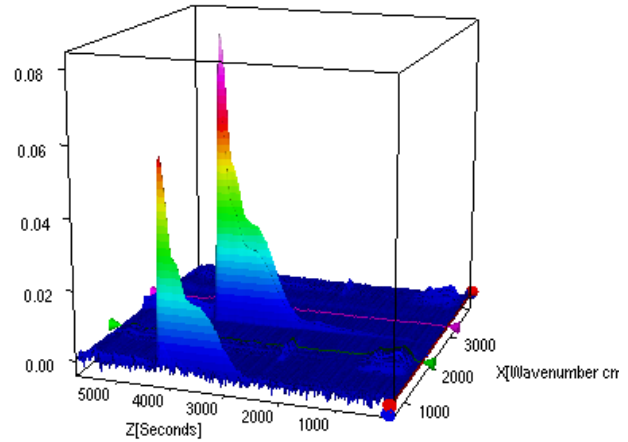
CO_2

CO_2?



Characterisation of Recycled Concrete Aggregates with TGA and XRF coupled with Statistical Data Analysis

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Motivation

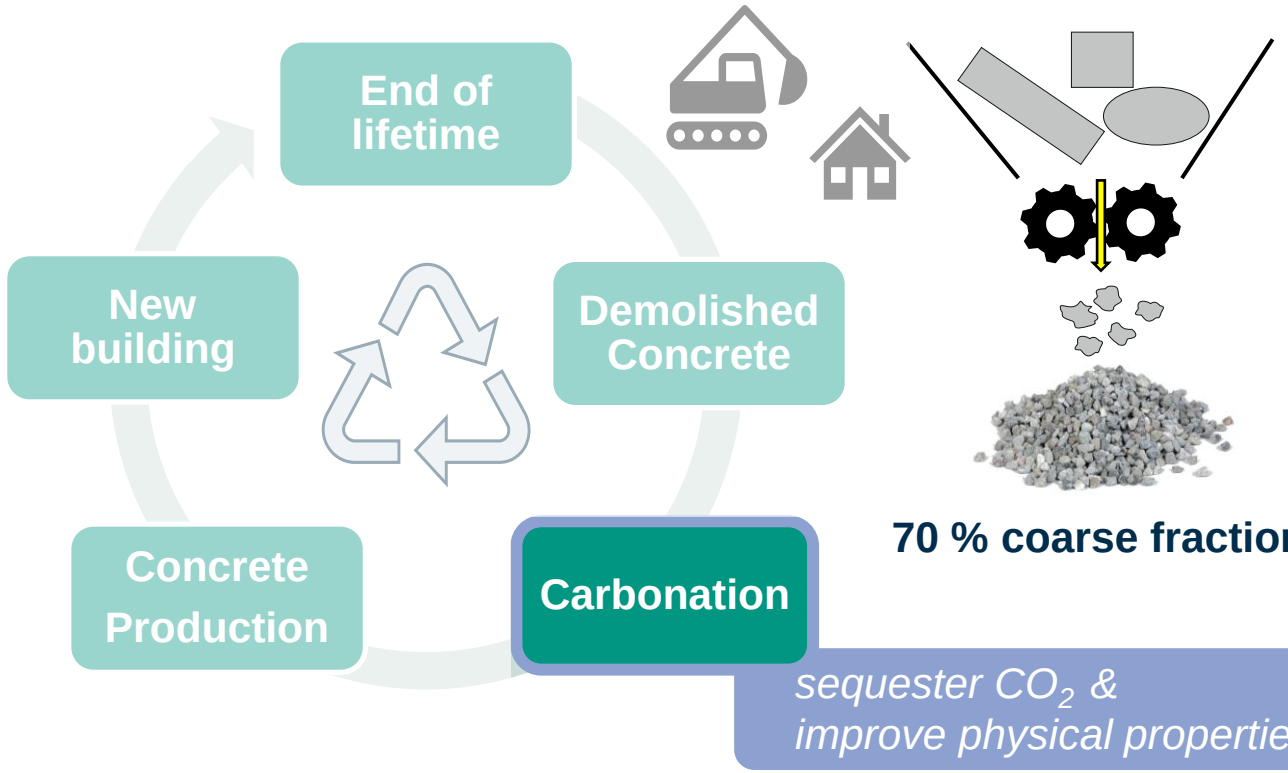
Facts:

~ 8 % man-made CO_2 emissions (cement industry) [1]

~ 200 mio. t of Construction and Demolition Waste (CDW) in Germany per year (in 2023) [2]

Solutions:

- CCUS (Carbon Capture Utilization & Storage)
- Sustainable and circular recycling routes



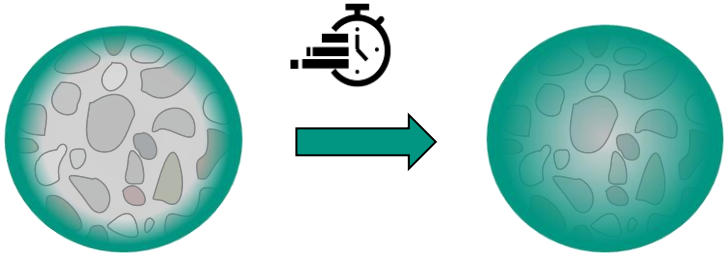
70 % coarse fraction ➡ Recycled Concrete Aggregate (RCA)

[1] Jan Skocek et al. 2020 DOI: 10.1038/s41598-020-62503-z

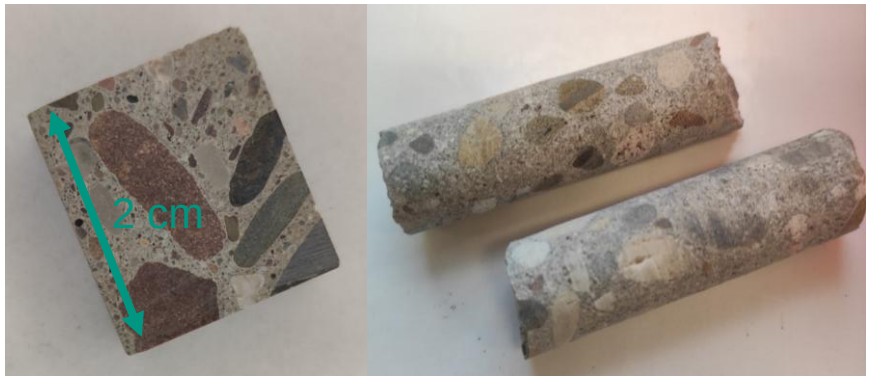
[2] *Mineralische Bauabfälle Monitoring 2022 - Bericht zum Aufkommen und zum Verbleib mineralischer Bauabfälle im Jahr 2022*, Bundesverband Baustoffe – Steine und Erden e.V., Dez. 2024.

Challenges

- Development & optimisation of an accelerated carbonation process
  - Aim: Complete carbonation of RCA in a short time (years ➡ minutes or a few hours)



- Inhomogeneity of the material
  - **CO_2-uptake potential of the material?**
  - **Comparability?**
  - **Precise assessment of the CO_2-uptake?**



Aim of this study:

Find a methodology

a) For the characterisation of RCA

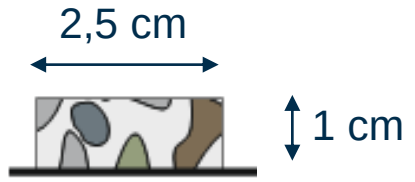
b) To quantify the carbonation of RCA from old paving stones

Approach

1. **Step:** Calculation of the theoretical maximum CO_2 uptake
   - Using a modified Steinour approach

2. **Step:** Analysis of 14 *not carbonated* concrete samples
   - Thermogravimetric Analysis (CO_2-content)
   - X-ray fluorescence Analysis (CaO-content)
   - Statistical Data Analysis

3. **Step:** 3 different Carbonation experiments (right)
   - Calculation of CO_2-uptake
   - Reference basis CO_2-uptake: Data Step 2

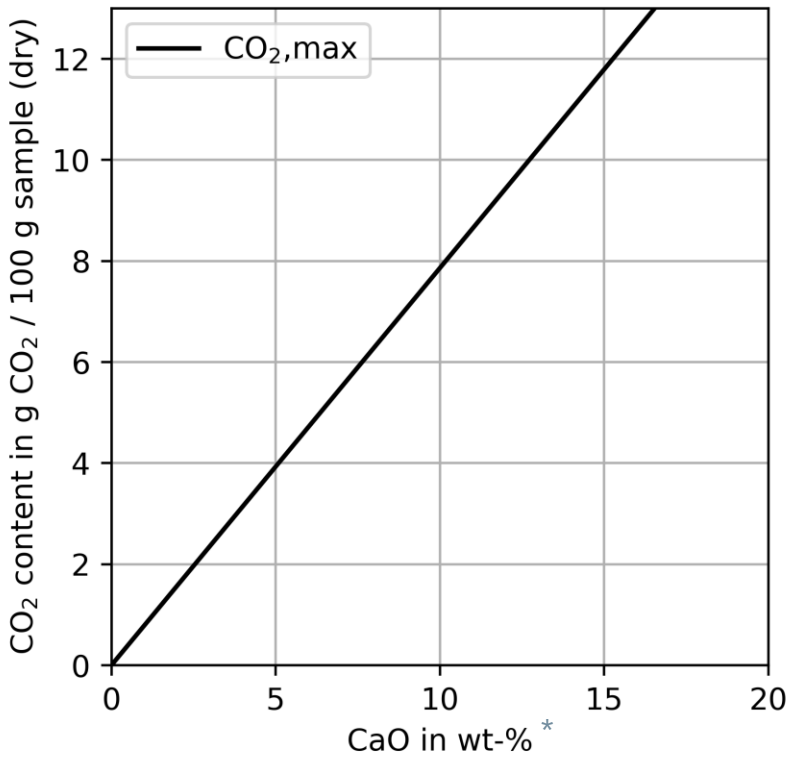


Sample (old paving stone)

Tab. 1: Carbonation conditions

	T / °C	t / h	p_{ges} / bar	p_{CO_2} / bar
Air	20	672	1	0,04
Moderate	20	672	1	0,4
Hydrothermal	170	4	5,7	4

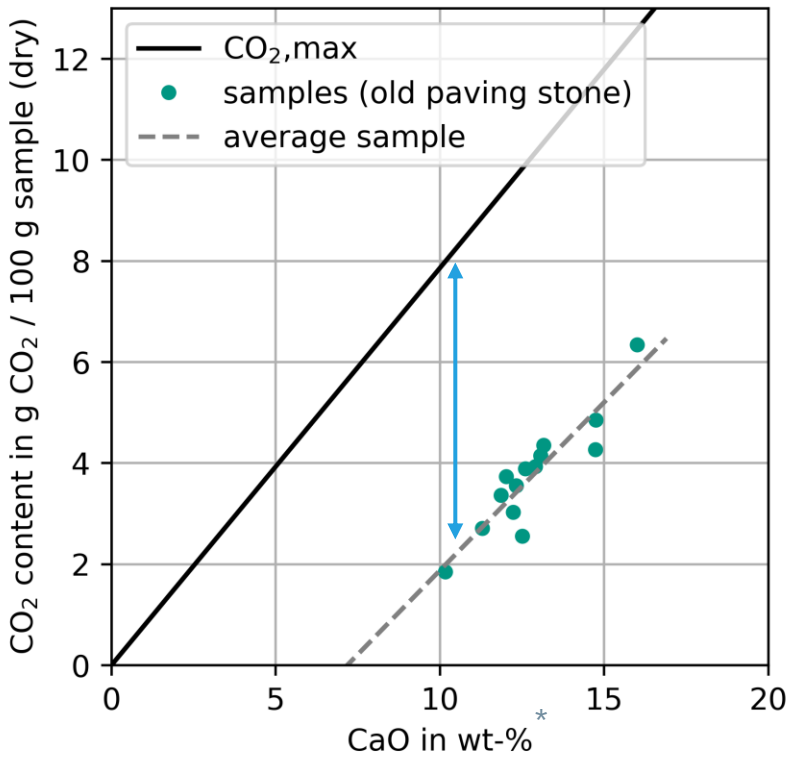
Results – Step 1: Maximum CO_2 uptake



* dry, CO_2 -free

- Theoretical maximum CO_2 uptake ($CO_{2,max}$) based on the CaO content of a sample
- *Assumption:* all non-sulphate-bound CaO is converted into $CaCO_3$ & other phases do not react with CO_2

Results – Step 2: Analysis of starting material



* dry, CO_2 -free

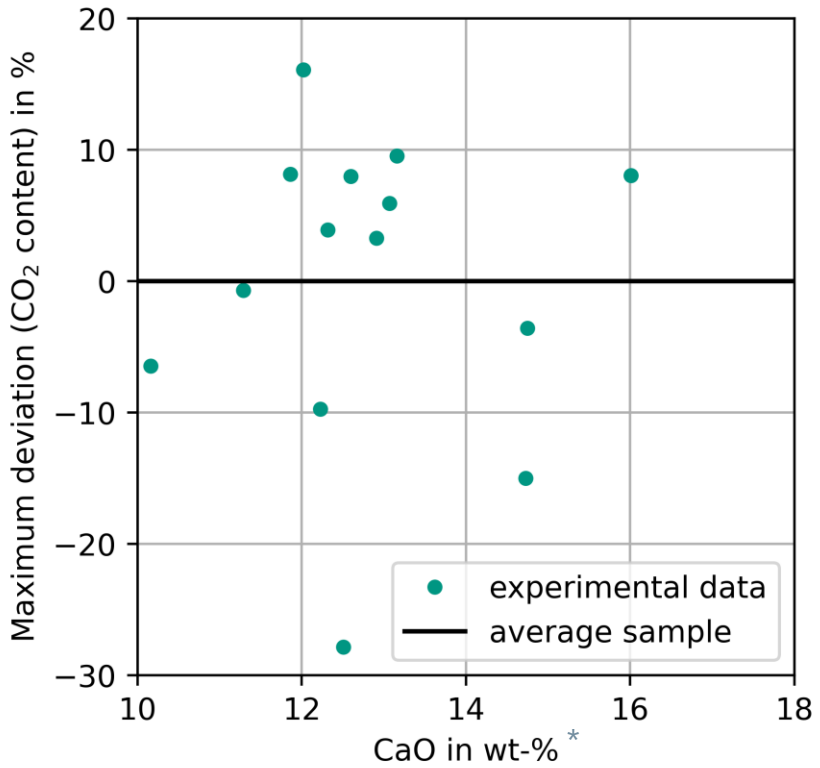
- Differences in CaO content (10-16 wt-%)
  - Different ratio of cement paste to aggregates
  - Different ratio of $CaCO_3$ aggregates to CaO-free aggregates
- Differences in CO_2 content
  - CO_2 from already carbonated hdcp or $CaCO_3$ aggregates

Findings:

- CaO content can be used as a tracer for characterizing the different samples
- Average sample = linear regression
- Theoretical carbonation potential ↕

DIN-EN 197-1 (CEM III/C)

Results – Step 2: Analysis of starting material



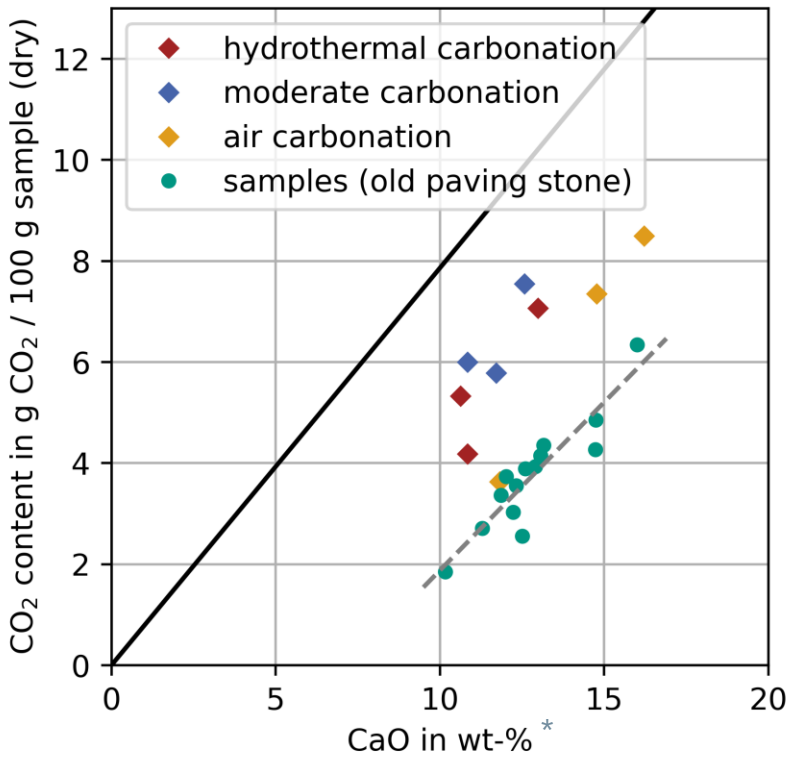
* dry, CO_2 -free

- Mean deviation (absolute): 0,34 $\frac{g\ CO_2}{100\ g\ sample}$
- Experimental data = sample (old paving stone)
- No clear trend, maximum deviation can be up to **28%**

Finding:

- Deviations have to be considered carefully, as they have an impact on a calculated CO_2-uptake (using this data as a reference basis)

Results – Step 3: Carbonation experiments



* dry, CO_2 -free

- Wide spread of data points
- CO_2-uptake:
  - Hydrothermal: $2{,}67 \pm 0{,}73 \frac{g\ CO_2}{100g\ sample}$
  - Moderate: $3{,}43 \pm 0{,}59 \frac{g\ CO_2}{100g\ sample}$
  - Air: $1{,}78 \pm 0{,}9 \frac{g\ CO_2}{100g\ sample}$

Findings:

- Successful CO_2-uptake for RCA
- Limited comparison between the different carbonation experiments

Conclusion and Outlook

✓ Characterisation of inhomogeneous RCA is possible with the combination of TGA, XRF and Statistical Data Analysis

✓ Detectable differences in CO_2-uptake under varying carbonation conditions

○ Difficulties in the investigation of individual influencing factors

🔍 Additional samples need to be analysed → minimize statistical impacts

+

🔍 Investigation of carbonation behaviour with modell system

+

🔍 More realistic calculation of the theoretical carbonation potential

Thank you!

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