XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

# Effect of Carbonation in Mortars with Different Types of Metakaolin and Curing Procedures

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## 1 Introduction

Carbonation is one of the facilitating phenomena of reinforcement steel corrosion, responsible for the deterioration of reinforced concrete structures. Alternative materials to cement have been studied to improve the properties of concrete, such as mineral additions. On the other hand, when considering carbonation, additions could lead to a negative effect, called "reducing the alkaline reserve" diminishing the material's carbonation resistance (Meddah *et al*., 2018).

The objective of this work is to analyze the influence of different metakaolin materials and curing conditions in the accelerated carbonation of mortars, trying to understand this behavior regarding the metakaolin materials' characteristics. In addition, it was sought to analyze the relationship between the measurements of carbonated depth using two chemical indicators: phenolphthalein and thymolphthalein.

## 2 Experimental

Three different mortars were prepared, one as reference and the other two with 10% replacement of cement by metakaolin (J1 and J2) from different deposits (Table 1).

**Table 1**. Summary Metakaolin materials' characterization.

| **Metakaolin** | **J1**  | **J2**  |
|---|---|---|
| **Fineness BET ($m^2/g$)** | 22,13 | 28,71 |
| **Chapèlle (mg $CaOH_2$/ g)** | 1037 | 1075 |
| $Al_2O_3$ – $SiO_2$ – $Fe_2O_3$ (%) | 37,1 – 52,7 – 2,3 | 39,5 – 47,6 – 5,3 |

The prismatic specimens 40x40x160 mm were submitted to four different curing conditions: no humid curing and cured by immersion in water for 3, 9 and 28 days. At 28 days of age, the specimens were preconditioned, according to ISO 1920-12 (2015), and placed in accelerated carbonation chamber (for 7 days) with (20±1)°C, (70±5)% of RH and 10% of $CO_2$. The carbonation depth was measured by pH indicators: thymolphthalein and phenolphthalein.

## 3 Results and Discussion

The carbonation depth is reduced with the realization of humid curing and with increased time in water, showing the importance of performing the humid curing in order to increase the

durability of reinforced concrete (Figure 1). Comparing the carbonation depths of the mortars submitted to humid curing for 28 days and the mortars not submitted to humid curing, one could notice a reduction in carbonation up to 70% for A-R and 45 % for A-J1 and A-J2. The increase of humid curing time from 3 to 28 days reflected in a less pronounced depth reduction, about 50%, 25% and 30% for mortars A-R, A-J1 and A-J2, respectively. The type of curing exerts a greater influence on the reference mortar than on the metakaolin mortars (A-J1 and A-J2) which without humid curing had higher carbonation resistance.

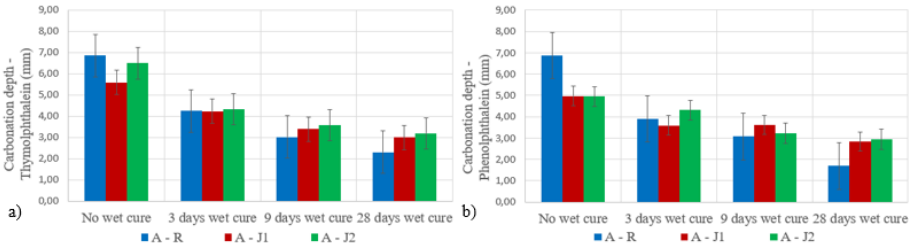


**Figure 1**. Carbonation depth with a) thymolphthalein and b) phenolphthalein.

Regarding the two indicators, thymolphthalein indicated greater depths than the phenolphthalein, which can be attributed to the difference between the indicators' pH turning ranges (phenolphthalein from 8.0 to 9.8 and thymolphthalein from 9.3 to 10.5). The equation obtained for this correlation can be highlighted ($R^2$ = 0,89); the carbonated depth readings with phenolphthalein are equivalent to 0.9 times the readings taken with thymolphthalein.

## 4 Conclusions

Despite of the chemical, coloring and fineness differences of both metakaolin materials studied, there were no statistically significant differences regarding the carbonated depths of the mortars prepared with them. These metakaolin materials had similar pozzolanic activity (measured by the Chapèlle method), showing that this characteristic is very relevant to explain the carbonation of mortars with metakaolin. The curing condition had a strong influence on the carbonated depths of the mortars. This depth is reduced with humid curing. However, metakaolin mortars suffer lesser effect of humid curing when compared to the non-pozzolan mortar.

As for the carbonate depth measurements performed with the chemical indicators' phenolphthalein and thymolphthalein, a strong linear correlation was observed between the two variables ($R^2$ = 0,89).

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