Mineral Carbonation Processes for Recycled Concrete Aggregate

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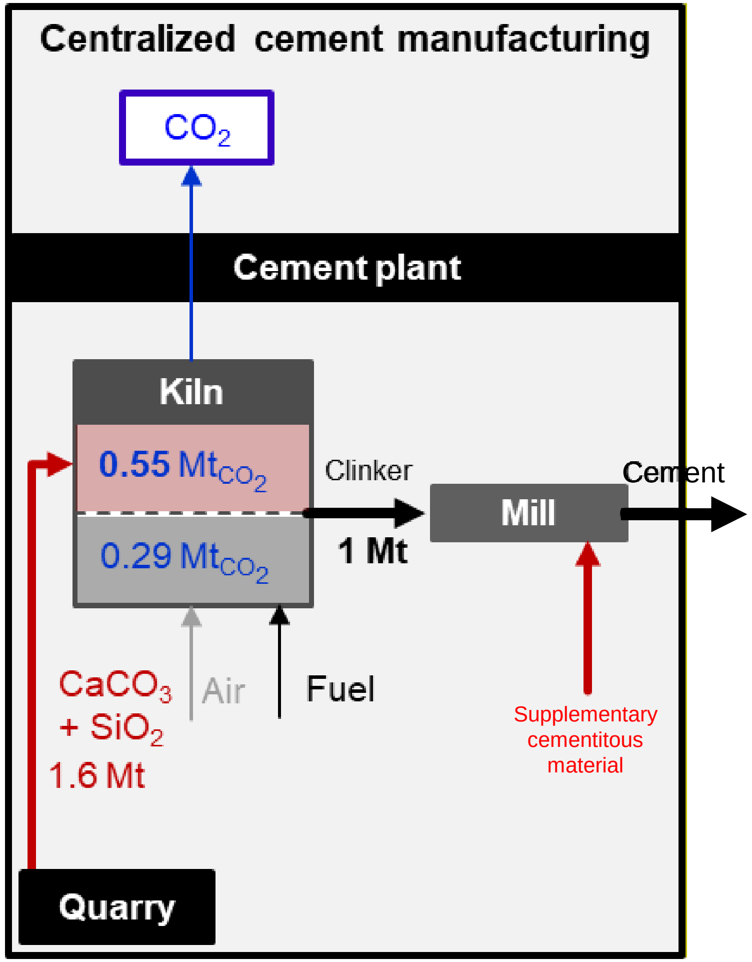
Outline

1) Background and motivation

2) System integration aspects

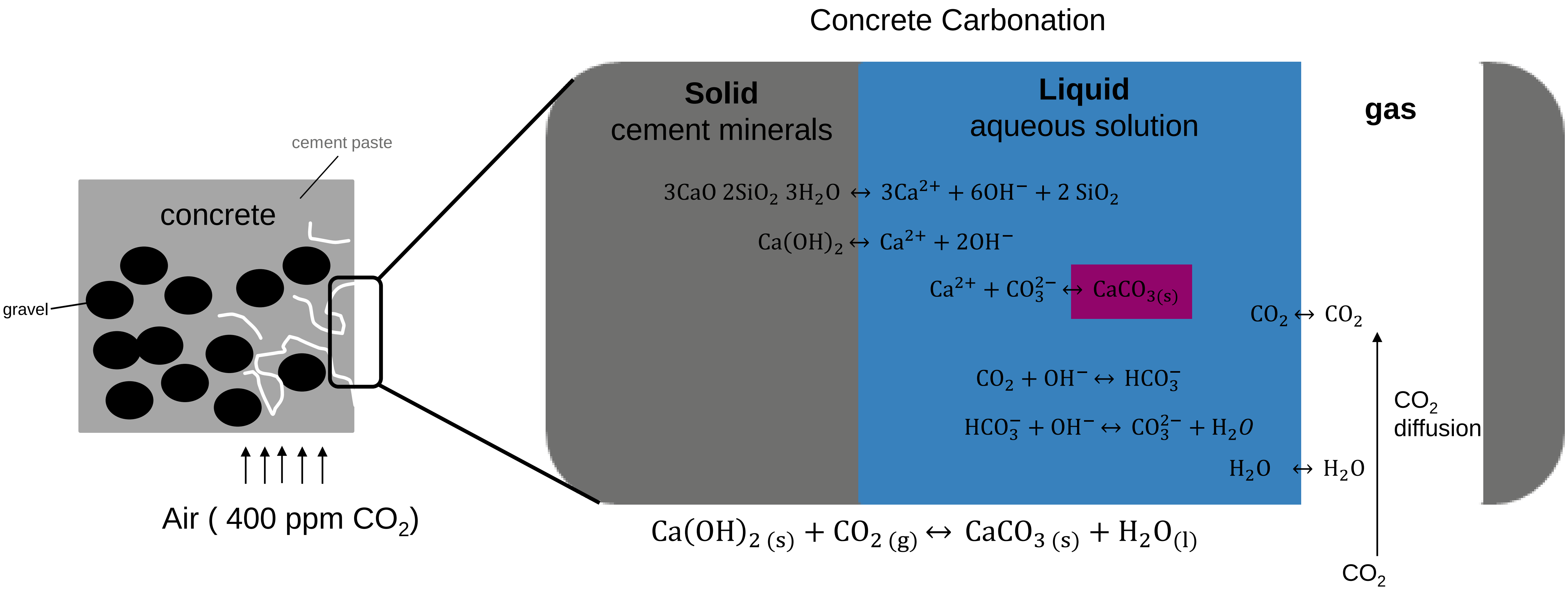
3) Experimental proof of concept

Concrete manufacturing and recycling landscape



Carbonation of concrete
- limits life time of concrete structure
- stores CO_2
- densifies the material

Physics behind carbonation of concrete



Lagerblad, B. (2005)

Carbonation of concrete – state of the art

Modelling

Mass balance over CO_2, $Ca(OH)_2$, CSH, C_3S, C_2S

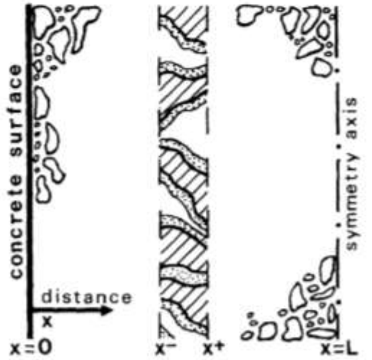


Figure 4. Slab and control volume geometry.

Diffusion with reaction

$$\frac{\partial c_{CO_2}}{\partial t} = \frac{\partial}{\partial x}\left(D_{CO_2}\frac{\partial c_{CO_2}}{\partial x}\right) - r_{CaCO_3}$$

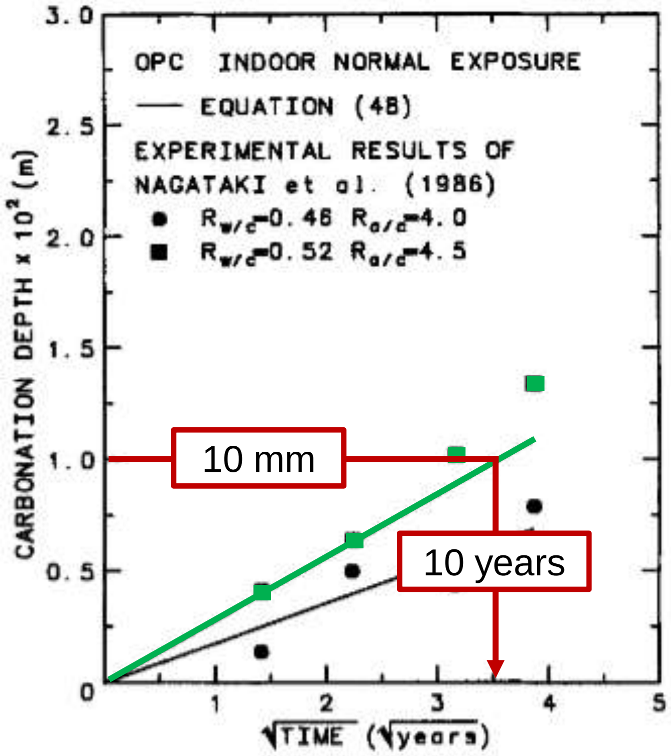
Carbonation depth

$$x_c = \sqrt{\frac{2 p_{CO_2} D_{CO_2} t}{c^0_{Ca(OH)_2} + c^0_{CSH}}}$$

Model validation

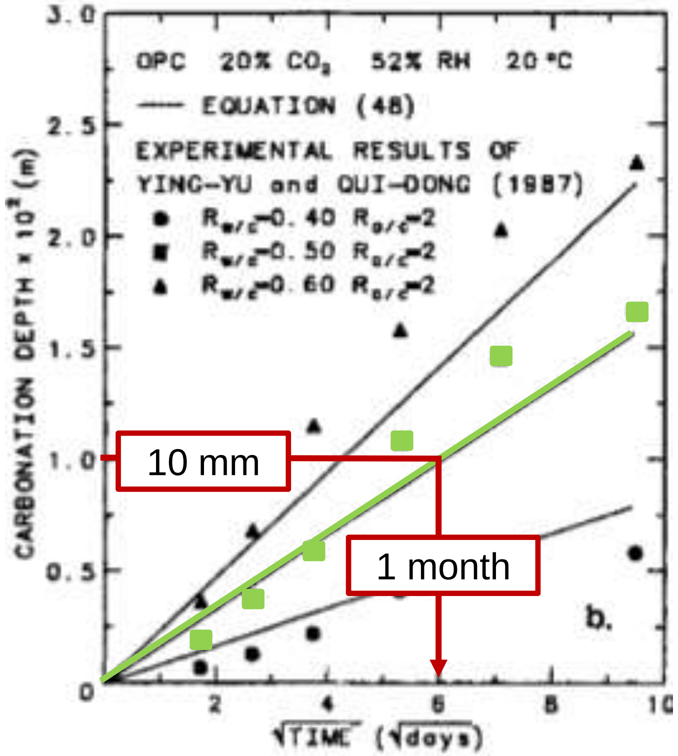
Natural carbonation

indoor exposure



Accelerated carbonation

20% CO_2 / 52% RH / 20°C / W/C 0.4 -0.6



Papadakis, V. G., Vayenas, C. G., & Fardis, M. N. (1991)
Papadakis, V. G., Vayenas, C. G., & Fardis, M. N. (1989).

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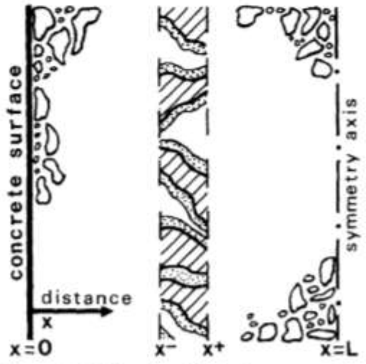

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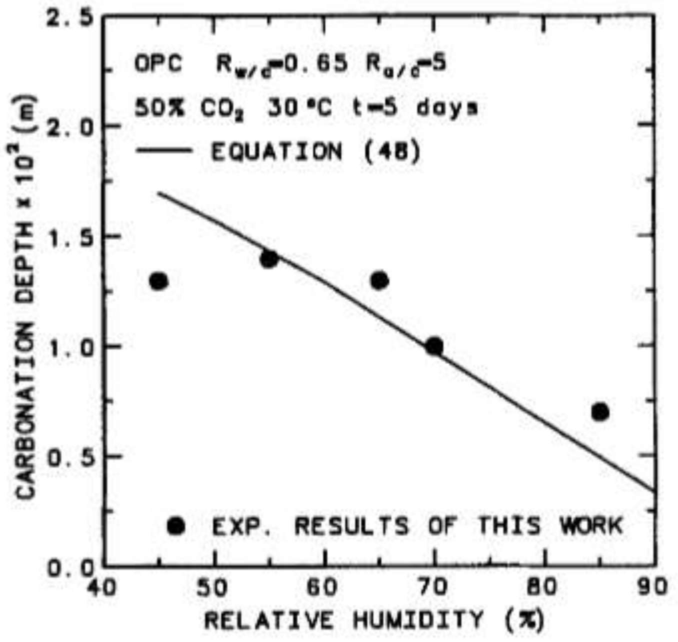
Effect of relative humidity

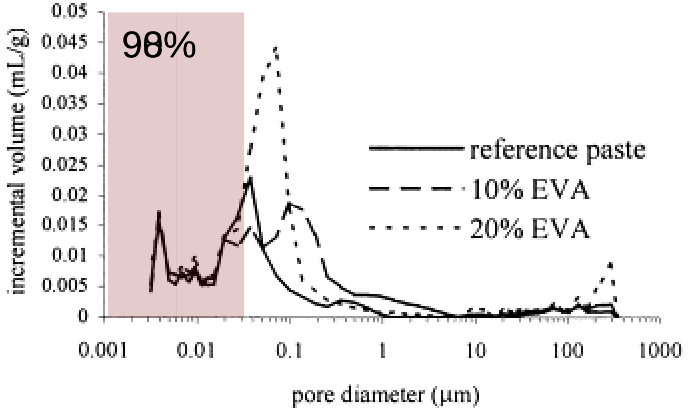
50% CO_2 / 30°C / W/C 0.65 / 5 days



Kelvin radius

$$r = -\ln\left(\frac{p_v}{p_{sat}}\right)^{-1} \gamma \frac{V_l}{RT}$$

Capillary condensation



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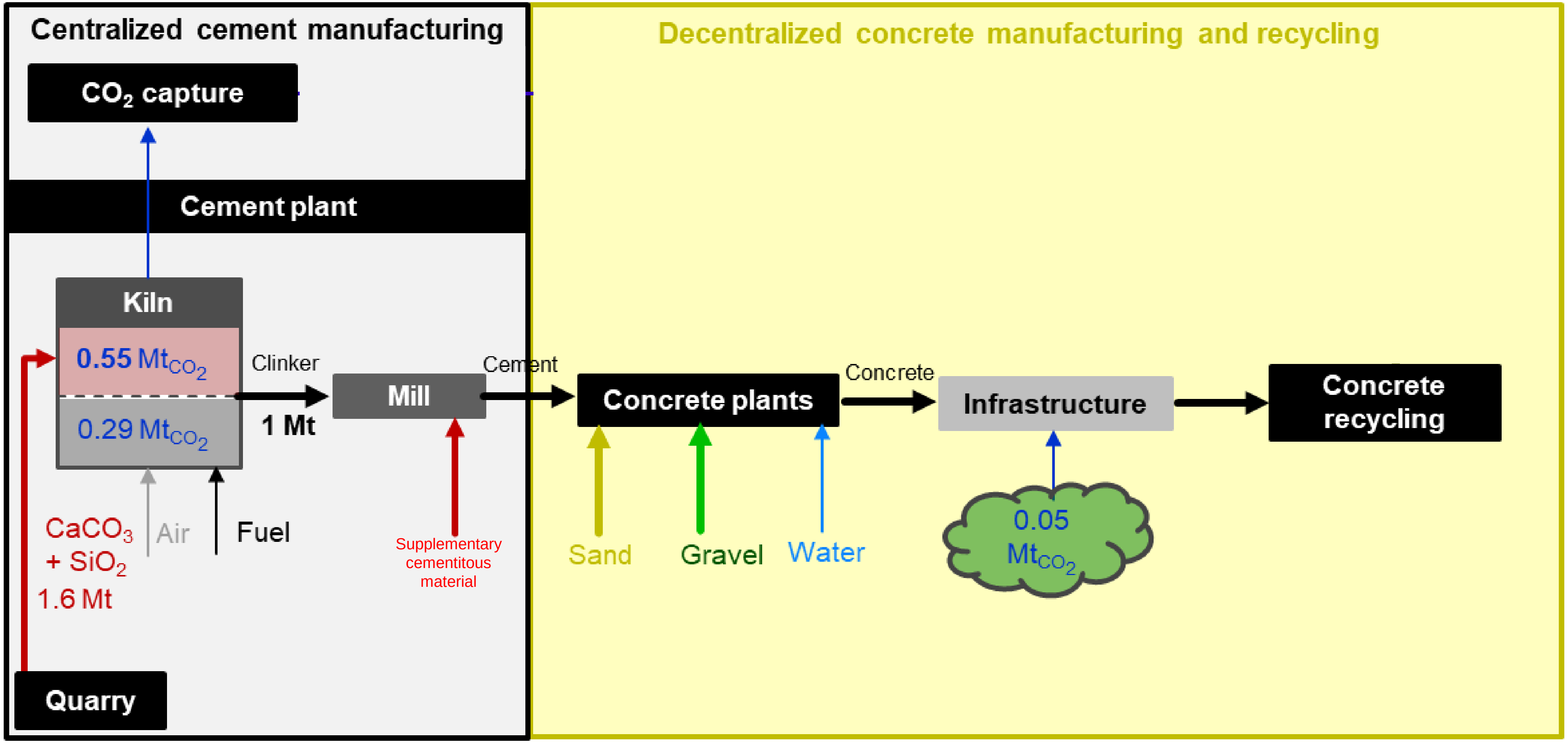
Objective and outline



Global CO_2 uptake potentials for direct mineral carbonation processes

Round numbers:

- Nominal CO_2 uptake capacity of concrete: 150 kg CO_2 / m^3
- Technical potential for direct carbonation processes: 100 kg CO_2 / m^3
- Natural carbonation: 10 kg CO_2 / m^3
- Global amount of demolition concrete: 400 Mm^3/y
- Global technical potential: 40 Mt CO_2/y

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Experimental setup – process flow sheet

Feed conditions

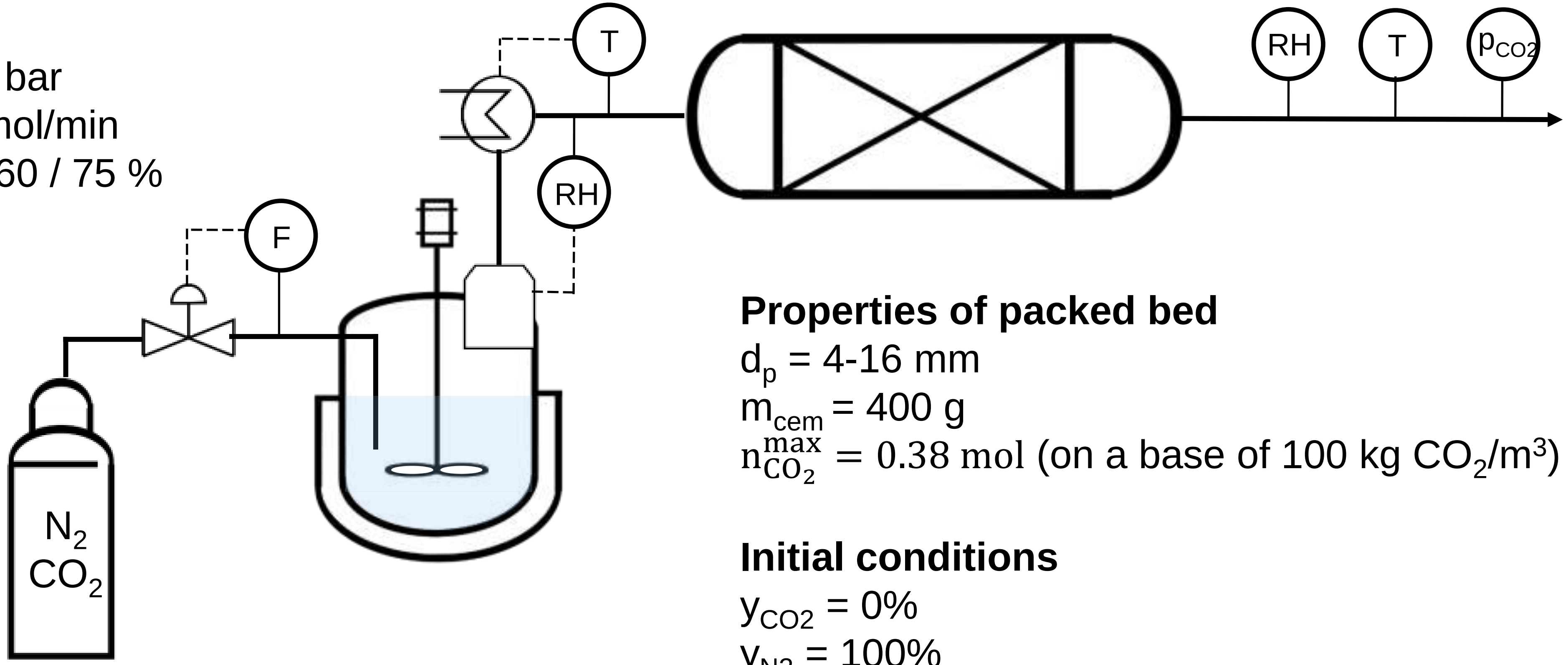
T = 25°C

y_{CO2} = 25%

$p_{amb.}$ = 0.95 bar

F_{in} = 3.1 mmol/min

RH_{in} = 55 / 60 / 75 %



Properties of packed bed

d_p = 4-16 mm

m_{cem} = 400 g

$n_{CO_2}^{max} = 0.38\ \mathrm{mol}$ (on a base of 100 kg CO_2/m^3)

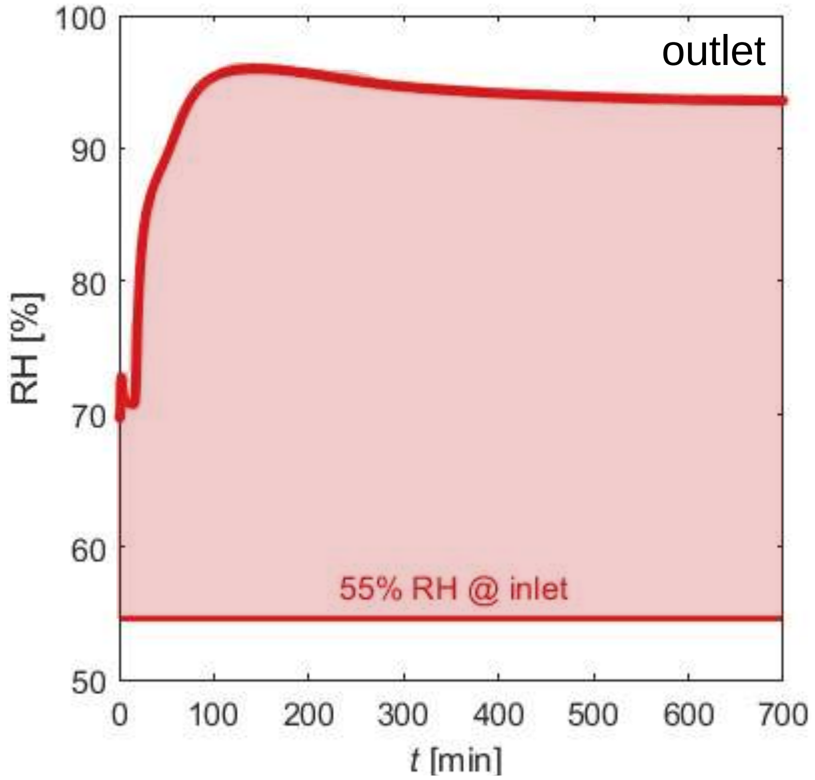
Initial conditions

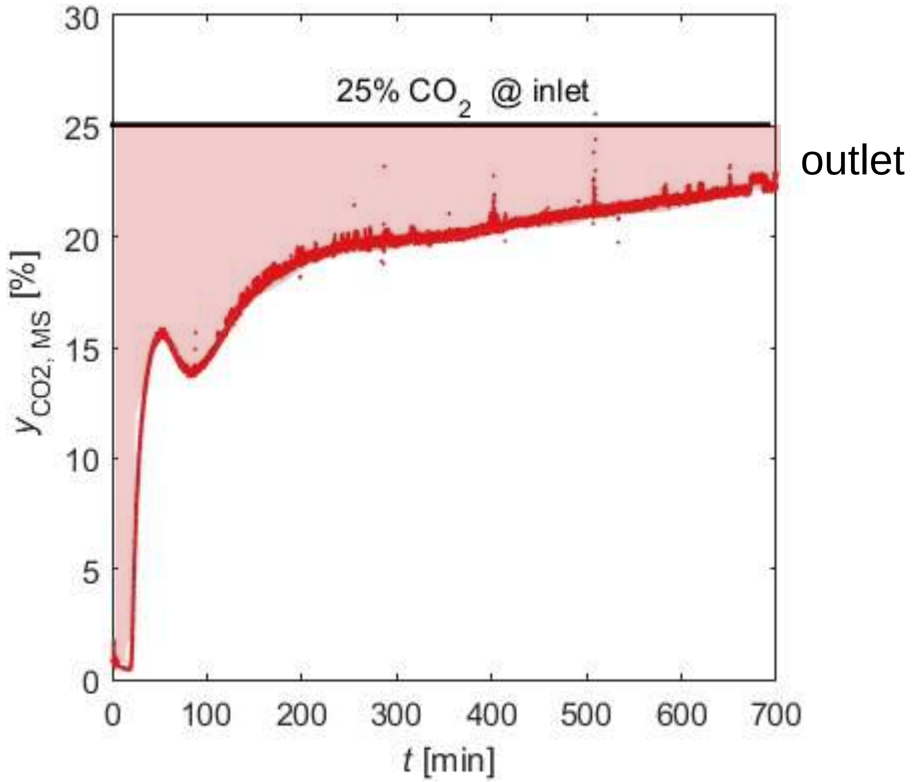
y_{CO2} = 0%

y_{N2} = 100%

RH = 55 / 60 /75 %

Experimental proof of concept I



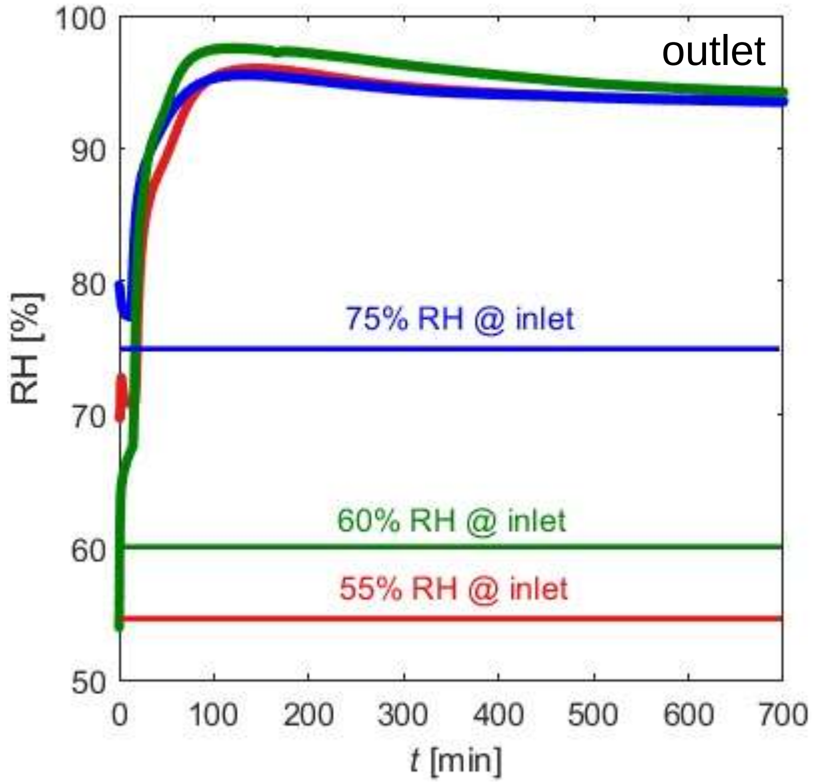


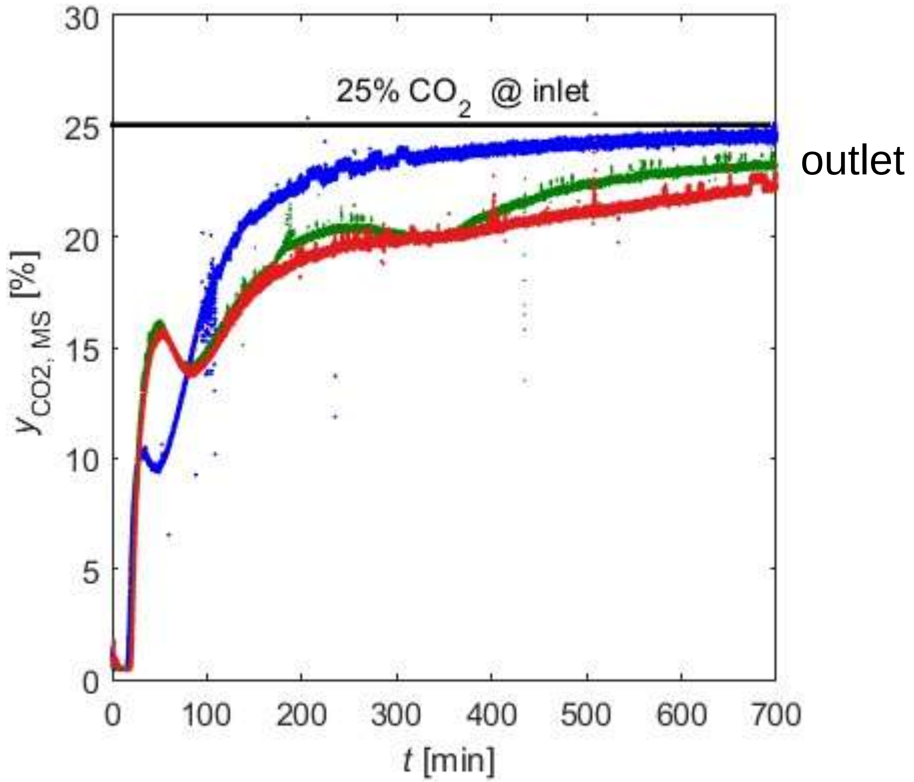
[mol]	RH 55

Observations I:

1. The gas outlet stream gets humidified throughout the carbonation process
2. The CO_2 outlet concentration profile has 3 phases.

Experimental proof of concept I





[mol]	RH 55	RH 60	RH 75
$n_{CO_2}^{in} - n_{CO_2}^{out}$	0.16 (38%)		
$n_{H_2O}^{out} - n_{H_2O}^{in}$	0.023		

Observations II:

1. At lower RH, significantly more CO_2 can be stored within the experimental time.
2. The RH of the outlet gas flow seems to be controlled by the evaporation of the water formed throughout the carbonation.

Conclusions

- We advocate the use of demolition concrete as a way to store CO_2 permanently, since:
  - carbonation processes can be integrated with current concrete recycling practices.
  - 40 Mt CO_2/y can be stored.

- Experiments showed that within 12 hours, demolition concrete of common particle size can store 30 kg CO_2 / m^3, corresponding to 1/3 of its technical storage capacity. .

- These preliminary tests confirm that lower relative humilities enhance the CO_2 uptake of demolition concrete.