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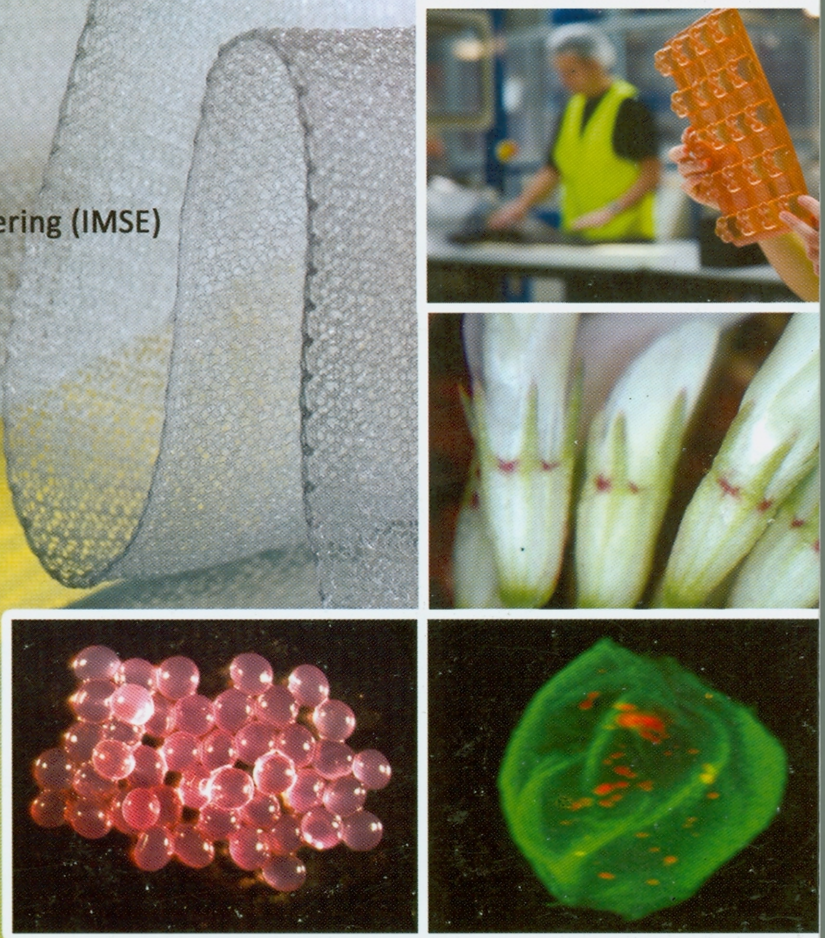

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Institute of Macromolecular Science and Engineering (IMSE)
Chathukulam Buildings
Parumbaikadu P.O., Kottayam
Kerala, India, 686028
&
Beijing University of Chemical Technology
Bei San Huan East Road 15#,
Chaoyang District, Beijing, China
&
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St. Primus Weg 68,
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Mahatma Gandhi University
P.D. Hills P.O., Kottayam, Kerala, India-686 560

Website: http://www.bipolymers.macromol.in
Email: biopolymers@macromol.in, naturalpolymers@macromol.in

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Biocomposites for Building Purposes: Effect of A Guar Gum Derivative and A Potato Starch as Viscosity Modifiers for Aerial Lime-Based Mortars

A. Izaguirre, J. Lanas, I. Navarro, J.M. Fernández, J.I. Álvarez
Universidad De Navarra
31080 Pamplona (SPAIN)
E-mail: jalvarez@unav.es

The use of two different biopolymers as admixtures to be added to aerial lime mortars have been studied with the aim of improving the performance of these construction materials. A guar gum derivative (hydroxypropylguar) and a potato starch were incorporated to aerial-lime based mortars and both fresh and hardened state properties of the mortars were determined.

The ionized groups at alkaline pH of the hydroxypropylguar made it possible to increase the guar gum derivative ability for calcium binding, giving rise to a viscosity increment through a cross-linking phenomenon. This viscosity enhancing action could be very useful in order to improve aerial lime mortars (for rendering purposes, as just one example). The air content increased in mortars modified by the guar gum derivative, changing the pore size distribution and giving rise, as a consequence, to some positive aspects such as a decrease in water absorption and an improvement in durability through freezing-thawing cycles.

At the different dosages assayed of the commercialized potato starch, it was found the effect of the starch to be strongly dosage-dependent: it performed as a thickener when the incorporated dosage was up to 0.30% of lime weight; conversely, above that dosage, the polymer behaved as a plasticizer. The thickening effect took place because polymer molecules were adsorbed onto lime particles, as confirmed by zeta potential and particle size distribution measurements. For large amounts of polymer, its plasticizing effect was related to steric hindrance and electrostatic repulsive forces.

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Biocomposites for building purposes: effect of a guar gum derivative and a potato starch as viscosity modifiers for aerial lime-based mortars

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1. Introduction

Viscosity enhancing admixtures that also act as water retainers are very common in the field of cement mortars, modified cellulose ethers being the most widespread products [1]. These agents are normally utilized to increase the mortar viscosity, reducing the risk of material segregation during transport and handling, leading to a hardened product having a better homogeneity and performance. It is not entirely understood how these products behave in lime-based mortars. Taking into account that there is a growing scientific interest in lime-based mortars as well as their uses (for instance, as a material for repairing works of the Cultural Heritage) the potential use of admixtures might be considered in order to improve these binding materials. The present study was designed to fill the gap in the scientific literature concerning the performance of some thickening, water-retaining agents in aerial lime mortars. The rationale of the present study is that the viscosity-enhancing effect of a guar gum derivative (hydroxypropyl guaran) and a commercialized potato starch could be useful for aerial lime mortars enhancing their workability and giving non-sag and anti-slip properties to the mixtures.

2. Materials and methods

An aerial commercial lime (class CL 90-S) and a pure limestone aggregate were used to prepare the mortars (binder: aggregate ratio (B:Ag) was 1:1, by volume). A dosage of 0.06% of the total dried mortar's weight was incorporated of the guar gum derivative (GG), whose chemical composition was hydroxypropyl guar (hydroxypropyl derivative of the guaran), from Lamberti Quimica S.A. (ESACOL HS-30®). A commercialized potato starch (PS) (OPAGEL CMT®, AVEBE, a natural modified potato starch, with around 80% of amylopectin and 20% of amylose) was incorporated into the other six mixtures, using a different dosage in each case. The following properties were studied according to the quoted standardized methods: consistency, through the flow table test, by measuring the slump (UNE 1015-3, 2000); density and air content (UNE 1015-6, 1999); water-retention capacity (UNE 83-816-93, 1993); and setting time. In order to assess the viscosity, zeta potential and the particle size distribution, with a view to elucidating the mechanism through which the polymer acts specific mixtures of lime, water, and additive were prepared.

3. Results and discussion

3.1. Guar gum derivative

A decrease of 3.8% for GG in density of the fresh mixtures was observed compared to the reference mixture. The more water was added, the lower the density that was achieved. The incorporation of the additive led to a larger air content: 5.0% of entrained air compared to the result of the reference mixture (2.8%). In order to give an explanation to this air-entraining ability, it must be taken into account that water-soluble synthetic and natural organic polymers (like guar gum) have inherent surfactant properties that lower the surface tension of the aqueous phase of the paste, giving rise to air entrainment [2]. This air content could enhance the durability of the material in the face of freezing-thawing cycles if the amount of entrained-air was not too large. This fact might be due to the generated voids that provide an escape boundary to which water can flow and freeze [3]. The addition of GG raised the water-retention capacity of the mortar (98.4%, while 94.3% for the plain mortar). Setting time was dramatically increased when GG was added to the mixtures (from 195 minutes for the reference mortar to 870 minutes for GG mortar). The influence of the water retention capability turned out to be greater in prolonging the setting time than the effect of an excess of mixing water. The carbonation process was also assessed by means of TG analysis, showing no significant differences at 91 days: as a result, the water retaining action of the GG, whilst caused a long delay in the setting time, had, if any, little influence on the carbonation degree in hardened mixtures.

The viscosity of GG solutions dropped when pH increased. The addition of alkali gives rise to ionization of hydroxyl groups (from OH^- to O^-), appearing electrostatic repulsions between chains of the polymer, thus inhibiting intermolecular association and hence reducing viscosity [4]. Nevertheless, when slaked lime was added, the experimental trend between GG and HPMC (a commercial tested polymer with comparative purposes) in alkaline or cement solutions was inverted: GG led to a larger viscosity values than HPMC, matching the water retention ability results (Fig. 1).

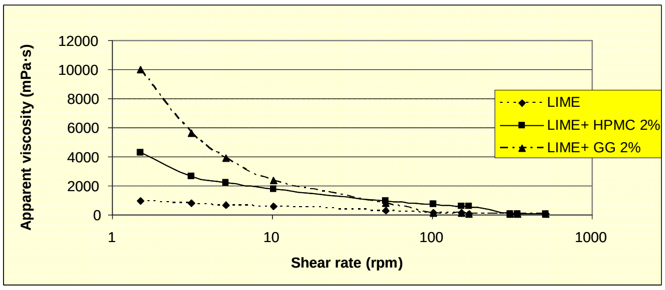

Figure 1. Apparent viscosity vs. shear rate for lime pastes.

3.2. Starch

When PS was incorporated in dosages from 0.03 to 0.30%, lower results of slump were obtained. However, when the dosage of 0.50% was used the fluidity became higher than the three previous ones and the workability was better, thus marking a critical point (Fig. 2). PS behaved as a thickener for dosages until 0.30%, and started to plasticize the mortars above that value.

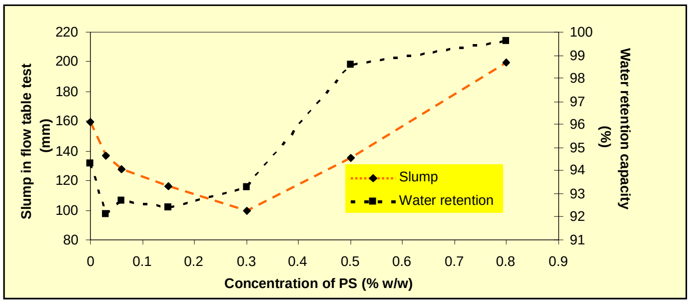

Figure 2. Slump results and water retention capacity vs. concentration of potato starch.

PS-5 and PS-6 showed a considerably greater water retention capacity, the highest dosage leading to a value of 99.6% (Fig. 2). Functional hydrophilic groups in the starch molecules would be able to bind water molecules by means of hydrogen bonds and this fact can be easily related to the setting time changes. The large retained water showed by PS-5 and PS-6 mortars could explain the delay in setting time (more than 900 minutes, while less than 200 for samples REF to PS-4): lime-based mortars must lose the excess water as a first step in the setting process. PS modified the setting time of the mortars, which showed its efficiency as a rheological modifier.

Up to a dosage of 0.30%, the coherence of the mortar and its adherence to the brick's surface - when applied on them - decreased, with a fall in PS-4. That fitted perfectly with the thickening effect observed in the flow table test and with the moderate water retention capacity of the mixtures. PS-5, which proved a workable and coherent material with high water retention capacity, permitted good adherence. The addition of the starch led to a reduction in zeta potential data of solid-liquid interface of samples, thus indicating an adsorption of the admixture on the lime surface: the hydroxyl groups of the starch molecules should be ionized at the strong alkaline pH of the lime solution. Consequently, the adsorption of the polymer onto the lime particles (by means of these "lime-anchoring" groups) would change their zeta-potential, shifting it towards more negative results [5] (Fig. 3, a).

The particle size distribution evidenced the flocculant action between particles produced by this additive at intermediante dosage (PS-3 and PS-4). However, when PS was added in dosages above 2% of lime weight (equivalent to PS-5 mortar), a plasticizing effect could be proved owing to steric hindrance as well as electrostatic repulsions between chains that might be generated due to the large amount of added polymer (Fig. 3, b).

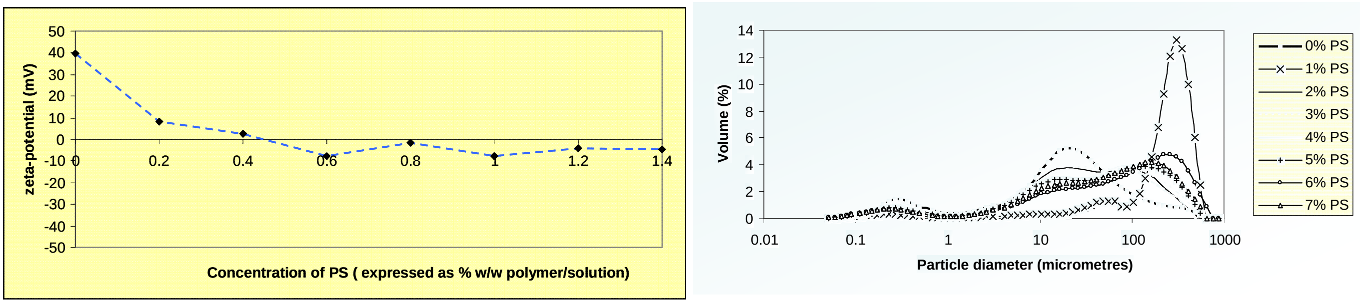

Figure 3.a) Zeta-potential of samples vs. concentration of starch. b) Particle size distribution of lime pastes with different PS dosages (amounts of PS are expressed as percentages of lime weight).

4. Conclusions

The viscosity enhancing action of the tested guar gum derivative could be very useful in order to improve aerial lime mortars (for rendering purposes, as an example). The air content increased in mortars modified by GG, changing the pore size distribution and giving rise, as a consequence, to some positive aspects such as a water absorption decrease and a durability improvement through freezing-thawing cycles. The behaviour of the starch polymer was found to be strongly dosage-dependent. When up to 0.30% of lime weight was added, it acted as a flocculant agent. This thickening effect led to an increase in viscosity values and a decrease in workability and adherence of the material. On the other hand, dosages of potato starch above 0.30% of lime weight produced a change in the behaviour of the polymer, which started to act as a plasticizer. Steric hindrance and electrostatic repulsions between chains might be generated due to the large amount of added polymer, resulting in dispersion of particles and, as a consequence, a plasticizing effect.

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