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Effect of a polypropylene fibre on the behaviour of aerial lime-based mortars

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ABSTRACT

A polypropylene fibre was added to lime-based mortars in order to check whether they were improved by this admixture. Different properties of lime-based mortars were evaluated: fresh state behaviour through water retention, air content and setting time; hardened state properties such as density, shrinkage, water absorption through capillarity, water vapour permeability, long-term flexural and compressive strengths, pore structure through mercury intrusion porosimetry, and durability assessed by means of freezing–thawing cycles. An improvement in some properties of aerial lime-based mortars – such as permeability, mechanical strengths, reduction in macroscopic cracks or durability in the face of freezing–thawing cycles – was achieved when fibre was added at a low dosage. When a larger amount of additive was used, only the reduction in cracks and the durability of the material were improved.

1. Introduction

During the 20th century, cement mortars have been frequently used instead of lime mortars in restoration work, showing several incompatibilities: high mechanical strength, efflorescence phenomena owing to formation of large amounts of soluble salts by migration of alkaline ions, low water vapour permeability and higher thermal expansion coefficient than most masonry [1–4]. Lately, there has been growing interest in using lime-based mortars for historical monument restoration [5,6], as compatibility between the new repair mortar and the original components of the masonry is essential for the structure [7]. This compatibility must be reflected in several aspects: (i) chemical compatibility between the applied mortar and the ancient stones, bricks and mortars; (ii) physical compatibility, especially related to solubility and water transport and (iii) structural and mechanical compatibility, reflected in similar mechanical strengths.

Within this framework, many different characteristics of lime pastes and lime-based mortars have been studied, such as fresh state properties [8], pore structure and capillary porosity [9], rheological behaviour [1,10], mechanical behaviour in long-term studies, and durability [11–13].

However, some problems related to the use of aerial lime-based mortars still remain: (i) long setting and hardening time; (ii) relatively low mechanical strengths; (iii) a high water absorption capacity through capillarity and (iv) major volumetric change as a result of shrinkage [4]. This last drawback is usually accompanied by the development of cracks, which might give rise to aesthetic and functional consequences.

In the field of cement-based mortars, fibre reinforcement has been suggested as one of the most effective methods to minimize plastic shrinkage and shrinkage cracking [14]. The use of different kind of fibre-natural products [15–17], manufactured admixtures [14,18–21] and even metallic ones [22] – is widely accepted in cement mortars [21]. Several properties improve thanks to these additives: (i) mechanical behaviour [19,23]; (ii) volumetric changes such as shrinkage [18,21,22] and expansion [20], phenomena which lead to cracks [22] and (iii) durability, especially in the face of freezing–thawing cycles [18]. The mechanism of action of these products seems to be related to their ability to act as a bridge between different grains of the cement mortar matrix, providing an additional surface where several components can crystallize [19]. At the same time, the uniformly distributed fibres reinforce the fresh mortar against the occurrence of plastic shrinkage and, once the hardened state has been reached, prevent microcracks from developing into macrocracks and the potential trouble which this may cause [21], such as a strength reduction, a water intake increase and a subsequent decay of the mortar by freezing–thawing cycles, and aesthetic involvements. This protection is possible because fibres can absorb the internal tensions generated in the structure [19].

Nevertheless, there is no previous research about the effect of fibres if they are incorporated into aerial lime-based mortars. As

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has been mentioned, mechanical strengths and shrinkage are some of the main problems associated with the use of lime mortars, so the addition of fibres could result in some interesting improvements for these materials. However, the hardening process and the final structure of lime mortar are very different from those of cement mortar, so a range of experiments has to be performed in order to determine whether the addition of fibres is appropriate for this binder.

Polypropylene fibre has been shown to be one of the most suitable fibres for cement mortars [21], which could be due to its efficiency as well as to its great cost-effectiveness [24]. In the present paper, the behaviour of aerial lime-based mortars modified with polypropylene fibres is reported. Drawing a parallel between cement and lime mortars, improvements in mechanical strength, volumetric changes and durability would be expected to be reached by introduction of polypropylene fibres. Fresh state properties, capillarity, water vapour permeability, mechanical strength over long-term studies as well as durability tests (freezing–thawing cycles) will allow us to draw conclusions about the improvement of aerial lime-based mortars.

2. Materials

An aerial commercial lime and a pure limestone aggregate were used to prepare the mortars. The lime (class CL 90-S according to Spanish standard [25]) was supplied by Calinsa (Navarra). The aggregate was supplied by Caleras de Liskar (grupo HORPASA), and was a calcareous type. Figs. 1 and 2 present the mineralogical composition of the lime and aggregate used (obtained by X-ray diffraction) and their grain size distribution, respectively. The selected binder: aggregate ratio (B:Ag) was 1:1, by volume. This decision was taken according to previous data that showed the best mechanical strengths and durability performance in aerial and hydraulic lime mortars for this volumetric proportion [5,26,27]. Volume proportions were converted into weight in order to avoid any imprecise measurement. Three different dried mixtures were prepared. One of them was composed only of

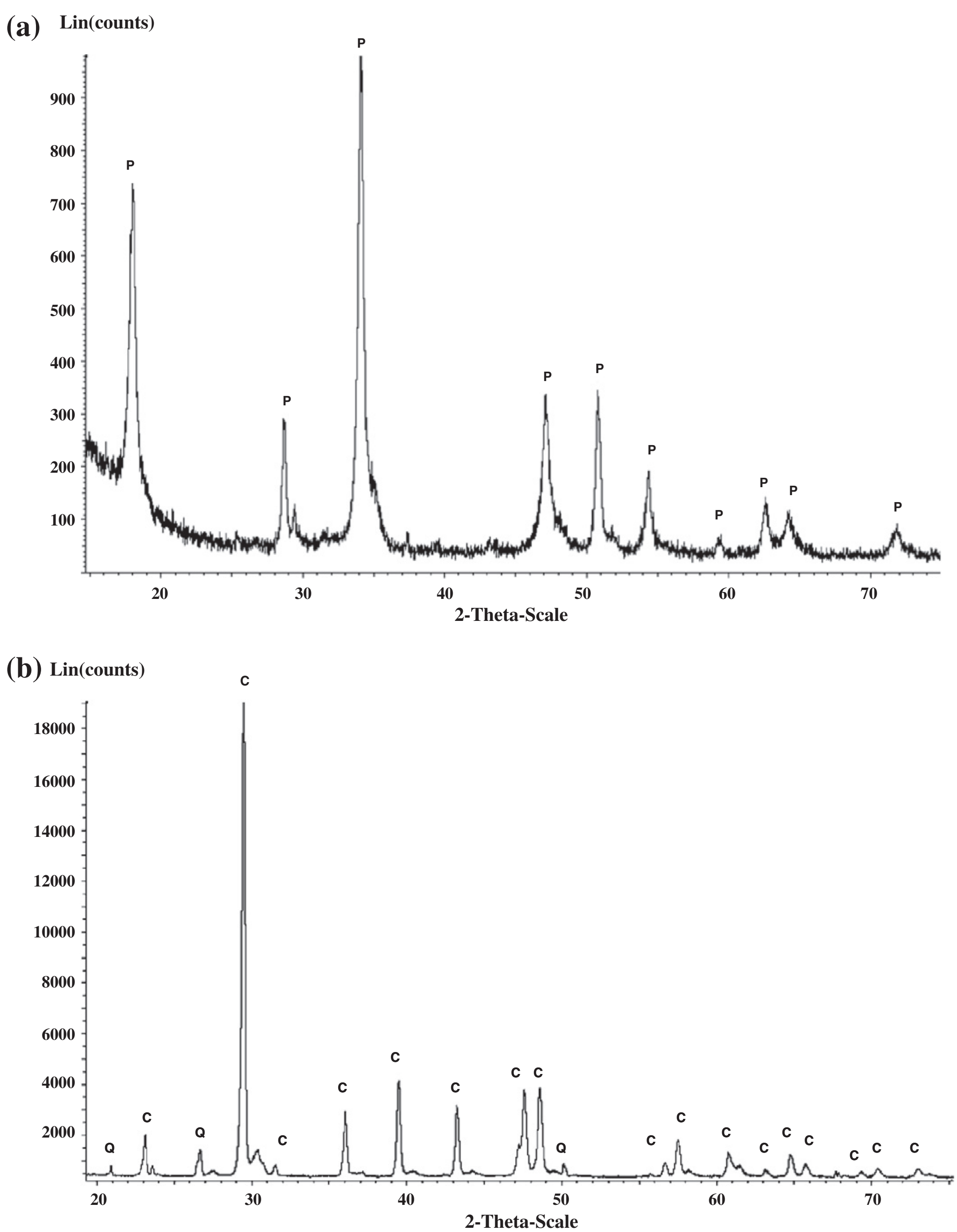

Fig. 1. XRD patterns for (a) lime and (b) aggregate, where P: portlandite; C: calcite; Q: quartz.