTs), Pyrograf-III PR-19-XT-LHT carbon nano-fibers (CNFs) and Cheap Tubes graphene nanoplatelets (GNPs). Neat clay brickes were also fabricated with the same matrix and burning procedure.

Table 1 lists the mix design of all the specimens. A physical dispersant Byk 154 was added in the nanomodified samples to improve the dispersion of the nanofillers. The samples had a cross section of 4100 mm^2 and an height of 70 mm. The carbon fillers were dispersed in a solution of water and dispersant through sonication (Fig.1a-b). Then, the nanosuspension was mixed with clay, the bricks were formed, the electrodes were embedded and the samples were cut (Fig. 1c-f). The electrodes consisted of four stainless steel wires of 2.2 mm diameter, placed symmetrically at the centre of each sample. The bricks were first dried at a maximum temperature of 90°C and then burned up to 900°C over six hours (Fig 1g-h). Figure 2 shows the setup of the electromechanical tests. A NI PXIe-1073 device recorded the electrical measurements.

Table 1: Mix design of the neat and nanomodified bricks with carbon nanofillers

Mix design	Neat (g)	MWCNTs (g)	CNFs (g)	GNPs (g)
clay	4800	4800	4800	4800
water	-	100	120	120
fillers	-	10.5	10.5	10.5
Byk154	-	10.5	10.5	10.5

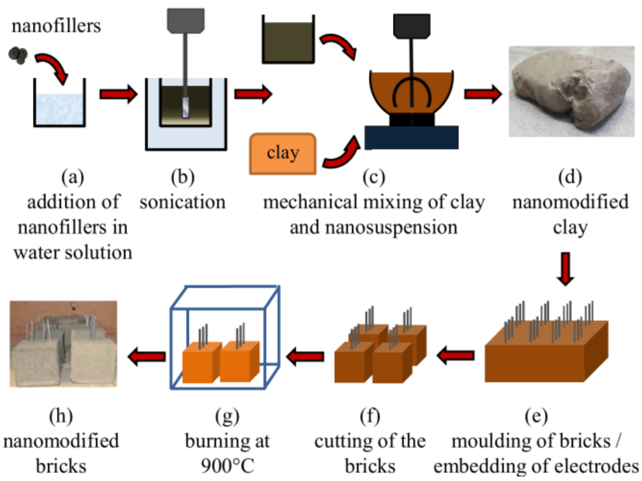

Fig. 1. Fabrication process of nanomodified bricks.

A 1 Hz square wave ranging from -10 V to 10 V with a duty cycle of 50% was applied to two electrodes placed at a mutual distance of 40 mm and the electrical current was measured at a frequency of 10 Hz. The electromechanical tests were conducted by applying uniaxial loads of 2.1 kN using an electro hydraulic press OMCN Mod. 156/ML of 200 kN capacity.

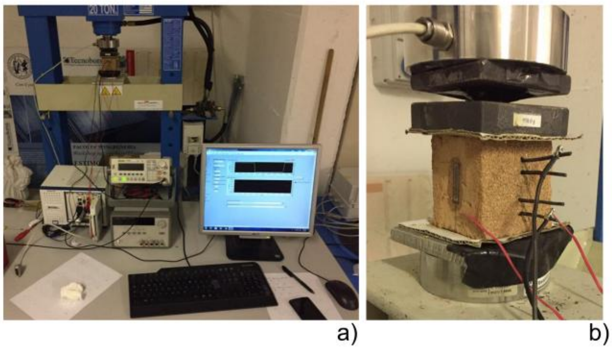

Fig. 2. Laboratory setup for a) conducting electrical tests; and b) loading of clay specimen

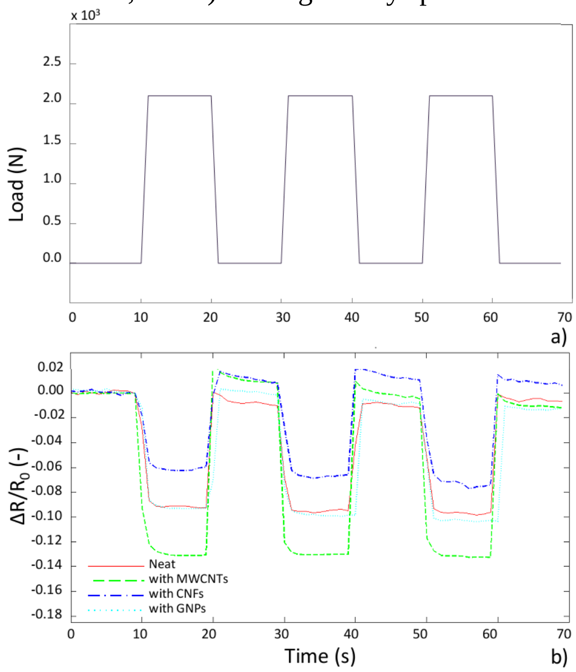

Fig. 3. Time histories of the applied load and normalized variation of electrical resistance from different tests on brick samples

Table 2. Results from strain tests on samples (R_0, ΔR and ε are the initial resistance, the variation of resistance and strain, respectively, E is the Young modulus, GF the gauge factor and S the sensitivity)

Sample type	R_0 **(MΩ)**	ΔR **(MΩ)**	ε $(\cdot 10^{-3})$	E **(MPa)**	GF	S **(MΩ)**
Neat	29.1	2,49	0.447	913	191	5575
MWCNTs	13.3	1,79	0.557	735	241	3206
CNFs	34.2	2,67	0.150	2997	520	17760
GNPs	24.4	2,30	0.765	571	123	5575

Experimental results and discussion

Figure 3 shows the time histories of the applied loads and the normalized variation of electrical resistance derived from the electromechanical tests which exhibit the self-sensing abilities of the bricks. Table II reports the values of the initial resistance, the variation of electrical resistance and strain obtained from the experimental tests, and the calculated Young's modulus E, gauge factor (GF) and sensitivity (S) obtained through the equations:

$$GF = \frac{\Delta R / R_0}{\varepsilon} \tag{1}$$

$$S = GF \cdot R_0 \tag{2}$$

where R_0 and ΔR are the initial resistance and the variation of resistance. The results demonstrate that the bricks doped with CNFs exhibit a higher Young's modulus, strain sensitivity, and GF with respect to the other samples.

Conclusions

This paper is aimed at investigating new smart carbon nanocomposite clay bricks with self-sensing capabilities for monitoring of masonry structures. Results demonstrated that brick doped with carbon inclusions appear promising at SHM applications. Clay bricks with CNFs exhibit higher sensitivity to applied strain.

Acknowledgment

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