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The influence of TiO_2 nanoparticles and poliacrilonitrile fibers on the rheological behavior and hardened properties of mortars

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HIGHLIGHTS

- DoE was used to formulate mortars with nano-TiO_2 and poliacrilonitrile fibers.
- The use of rheometry can play a relevant role on the final properties.
- Mortars with similar initial yield stress and workability diverged over time.
- Rheology was governed by nano-TiO_2.
- Mechanical properties were mainly influenced by poliacrilonitrile fibers.

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ABSTRACT

This experimental research evaluates the individual and combined influence of poliacrilonitrile (PAN) fibers and nanoTiO$_2$ (nT) particles on the fresh and hardened properties of mortars up to 28 days. Samples with 0–0.125 wt% PAN, 0–1.0 wt% nT and 0.83–0.87 *W*/*B* were prepared. Samples with similar workability showed distinct rheological behavior along time and the yield stress was the best rheological parameter to represent such variations. The very high specific surface area and wettability of nT was dominant over the one induced by PAN fibers and severely limited the rheological behavior maintenance up to 0.050PAN + 1.00nT sample. The physical properties (apparent density, water absorption, apparent porosity) indicate that PAN is dependent on the correct correlation with nT particles. In addition, the optimal concentration of PAN is about 0.05 wt% to the flexural and compressive strength, while the most active NO_x degradation reached ~77% to those containing 1 wt% nT, regardless the concentration of PAN.

1. Introduction

Innovative applications have been reached by using titania nanoparticles (nT) in cementitious materials, such as environmental pollution remediation, self-cleaning and self-disinfection [1]. Nanotitania is composed by ultra fine particles able to fill out the voids created by the other components in the bulk of mortars, reducing the volume of pores in the matrix (<1 μm) [2] and the water permeability [3]. However, the fineness of titania particles does not influence the wear resistance of the mortar surface [4], despite the increase of roughness created by their addition, as a condition to improve the photocatalytic activity (PCA) towards air pollutants, especially under higher relative humidity environments [5]. In addition, TiO_2 sol–gel coatings were applied to the surface of adobe substrates, assuring novel functionalities (e.g. higher water resistance and bactericidal behavior) [6]. However, nT may affect markedly the workability of the fresh mixture, while the mechanical strength gain is not relevant regarding standard mortars [7]. In this way, the use of fibers in cementitious matrices can be one alternative to improve their mechanical resistance. In fact, they tend to restrict the propagation of microcracks created upon curing or when the material is under stress. Ductility, toughness, flexural and shear strength are then improved [8,9]. However, the critical volume fraction of fibers should be defined correctly, since the mechanical interlocking, or entangling, can affect the flow behavior, when the optimal dosage is surpassed [10].

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Table 1
Chemical composition of Portland cement CEM I – 42.5R.

Component (wt%)	Portland cement (PC)
SiO_2	20.37
CaO	63.05
Al_2O_3	4.78
Fe_2O_3	2.96
SO_3	3.70
MgO	2.02
Cl^-	0.02
K_2O	–
Loss on ignition	2.37

From the above reported indications, cement composites containing fibers and nT particles have shown promising alternatives under distinct perspectives. If the physical characteristics of fibers ensure mechanical reinforcement, the use of nT particles might give self-cleaning properties due to their photocatalytic action. However, a considerable drawback regarding the use of such additives is related to the negative effect on the workability of fresh mixtures. Although the use of distinct dosage of water allows to control the misadjusted workability – a common procedure followed to control the workability of mortars – the fresh and hardened material properties cannot be considered solely due to the additives added, but are also controlled by the amount of water utilized. For that reason, the use a systematic study that clarifies the role of each individual mixture component and the eventual synergetic action on a particular characteristic of the material is crucial to optimize its rheological, chemical and mechanical behavior [11–14].

Therefore, this paper details an experimental research that identifies the individual and combined influences of poliacrilonitrile (PAN) fibers and nT particles, in order to established an optimized formulation according to the photocatalytic application. Several properties are evaluated, covering the fresh state (rheology, flow table test) and the hardened state (apparent density, water absorption, apparent porosity, capillary index weight variation, flexural and compressive strength) as well as NO_x photocatalytic degradation.

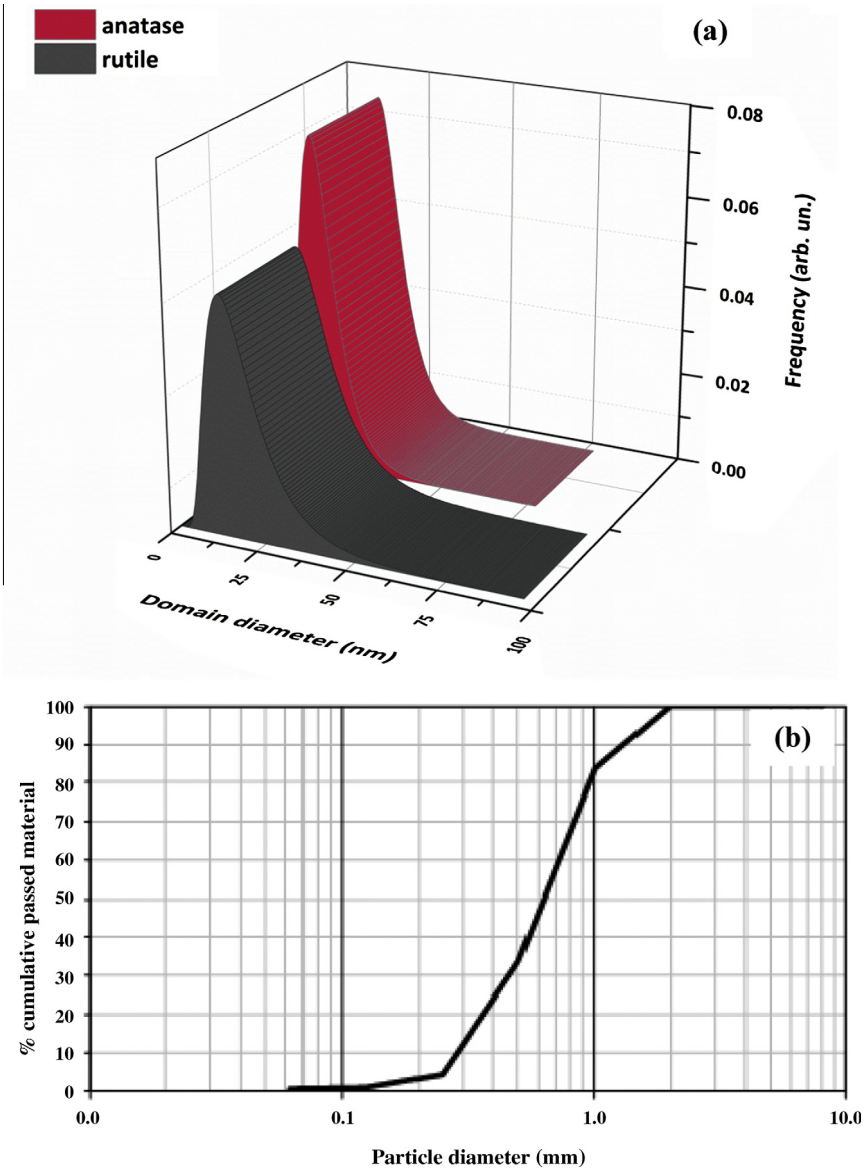

Fig. 1. Particles sizes distribution of (a) anatase and rutile present in P25 [15] and (b) sand used as aggregate.