Upcycling of construction waste in wood incinerators

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NEW BED MATERIAL

Every wood plant uses ~1000 t/y of quartz sand as bed material. The resulting bottom ash largely consists of the derivates of this bed material. **Quartz sand produces bottom ashes that have no reuse application.** A bed material with reuse potential for the cement production is **construction waste (sand fraction).**

WOOD ENERGY PLANT

Largest incinerators use the fluidised bed technology: Hot, circulating bed material provides robust incinerating conditions. **The incinerator will function as an upcycling factory for construction waste.**

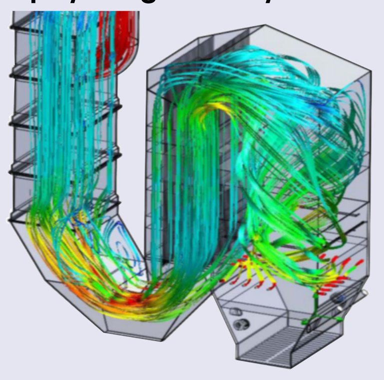


Fig. 1: Air stream circulating through a fluidised bed incinerator. New bed material continuously replaces old material in order to avoid agglomeration [1].

REUSE BOTTOM ASH

Construction waste as a new bed material could produce **bottom ashes with mineral assemblages suitable for reuse as cement additive**. Testing the thermal behaviour of this new material will help to **optimise process parameters in the incinerator to maximise the formation of cement phases, i.e., clinker minerals.**

Investigation of material reactions from 50 to 1000°C temperature

Optimisation of process parameters to improve ash quality for reuse as cement additive

SAVE LANDFILL VOLUME

Fig. 2: landfill site.

The sand fraction of construction waste is a largely unused material. More than 1 Mio m³ are deposited on landfill [1].

CONSTRUCTION WASTE

This material consists mostly of hardened and **carbonated cement rock** (carbonates), **quartz**, **sheet silicates**, **amorphous** phase, and feldspars.

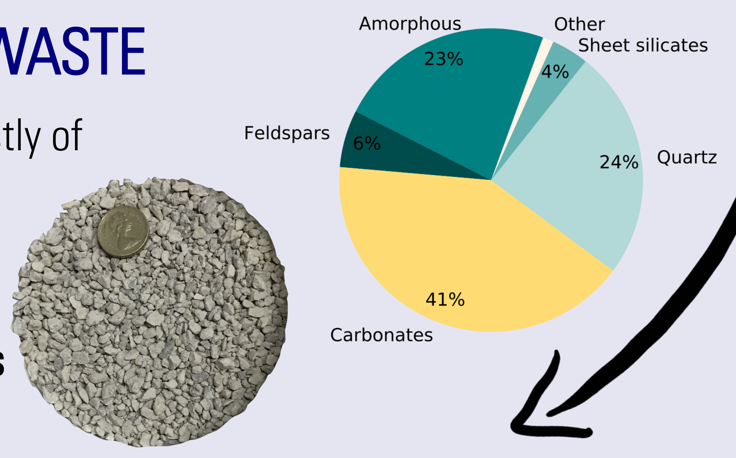


Fig. 3: construction waste. Left—macroscopic impression. Right—XRD results.

NEW CEMENT ADDITIVE

The bottom ash may be used as a **secondary raw material in cement.** This replacement will **save primary resources** and thus **decrease the carbon footprint of cement.**

Methods

Heating stage

Anton Paar heating stage on a X'Pert diffractometer. Measurement from 50-1000°C with an interval of 50°C. Heating curve: 30°C/min, 5min equilibration. Data analysis using TOPAS.

Rotary kiln

Conditions more comparable to fluidised bed incinerator. Treatment time: 2h, T = 1000°C.

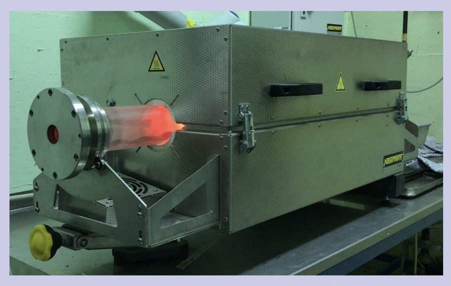
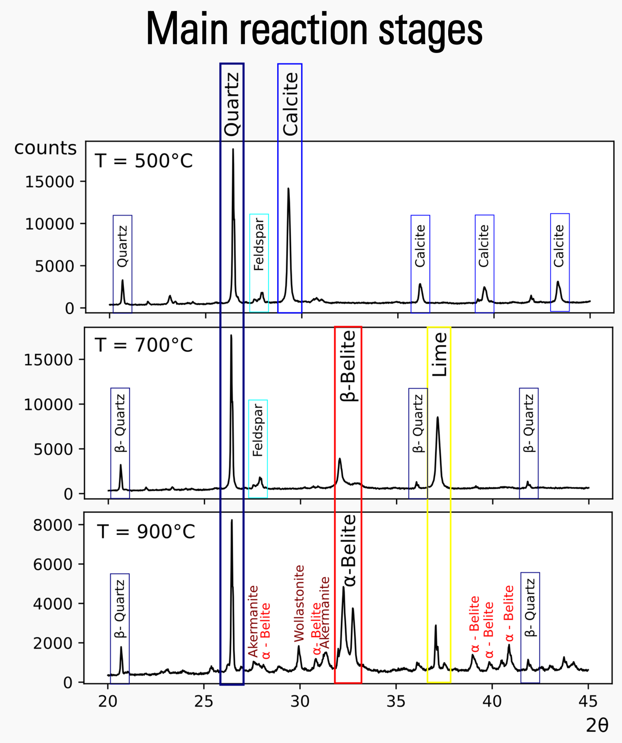


Fig 4: Rotary kiln (1m length).

Electron microscopy

Ash petrography using the BSE and EDX-detectors on the Zeiss EVO50 SEM.

Interpretation of the heating stage diffractograms

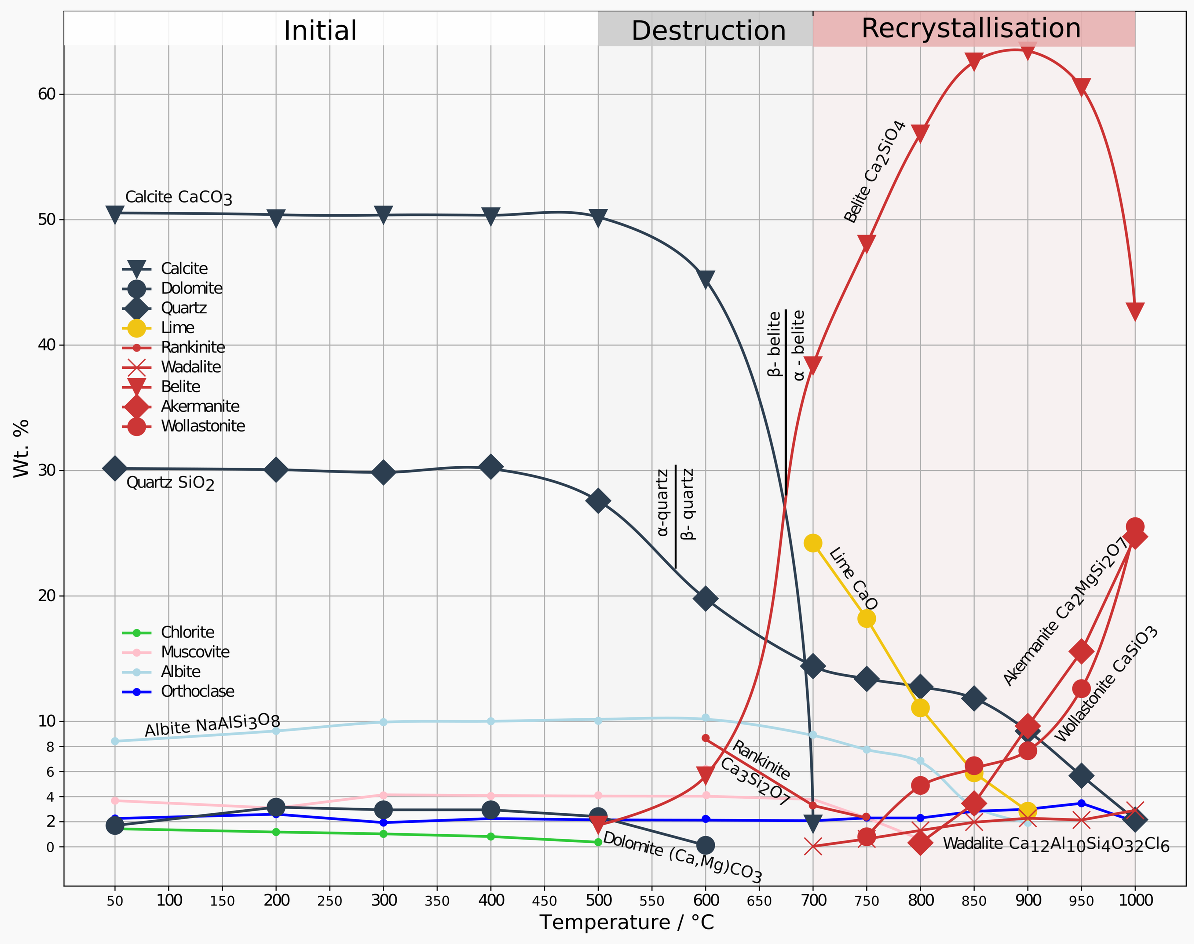


Many new minerals form during heating. Because of a lack of information on high temperature crystal structures in the database, the following approach was used:

1) Select **main reaction stages** graphically.
2) Identification of the **phase assemblage** by help of previous studies [2], [3].
3) **Semiquantitative** interpretation (Fig. 6).

Fig. 5: Selected diffractograms showing the three main phase assemblages identified using XRD-heating stage experiments.

Semiquantitative phase analysis: reactions from 50—1000°C



Destruction (500-750°C)

Calcite ⟶ Lime

Calcite + Quartz ⟶ Belite + Rankinite

Recrystallisation (700-1000°C)

Quartz + Lime ⟶ Belite

Belite + Quartz ⟶ Wollastonite

Belite + Quartz + Dolomite ⟶ Akermanite

Fig. 6: Change of phase assemblage with increasing temperature. The wt-%-indications are estimations based on semiquantitative analysis using TOPAS structural refinement. Not for every phase, all necessary crystallographic parameters are known for every T-step.

Differences between heating stage & kiln experiments

Phase [wt. %]	ambient	rotary kiln 1000°C	heating stage 1000°C
Amorph	22	11	?
Quartz	24	34	2
Calcite	39	1	
Dolomite	1	1	
Portlandite		25	
α-Belite			43
β-Belite	1	12	
Akermanite		4	25
Wollastonite		1	26
Wadalite			3
Feldspars	8	8	2
Sheet Silicates	4	1	

Table 1: XRD-results of different experimental setups.

Evaluation of reaction kinetics:

Reactions without chemical exchange are **fast**: **calcite—lime—portlandite**

Reactions with chemical exchange are **slow**: **Formation of belite, akermanite, wollastonite**

The amount of the **amorphous phase** decreases with higher temperature. Its role in the phase formation is still under investigation.

Bottom ash microscopy

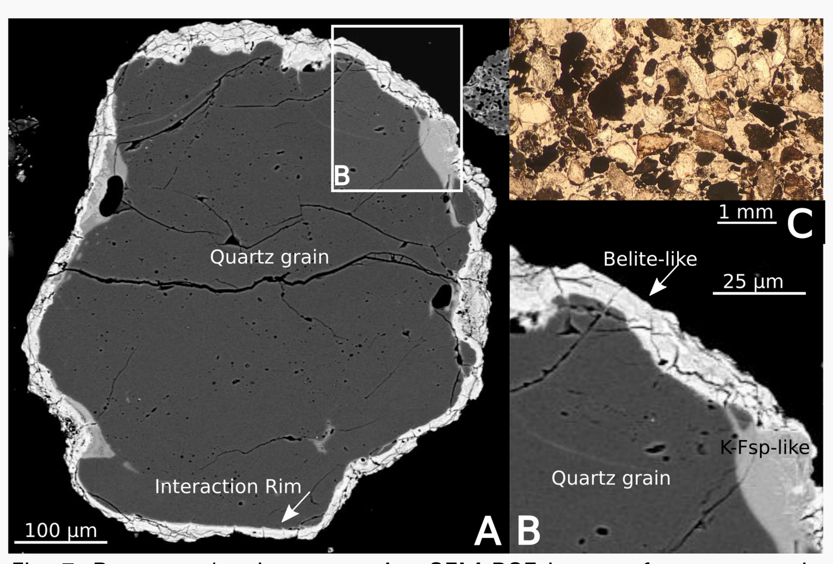


Fig. 7: Bottom ash microscopy. A—SEM-BSE image of a quartz grain with reaction rim. B— Detail: 2-step layer formation. C—optical microscopy (PPL).

Observations on the bottom ash petrography reveals **ash layer formation** arising from reactions between bed material and the wood-derived inorganic compounds.

The **reaction interface** is along the grain boundaries. The interaction rim is approximately 15 to 20 µm thick.

Two layers may be distinguished:

An inner, K– and Al-rich layer (composition similar to alkali feldspar), and an outer, Ca-rich-layer (belite-like).

Extrapolation of the laboratory results to fluidised bed conditions

Heating stage

Small grain size lead to high interaction between grains and a slow heating curve: Results **represent equilibrium conditions.** No likely scenario.

Rotary kiln

Rotary kiln experiments with real grain size represent movement in incinerator: Results give **indications on reaction kinetics.**

Ash microscopy

Limited **bed particles interaction before ash coating** forms. New phases form from interaction of quartz sand with wood ash components.

Implications for optimising incinerator process parameters

Heating stage experiments revealed that at T=700°C, **belite, a clinker mineral, forms.** The preceding **ash coating favours its formation**. Belite gives late strength to the cement.

Ca-silicate formation starts at T=750°C, but its formation is **kinetically hindered**, as rotary kiln experiments show. Ca-silicates give no strength to the cement.

Selecting a **bed temperature of 700-750°C** will thus optimise the resulting bottom ash to a phase assemblage most suitable for **the reuse of the material as a cement additive.**

References

[1] Rübli, S. (2022). KAR-Modell—Modellierung der Kies-, Rückbau und-Aushubmaterialflüsse: Nachführung Bezugsjahr 2020. Umweltämter der Kantone Aargau, Basel-Landschaft, Basel-Stadt, Bern, Luzern, Schwyz, Solothurn, St.Gallen, Zug, Zürich.

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[3] Peters T., Iberg, R. (1987). Mineralogial changes during firing of calcium-rich brick clays. Ceramic Bulletin, 57, 503-509.

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