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Functionalization of mortars for controlling the indoor ambient of buildings

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ABSTRACT

This paper reports on the use of nanoparticles of titania (nT), superabsorbent polymer (SA) and phase-change material (PCM) in order to obtain the functionalization of mortars. Single, binary and ternary mixtures with 0–1 wt.% nT, 0–1 wt.% SA, 0–20 wt.% PCM were based on flow table measurements (∼140 mm) to estimate the individual and interactive effect between the additives. In general, the mentioned additives showed distinct behaviors, but the PCM particles predominate on most of properties and also on the performance of others additives. SA particles exhibited quite different rheological behavior if compared with other additions, due to high affinity with the water and stronger absorption levels. The PCM-containing mortars attenuate and delayed the temperature changes, while 1SA particles resulted in higher hygroscopic capacity. Moreover, the photocatalytic degradation of NO_x reached 40–45%. In addition, the moisture buffering value of 1SA, 1nT and 20PCM mortars were classified as good according to the Nordtest method.

1. Introduction

In recent years, there is growing concern about the poor indoor air quality of the buildings and its effect on people's health. In fact, the excess humidity in a building can be responsible for several problems, such as respiratory discomfort, health, irritation of eyes or skin and allergies [1–3]. The level of moisture in indoor envelopes is a natural consequence of outside weather conditions (wind, temperature, etc.) but is also affected by the number and diversity of materials inside the building (furniture or exposed objects) and also by their nature (wood, textiles, paper) [2,4–6]. The importance of monitoring the moisture level is now recognized, and the Nordtest is one of the methods commonly used, also to evaluate the ability of certain building materials in passively adjusting the seasonal variation of humidity in the room [7]. In fact, the building materials (e.g. mortars, interior panels) can interact and help to modulate somehow the temperature and relative humidity inside the room, depending on their nature and porous structure [8]. In this way, several additives – lightweight aggregates (e.g. perlite and vermiculite), aluminum powder and sodium olefine-sulphonate have been utilized in mortars or concrete, in order to modify their porous structure [9–11] and then assure some control of moisture and temperature levels in the room.

Additionally, there are materials that might be able to act as self-cleaning, and self-disinfection agents of the indoor ambient [12–14]. In fact, when applied in ceramic tiles or in cementitious materials, the photocatalytic effect of semiconducting particles allows the degradation of organic and inorganic pollutants present in the air [15,16]. For this purpose, several additives have been tested, but the use of P25 titania nanoparticles in mortars is probably the most popular. Therefore, when the dosage of P25 is defined and applied properly, it can prevent the accumulation of dirt and also the growth of microorganisms (mold, moss, etc.), preserving the appearance of the coating surfaces cleaner for longer and minimizing health risks.

Finally, the energetic efficiency of constructive systems is another crucial aspect nowadays. Once properly adjusted, it allows significant economic reduction and exerts an important influence on the comfort of people. As a possible alternative to improve the thermal efficiency of buildings, phase change materials (PCM) have been added to mortars and concrete, due to their ability to storage energy [17–21]. In fact, such component is capable to store and release the heat, through endothermic and exothermic reactions associated to the latent heat of its phase transformation [22,23]. Therefore, the incorporation of PCM in the building can reduce the energy consumption of HVAC equipment's used to control the indoor temperature of the room.

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Table 1
Formulations of mortars.

Mixtures			Mixture components (wt.%)				Water/solid wt. ratio
			REF	SA	nT	PCM	
–	Reference	REF	100	–	–	–	21
1	Superabsorbent polymer	1SA	–	1.0	–	–	20
2	Titania	1nT	–	–	1.0	–	24
3	Phase change material	20PCM	–	–	–	20	35
4	1SA + 1nT	1SA1nT	–	1.0	1.0	–	22
5	1nT + 20PCM	1nT20PCM	–	–	1.0	20	35
6	1SA + 20PCM	1SA20PCM	–	1	–	20	39
7	1SA + 20PCM +1nT	1SA20PCM1nT	–	1	1	20	40

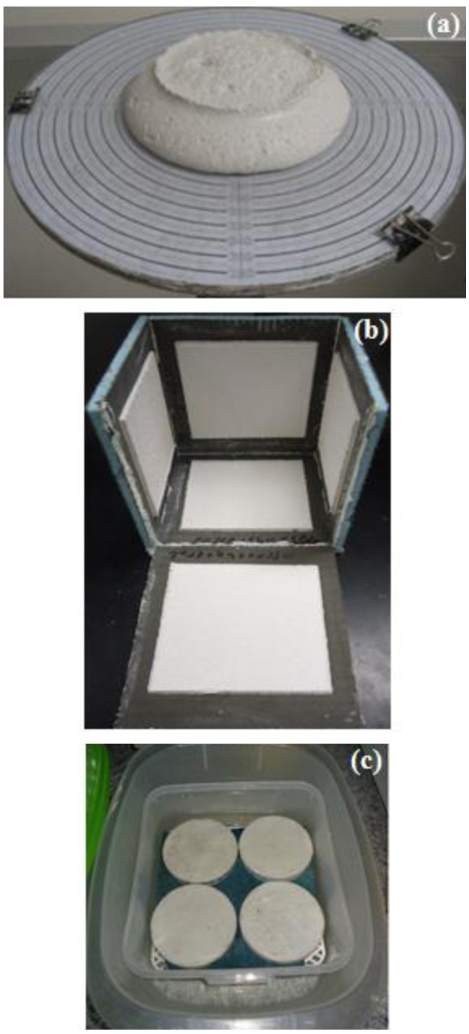

Fig. 1. (a) Spread on table of mortar 1SA20PCM after 15 strokes, (b) cubic box used to the PCM thermal efficiency test and (c) samples to the saturation and release humidity test.

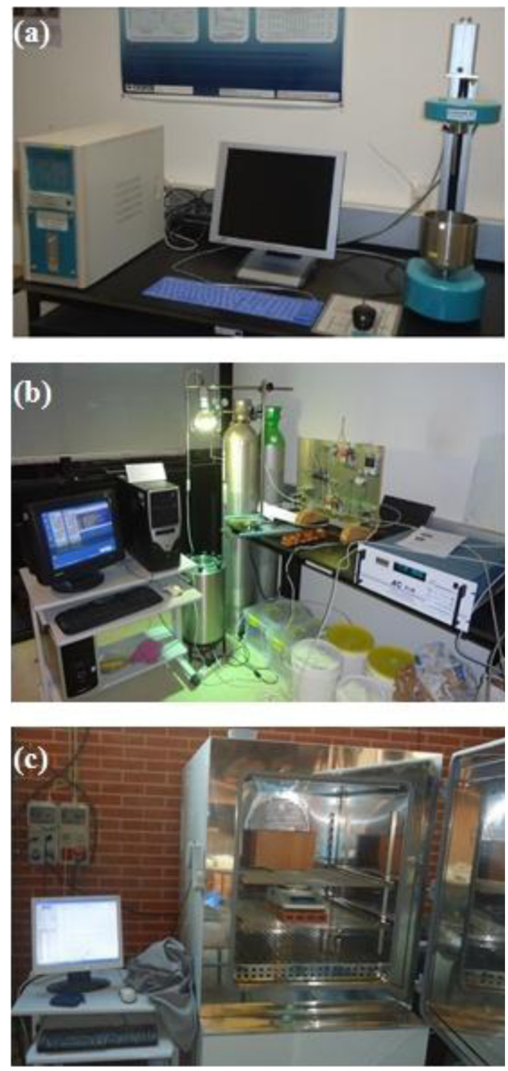

Fig. 2. (a) Rheometer apparatus, (b) reactor for NO_x photocatalytic degradation and (c) climatic chamber used to the MBV_{pratic}.

Normally, the experimental research evaluates individually the benefits of the additives above mentioned, without estimating a possible interactive effect of the additives or mutual influence between them. For that reason, the main purpose of this experimental research is comparing the impact of PCM, P25 and superabsorbent polymer (SA) additives on the fresh and hardened state of mortars, through binary and ternary blends, in order to estimate eventual influence between the additives.

2. Experimental

2.1. Materials

In this experimental research, the reference (REF) samples were based in the commercial mortar (Saint-Gobain Weber-Portugal) in which three distinct additives were incorporated to give a new functionalization: (a) phase-change material (PCM,