THE REACTIVITY OF WOODY ASH IN COMPARISON WITH SLAG

Prof. Dr. E.A.B. Koenders

Institute of Construction and Building Materials

TU Darmstadt

Germany

1. WORKSHOP „Transformation of Wood Biomass Ash into Resilient Construction Composites “,
Croatian Chamber of Economy, 20th October 2017.

Introduction

Content

1) Introduction
2) Experimental part
3) Results of testing and discussion
4) Conclusions and future work

WiB Microlab

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- **Experimental**
  - Set-up
  - Slag comparison
  - Sample preparation
  - Thermogravimetric analysis

Results

- Chemically bounded water
- Calcium hydroxide
- Pore volume
- Compressive strength

Sveučilište u Zagrebu Građevinski fakultet

HRZZ Croatian Science Foundation

Experimental: Plan

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- CEM I 52.5 R
- Slag 1
- Drinking water

replacement rates:
3, 5, 10, 20, 30, 40, 60, 80, 95 mass %
w/b = 0.35 and 0.45

- CEM I 52.5 R
- Slag 2
- Drinking water

replacement rates:
10, 20, 40, 60, 80, 100 mass %
w/b = 0.45

- CEM I **42.5 N**
- **Woody ash**
- Drinking water

replacement rates:
10, 15, 20, 100 mass %
w/b = 0.5

Stop after 1 day, 7, 14, 28, 56, 365 days

Experimental: Slag comparison

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Components [mass %]	Slag 1	Slag 2	WA
CaO	42.44	41.22	41.3
SiO_2	35.85	36.18	26.7
Al_2O_3	11.38	12.13	4.72
MgO	6.00	7.23	7.5
S^{2-}	1.25	1.06	
TiO_2	0.78	0.74	0.34
K_2O	0.37	0.55	7.86
Na_2O	0.22	0.39	1.95
Fe_2O_3	0.41		2.04
Fe		0.22	
MnO	0.255		0.63
Mn		0.21	
Cl^-	0.014	0.04	0.054
SO_3	0.17		0.68
Mn_2O_3	0.283		

- CaO/SiO_2 (Slag 1) > CaO/SiO_2 (Slag 2)
- Al_2O_3 (Slag 2) > Al_2O_3 (Slag 1)
- MgO (Slag 2) > MgO (Slag 1)

\+ Slag 2 is finer

	Slag 1	Slag 2
Blaine value [cm^2/g]	4000	4600

d_{50}(WA) = 146 um

Experimental: Sample preparation

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1 Mixing

2 Storing

3 Hand-milling

4 Treating with acetone

Experimental: Sample preparation

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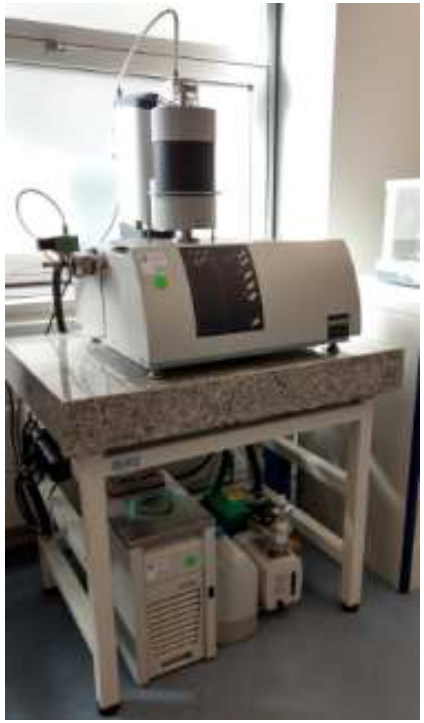

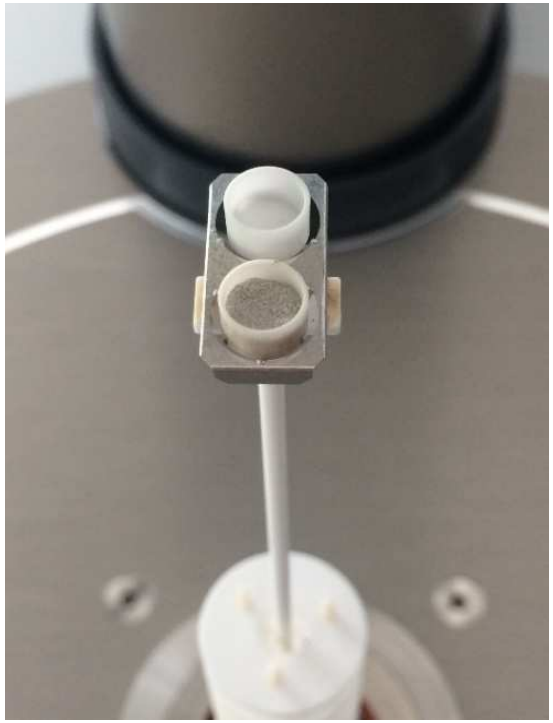

Before you start: When / How to stop hydration ?

Hydration Stoppage: Different Techniques

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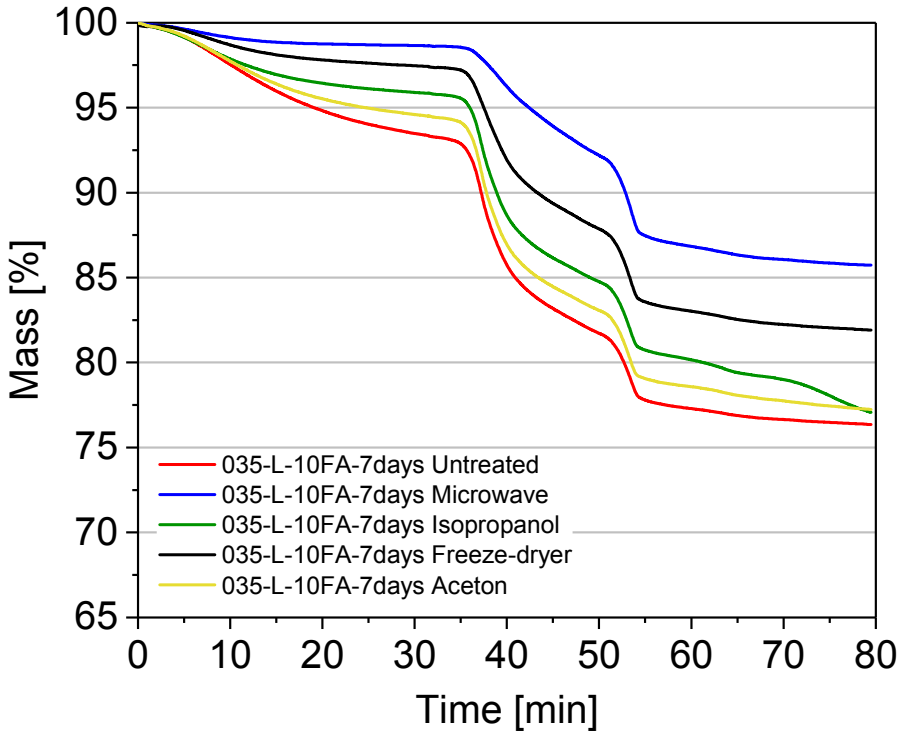
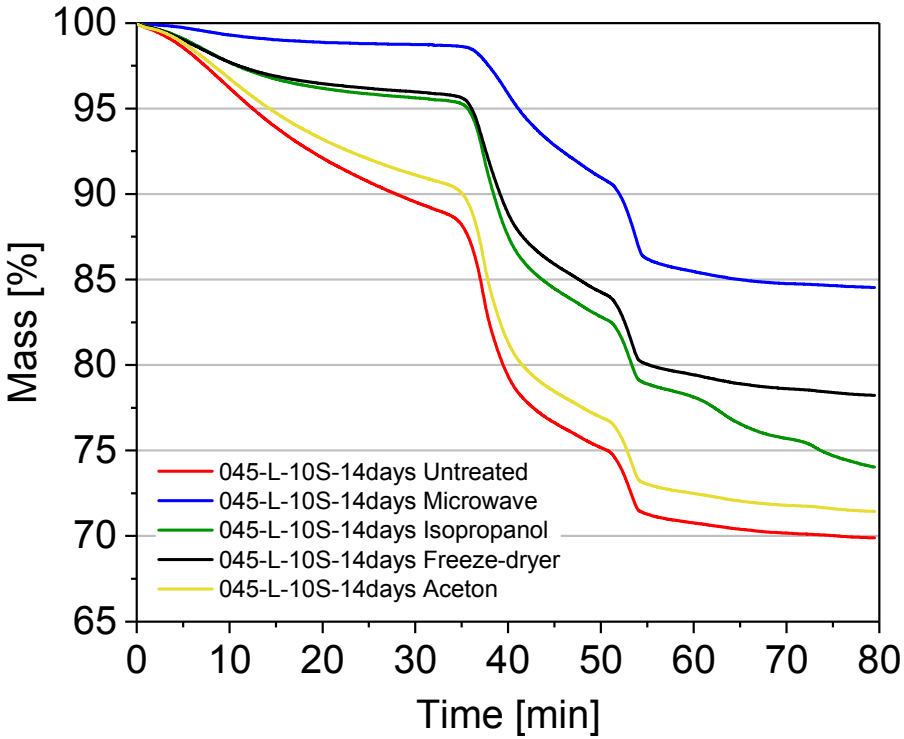


w/b 0.35



w/b 0.45

Experimental: Thermogravimetric analysis

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- Corundum crucible filled with 40 - 50 mg sample powder
- Nitrogen used as inert gas

•Temperature programme:

- 30 minutes at 40 °C and
- Heating to 1000 °C with a constant heating rate of 20 °C per minute

Results: Thermogravimetric analysis

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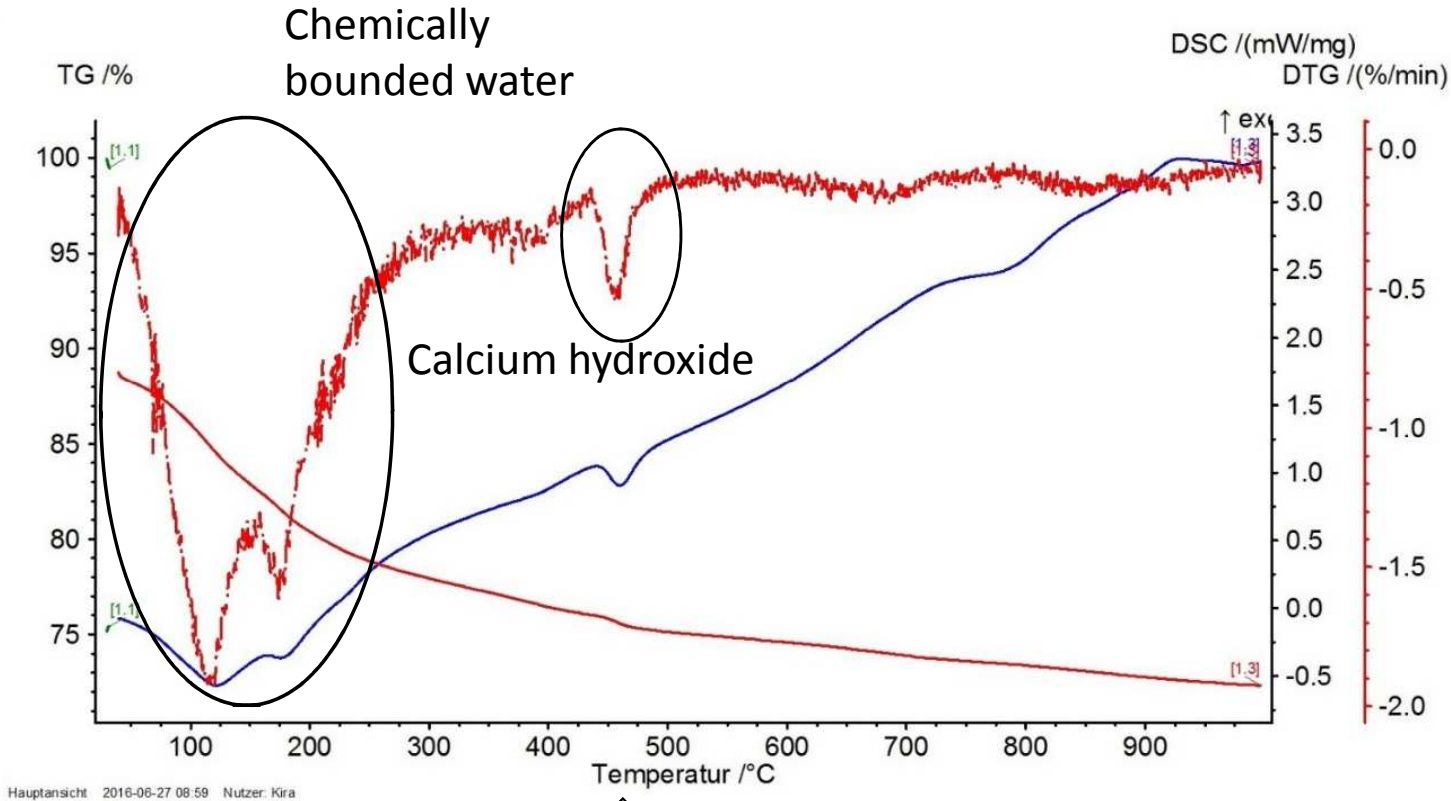

$Ca(OH)_2$ disintegrates between 400 – 500 °C

$Ca(OH)_2 \rightarrow CaO + H_2O$

Results: Chemically bounded water (BW)

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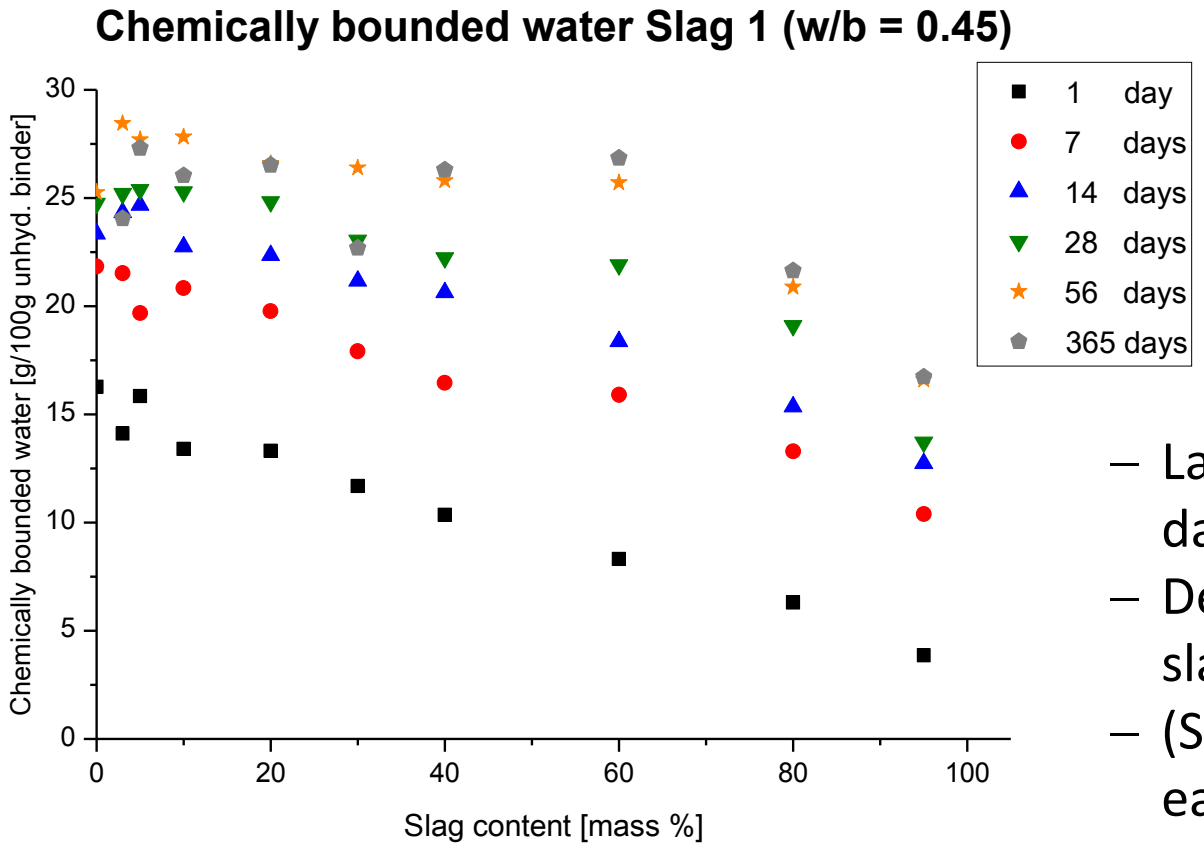

- **BW removed from 40 - 600 °C**

– Largest increase from day 1 to 7
– Decrease with higher slag content
– (Slag > 20 mass % and early age)

Results: Calcium hydroxide (CH)

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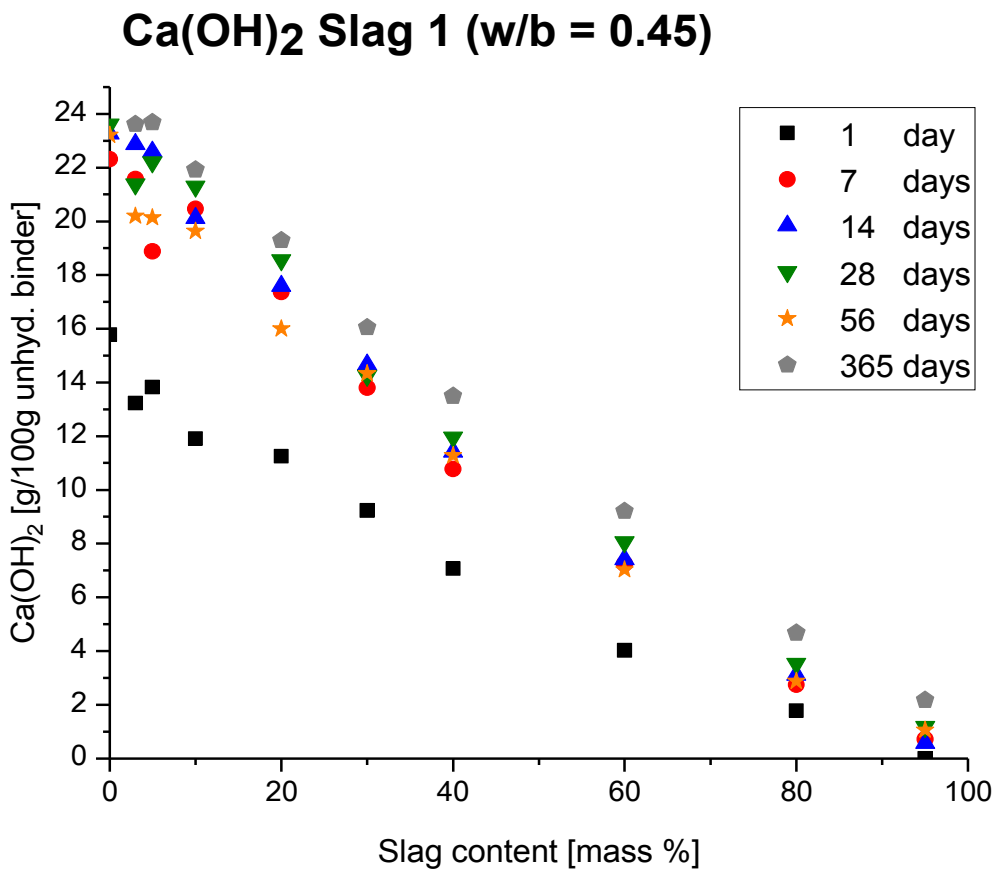

- CH decomposes from **360 - 550 °C** (tangential method was used)
- CH content decreases with increasing slag content
- CH content increases with time
- w/b = 0.35 lower CH content when slag content ≤ 20 %

Results: Consumption of calcium hydroxide

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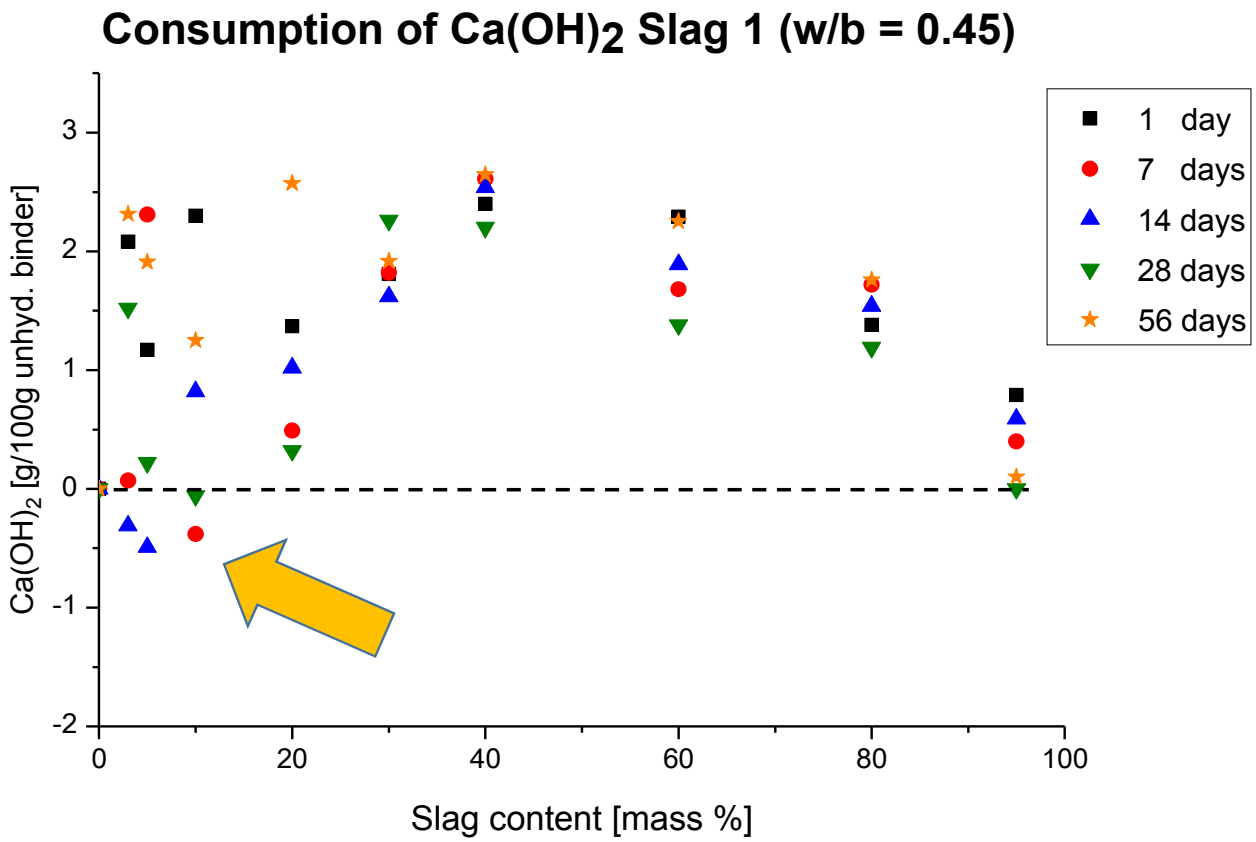

Consumption = $Ca(OH)_2$ produced by cement (reference) - $Ca(OH)_2$ measured

Results: Calcium hydroxide slag (S) versus Woody ash (WA)

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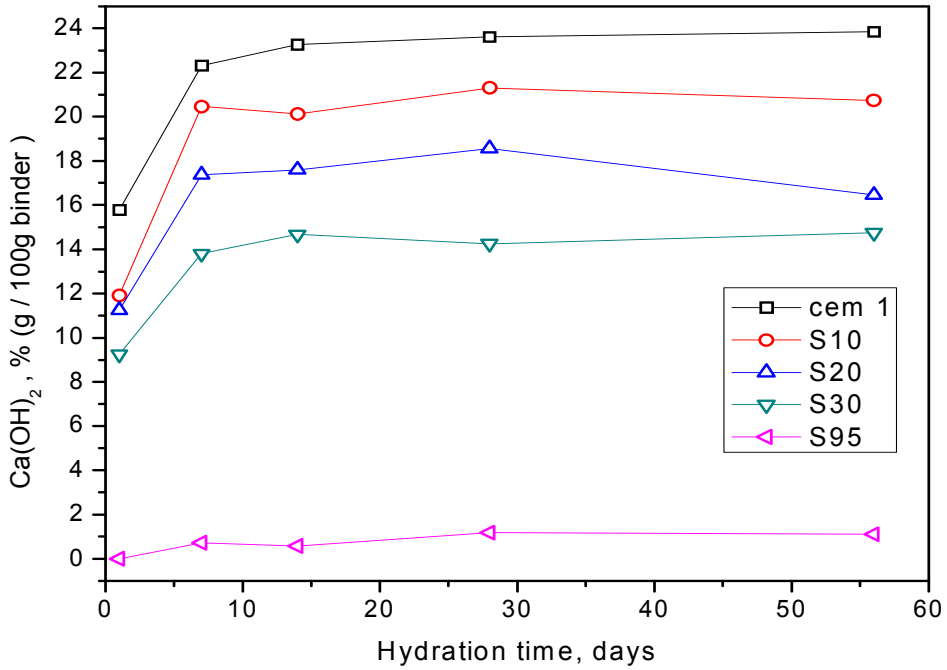
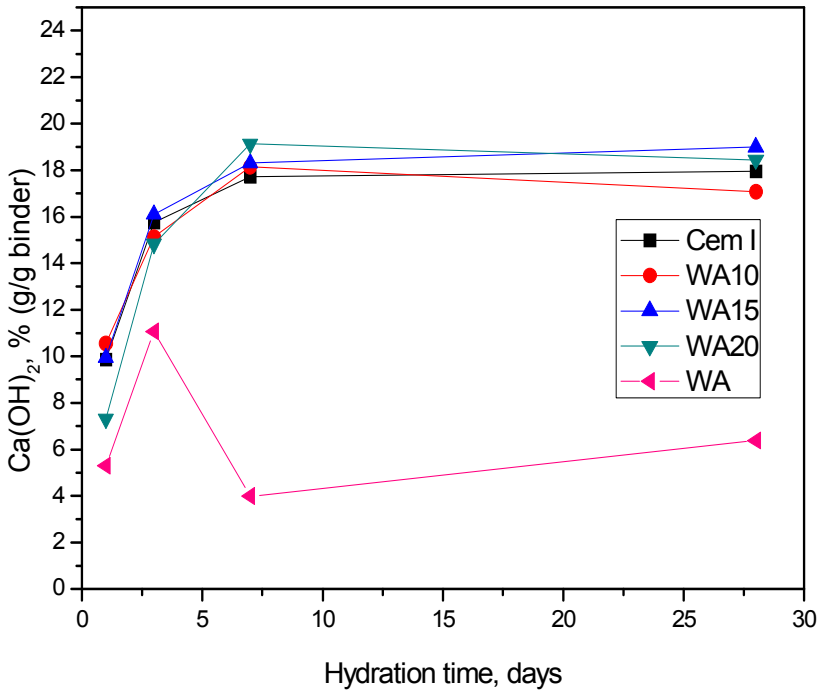
$Ca(OH)_2$: mas.% per powder (cem I + slag 1)



$Ca(OH)_2$: mas.% per powder (cem I + WA)



Results: Calcium hydroxide (CH)

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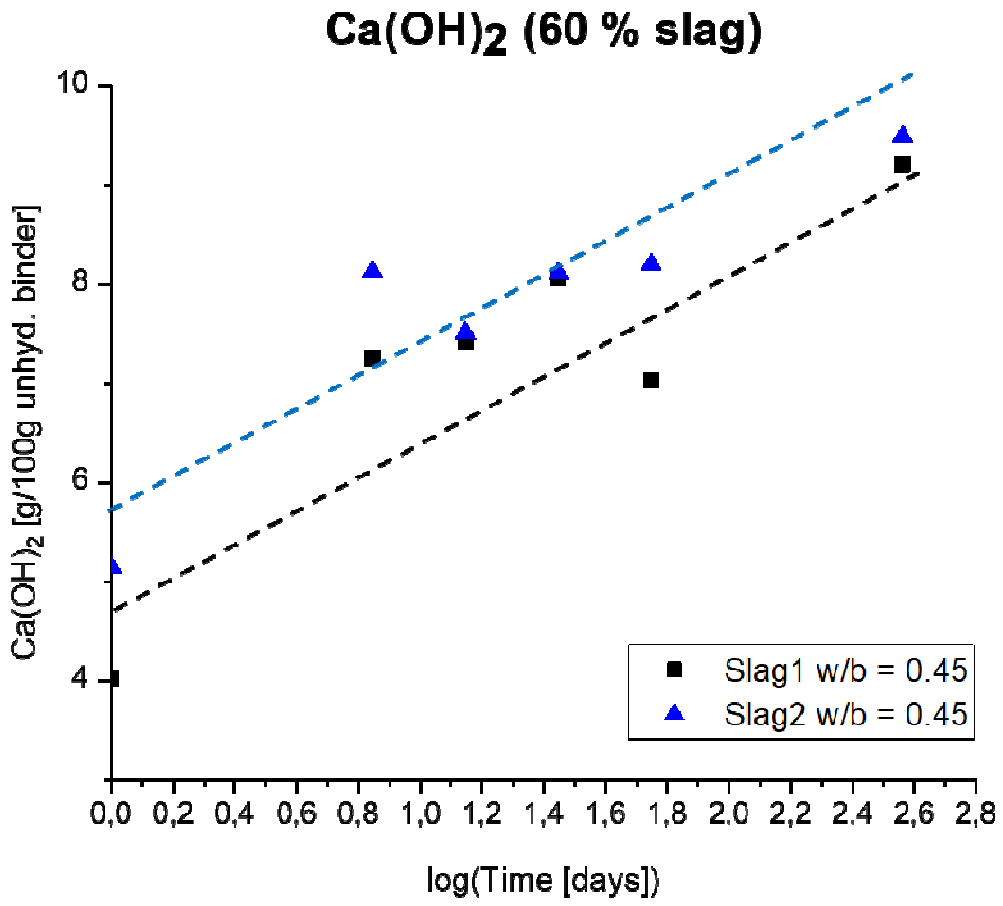

- Logarithmic scale
- CH content increasing linerarly with log of time
- Slag 2 slightly higher CH content

Results: Calcium hydroxide regression model

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Regression model:

$$CH = \beta_0 + \beta_1 \cdot Slag + \beta_2 \cdot \log(t)$$

$CH = Ca(OH)_2$ [g / 100g unhyd. binder]

Slag = slag content of initial mixture [mass %]

t = hydration time [days]

Slag	w/b	β_0	β_1	β_2	R^2
Slag1	0.35	15.56	-0.19	1.66	0.9556
Slag1	0.45	16.73	-0.22	1.83	0.9462
Slag2	0.45	18.14	-0.22	1.45	0.9604

Results up to 28 days included.

Additional results: Pore volume

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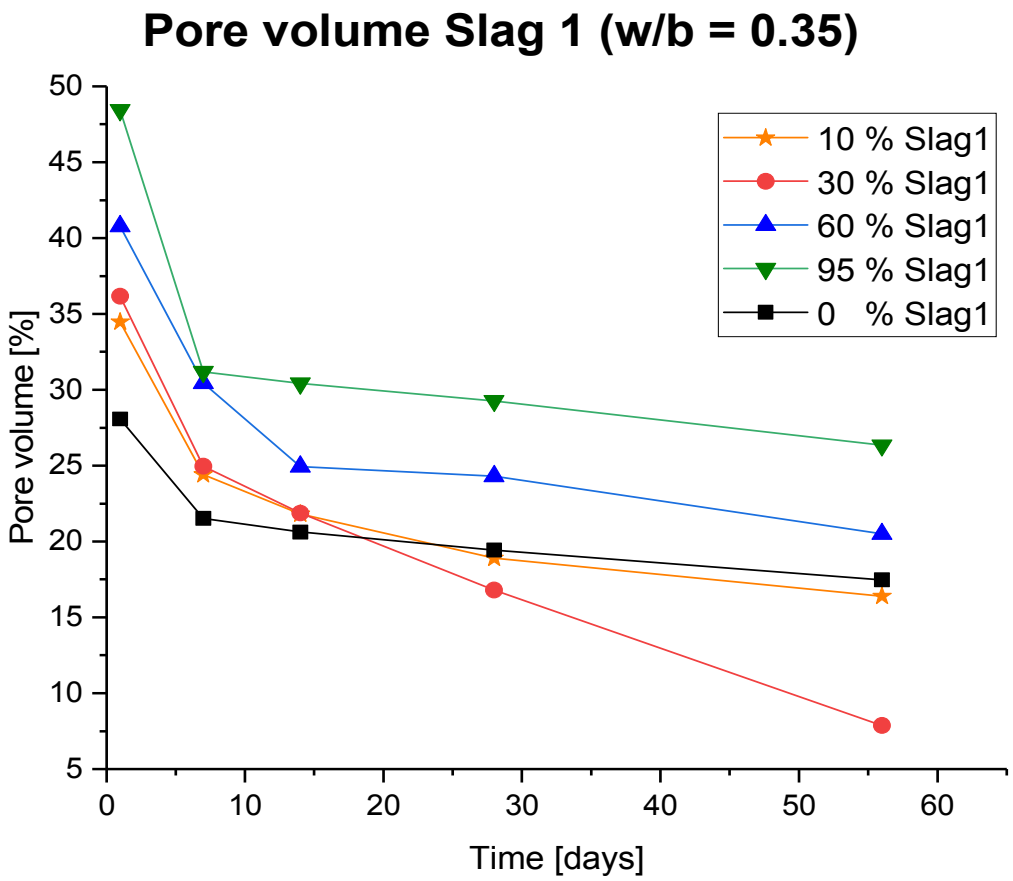

- Pore volume measured with pycnometer
- Decreasing pore volume with time
- Porosity increases for slag content > 30 %

Additional results: Pore volume

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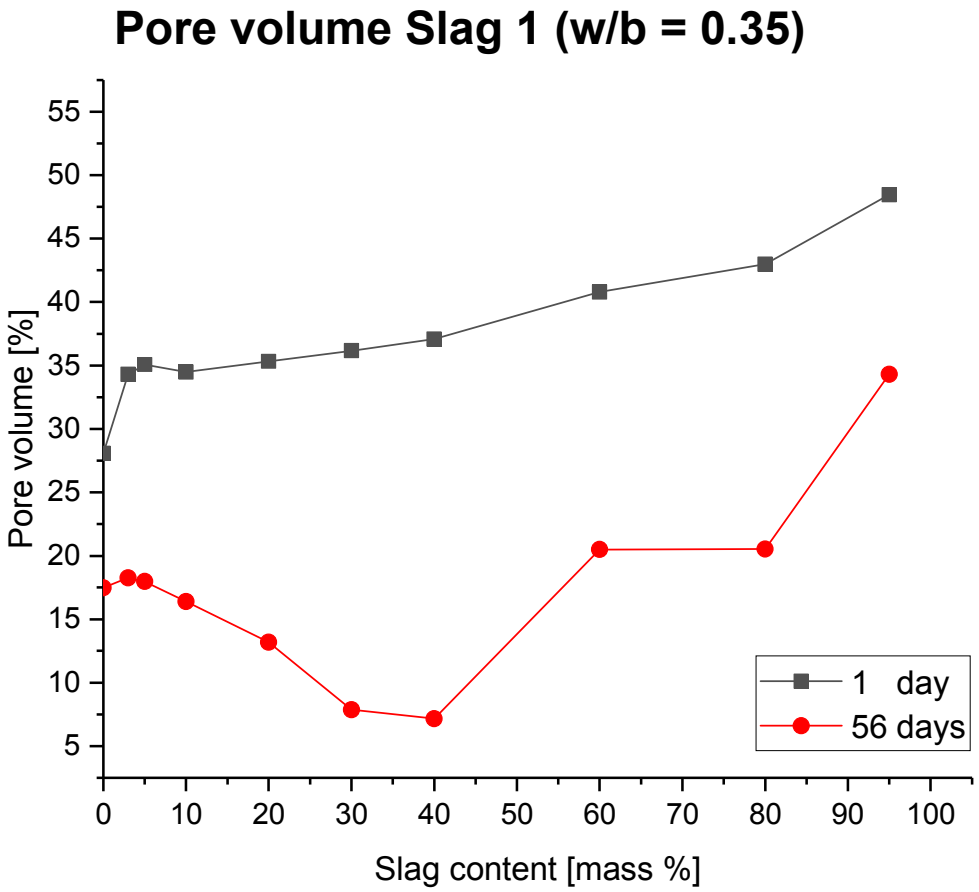

- After 1 day higher porosity with increasing exchange rate
- After 56 days the minimum calculated porosity is with 40 % exchange rate

Additional results: Compressive strength

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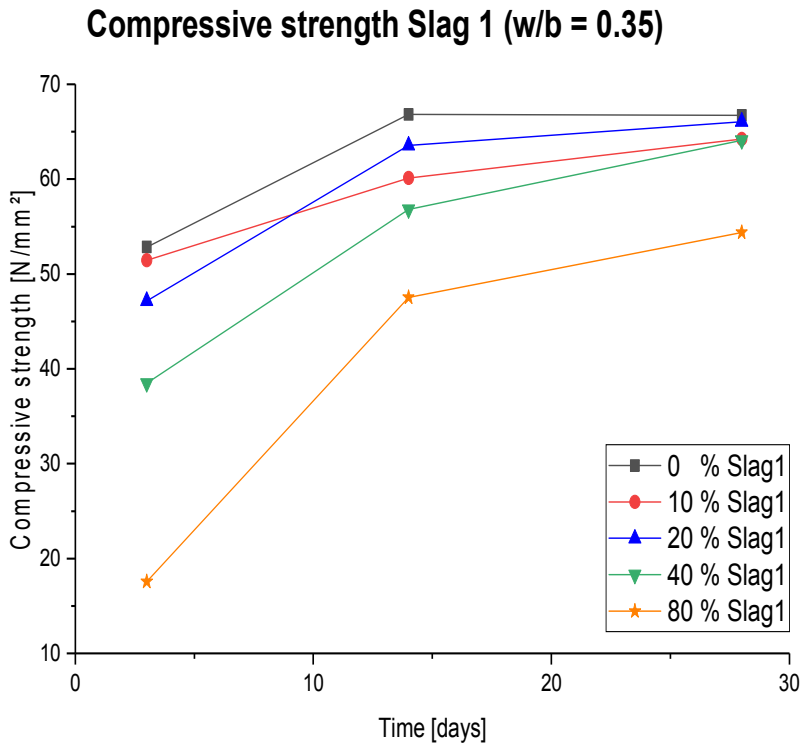

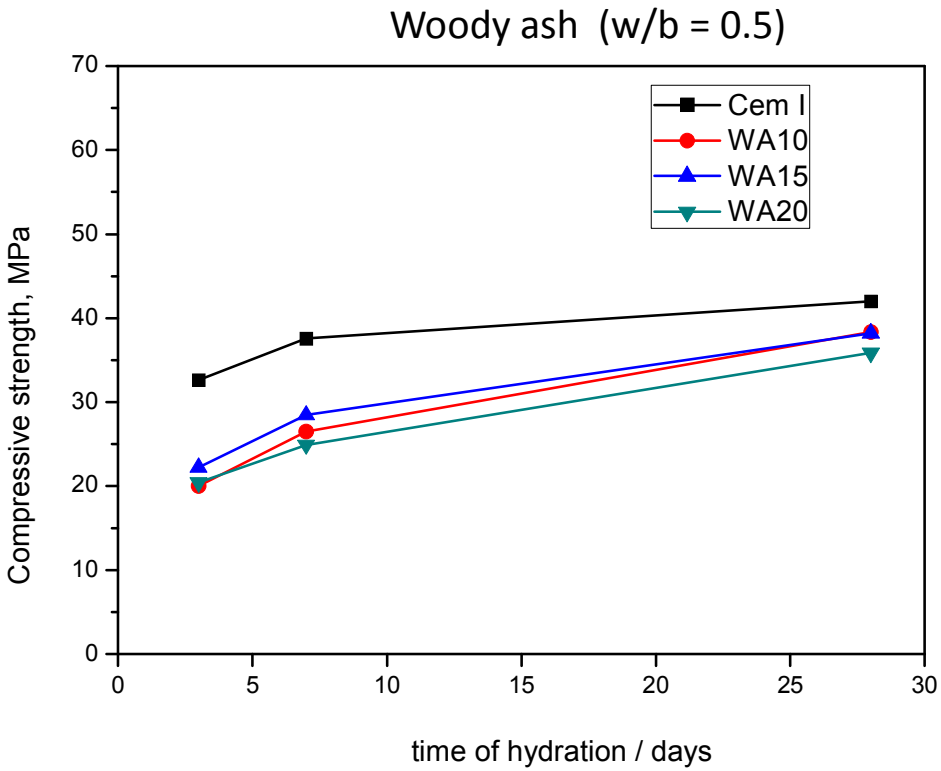

Conclusions

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- Ca content of slag and WA are nearly the same
- CH consumption for WA has almost negliglable up to 20%
- Reactivity of WA differs from slag
- Pore structure depending on replacement ratio
- For WA replacement rate up to 20% has constant impact on strength

Greetings from Darmstadt!

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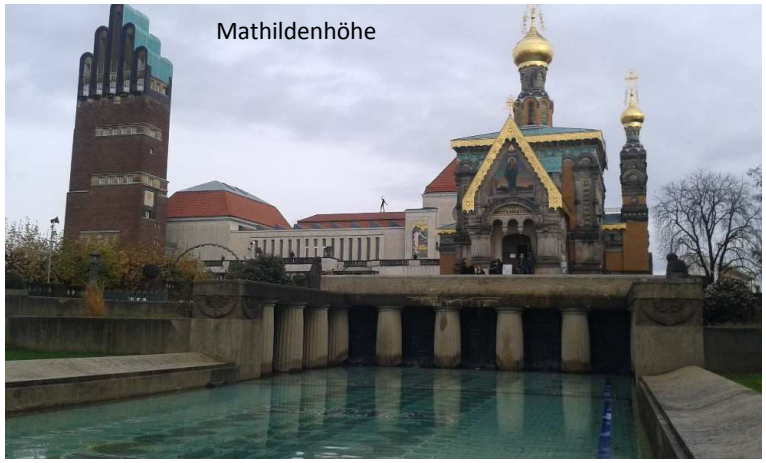

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THANK YOU FOR YOUR ATTENTION

Mail: koenders@wib.tu-darmstadt.de

www.wib.tu-darmstadt.de

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