Natural and enforced carbonation of hydrated cement paste

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Mineral carbonation is a technology that enables the utilization of CO_2 into Recycled Concrete Fines (RCF). While this is an enforced process induced in a reactor, carbonation also occurs naturally. Our study helps distinguish between natural and enforced carbonation on hydrated cement Paste (P) by focusing on the quantification of a) P's natural and enforced carbonation and 2) the effect of enforced carbonation on the reactivity of carbonated paste (cP) as a cement replacement by compressive strength tests (f_c).

Natural carbonation is studied by exposing hydrated cement paste (P) to: N – N_2 in a glove bag; E – lab controlled environment (CO_2: 366±12 ppm, %RH: 26±9%, T: 23±0.3°C) for 1 and 14 days; and O – oven controlled environment (CO_2: 153±17 ppm, %RH: 40±1%, T: 40±1°C) for 1 day. Next, all samples are carbonated (Wet Carb) in a reactor using a water/solid mass ratio of 10 and a gas flow rate of 2.0 L/min at 25% CO_2. Then, the carbonated samples are exposed to E conditions (for 1 week) to check if additional carbonation occurs (Post Nat). Fig.1a shows the CO_2 uptake – normalized to the fresh paste mass (LOI: 27.5%). While limited to the evaluated cement paste and test conditions, our results highlight that:

- it is important to measure the CO_2 content of the fresh material prior to experiments to establish a baseline;
- P's CO_2 uptake due to natural carbonation is rather low (Max 1.38%±0.01), still must be prevented.
- CO_2 uptake from wet carbonation is not affected by either the starting state or natural carbonation (2 – 4%), since all tested exposure conditions yield similar final contents, i.e. 28.6%±0.6%; and
- no further natural carbonation – or a rather negligible amount – takes place after enforced carbonation;

Fig.1b shows the f_c results for binder systems P, cP, and quartz (Q), where CEM I 52.5N is replaced at ratios from 5 to 15% by weight of cement. The results indicate that, up to 28 days, replacing up to 10% of cement with cP does not compromise the cement's f_c performance significantly.

a) CO_2 Uptake (%)

Exposure	N	E 1 day	E 14 days	O 1 day
Fresh paste	2.21± 0.06	2.36± 0.02		
Nat Carb		0.55± 0.01	1.12± 0.01	1.38± 0.01
Wet Carb	27.80± 0.72	28.02± 0.97	29.35± 1.04	28.78± 2.43
Post Nat	27.91± 0.71	28.89± 1.19	29.06± 0.27	28.74± 2.03

b)

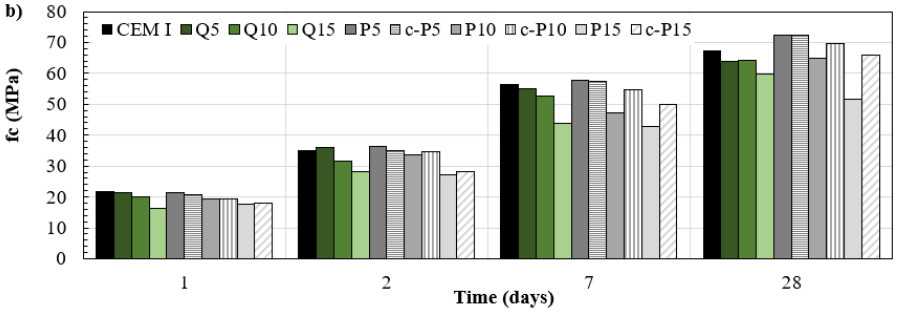

Fig. 1. Test results: a) CO_2 uptake and b) compressive strength (fc)

To conclude, this study provides quantitative data on the natural carbonation that might occur during storage and experimental procedures. Our results suggests that proper assessment of the initial carbonate state of the fresh material is relevant for a reliable quantification of the enforced carbonation and control of measurements, keeping the CO_2 uptake baseline constant. Also, we identified that replacing up to 10% of CEM I with carbonated paste is practically achievable, opening venues for the use of carbonated RCF.