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# The water retention role in the carbonation of air lime: hero or villain?

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**Abstract.** Recent studies have been focusing on the carbon sink potential of carbonatable binders as an attempt to reduce $CO_2$ levels. Air lime is a carbonatable binder that fully relies on $CO_2$ absorption to harden and, thus, offers great carbon sink potential. Yet, $CO_2$ absorption is favoured only after the evaporation of the excess water. Therefore, this study investigated the behaviour of air lime-containing mortars regarding water retention and evaporation. Four groups (with different contents of air lime) were monitored for up to 91 days after curing. Results showed that higher contents of air lime yielded greater water retention capacity. Yet, water retention did not prevent the carbonation front from further advancing – especially within lime-cement groups. In this case, greater porosity proved to be an open door for the simultaneous evaporation and ingress of $CO_2$. Thus, hero or villain? It depends on the mixture.

## Introduction

Binders such as alkali-activated materials, limestone calcined clay, and building lime represent some of the newly developed sustainable binders designed to tackle issues on feedstock and carbon neutrality, for example. This study will focus on building lime.

Building lime is used as a construction binder since antiquity but it declined with the creation of Portland cement. Today, lime is trending once again because its manufacturing process is less energy intensive than Portland cement. Also, lime relies on carbon sequestration for strength development, offering a greater carbon sink potential [1].

Among the building lime cluster, the carbon sink potential is greater for air lime, the focus of this study. Air lime only hardens after carbonation but, at early ages, its water retention capacity hinders $CO_2$ absorption. Yet, this same property ensures gradual, long-lasting evaporation of water, promoting carbonation especially at later ages [2]. Thus, water retention/evaporation are pivotal mechanisms for its microstructure development.

This study investigated water retention in the fresh state. In the hardened state, the progress of carbonation was monitored using phenolphthalein. Open porosity was assessed through water absorption, and mass tracking was continuously monitored over 91 days.

## Experiments and discussions

The materials used to produce the four mortar groups included Portland-limestone cement (CEM II/A-L 32.5R), air lime (type CL90S), siliceous sand (0 – 2 mm), and tap water. All mixtures were tested for consistency according to EN 1015-3:1999 and had a flow diameter of (164 ± 8) mm. Water retention and carbonation were measured according to EN 459-2:2021 and RILEM CPC-18:1988, respectively. Open porosity and water absorption were tested according to EN 1015-18:2002. Mass variation was measured weekly. After curing for 7 days under 95% RH and 20ºC, specimens were stored at (50 ± 5) % RH and (20 ± 2) ºC.

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The mixture design together with results on water retention and carbonation depth are shown in Table 1. Obtained values for water absorption and mass variation are presented in Figure 1.

**Table 1.** Details on the mixture design and results on water retention and carbonation depth.

| Mixtures[1] | Portland Cement (kg/m³) | Air Lime (kg/m³) | Siliceous Sand (kg/m³) | Tap Water (kg/m³) | Water retention (%) | Carb. Depth (mm) | |
|---|---|---|---|---|---|---|---|
| | | | | | | 28d | 91d |
| C100L0 | 340 | - | 1677 | 252 | 57.1 | 0.9 | 3.5 |
| C50L50 | 176 | 65 | 1741 | 248 | 94.2 | 1.7 | 6.9 |
| C33L67 | 118 | 86 | 1742 | 256 | 95.2 | 2.0 | 8.8 |
| C0L100 | - | 131 | 1760 | 265 | 98.8 | 2.0 | 3.5 |

[1] *The nomenclature of each group is based on the percentual content of cement (C) and lime (L), proportioned by binder volume (i.e., C100L0 contains 100% of Portland cement and 0% of lime).*

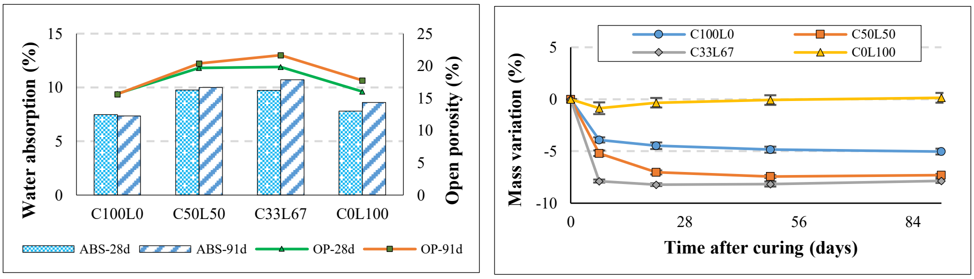

**Fig. 1. Results on (a) water absorption and open porosity; (b) mass variation.**

According to Table 1, higher contents of air lime led to higher water retention (most likely due to its increased specific surface area) and greater carbonation depth at 28 days (showing that retentivity was not an issue). However, at 91 days, carbonation was greater in lime-cement systems, showing that hydration may have benefited from the water retained (which together with evaporation, may have decreased pore saturation levels and allowed carbonation to take place earlier). Thus, hero or villain? It depends. Regarding Figure 1, limited changes in water absorption, open porosity, and mass variation were observed between 28 and 91 days, indicating that carbonation is indeed a slow mechanism at normal atmospheric conditions [1]. An extended monitoring period is being investigated.

## Concluding remarks

This paper investigated the influence of water retention in lime-containing mortars. Mixtures with higher contents of air lime had higher retentivity but carbonation was not prevented. Open porosity also seems to have a relevant role. Thus, water retention could be the hero for lime-cement systems but the villain for pure lime. Regarding water absorption, open porosity, and mass monitoring, an extended evaluation is needed for more accurate conclusions.

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