Institut für Angewandte Bauforschung
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Construction and Demolition Waste as new raw material resource?

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Construction industry <u>consumes</u>

- Landscape
- Energy
- Mineral resources

Construction industry <u>produces</u>

- Building materials
- Buildings and infrastructures
- Construction and demolition waste
- CO_2

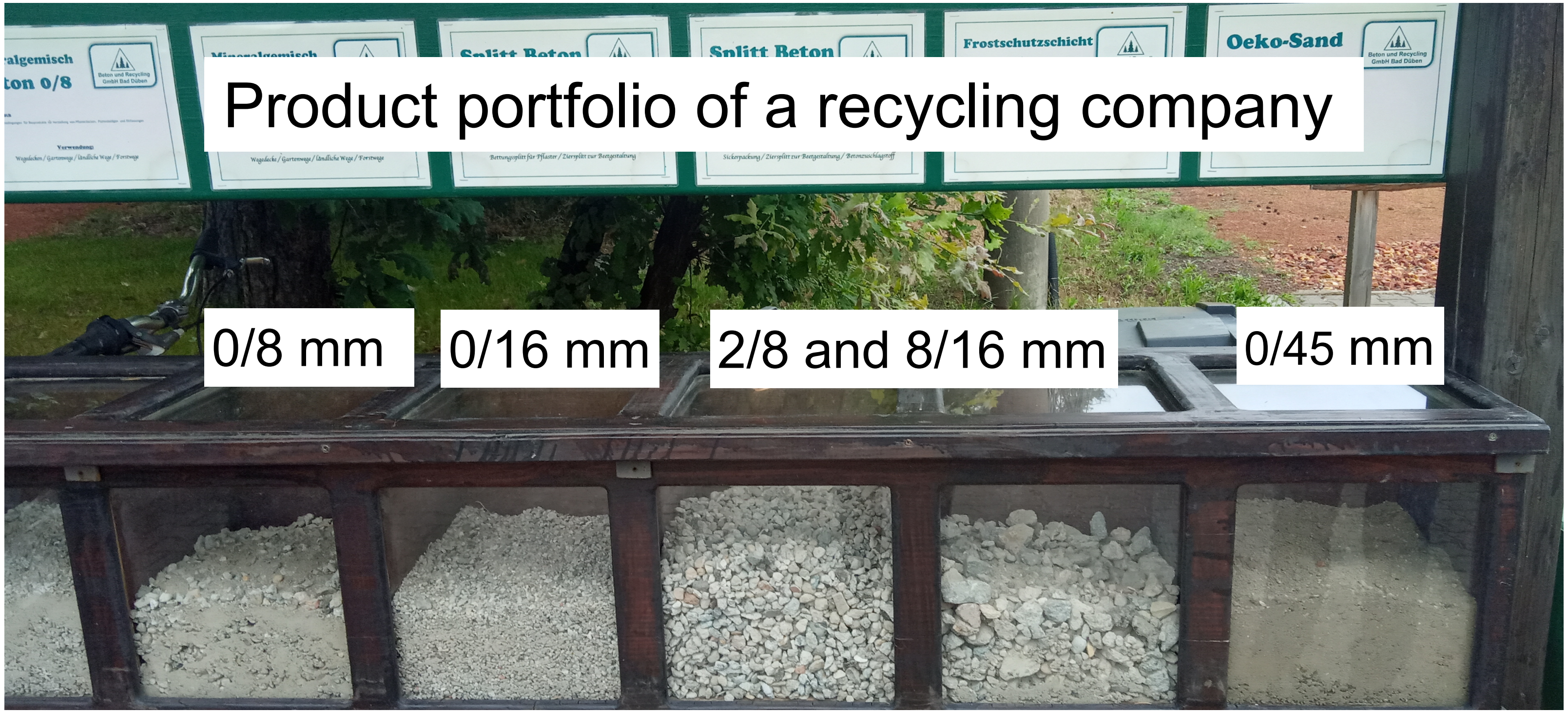
All activities are connected one with the other, all have to be reduce

Concrete as raw material resource

Concrete as raw material resource

Main characteristics

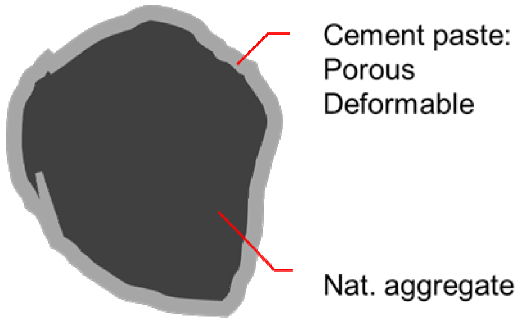
- Hardened concrete in its initial state: Composite of hydrated cement + fine and coarse aggregates
- Concrete aggregates from CDW after processing: Rather pure material with 80 M-% of concrete + gravel + stone in average



Concrete as raw material resource

Very large, hardly overseeable number of research results on recycled concrete aggregates and recycled aggregates concrete

Summary in one figure

Natural aggregates	Recycled concrete aggregates
	
Effect on compressive strength	
Somewhat lower compressive strength, because of porosity of the RCA	
Modulus of elasticity	
Significant lower modulus of elasticity, because of higher porosity <u>and</u> higher deformability of the RCA	

Concrete as raw material resource

Amount of substitutable aggregates vs. available quantity of RCA

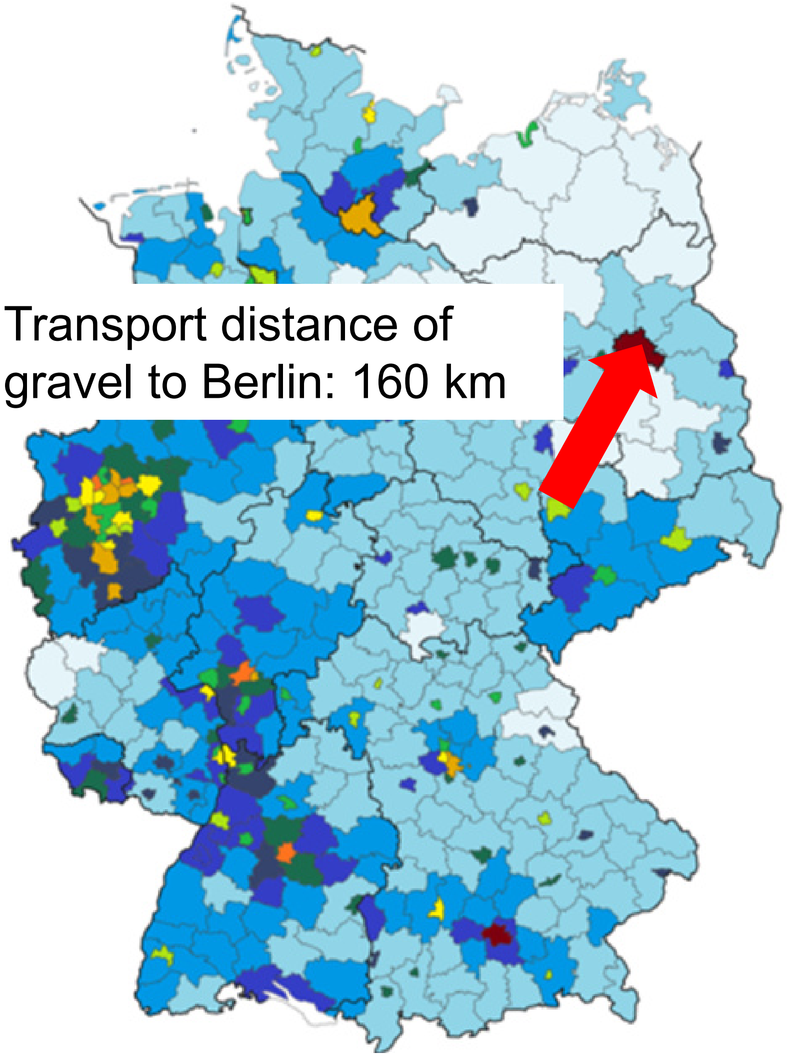
Produced amount of ready mixed concrete in Germany 2020 55.25 Mio m³/a 127.075 Mio t/a	Estimates amount concrete CDW for processing in Germany 27.3 Mio. t/a
Portion of the strength classes C 20/25, C 25/30, C 30/37 73.5 M.-% 93 Mio t/a	Assumed portion > 2 mm: 75 mass-% 20,5 Mio t/a
Required amount of aggregates > 2 mm 62 M.-% 57.9 Mio t/a	Percentage of recycled aggregates feasable according to the mass balance: 35 mass-% Allowed maximum percentage: 45 mass-%

Concrete as raw material resource

All recycled concrete aggregates > 2 mm could be consumed for the production of new concrete

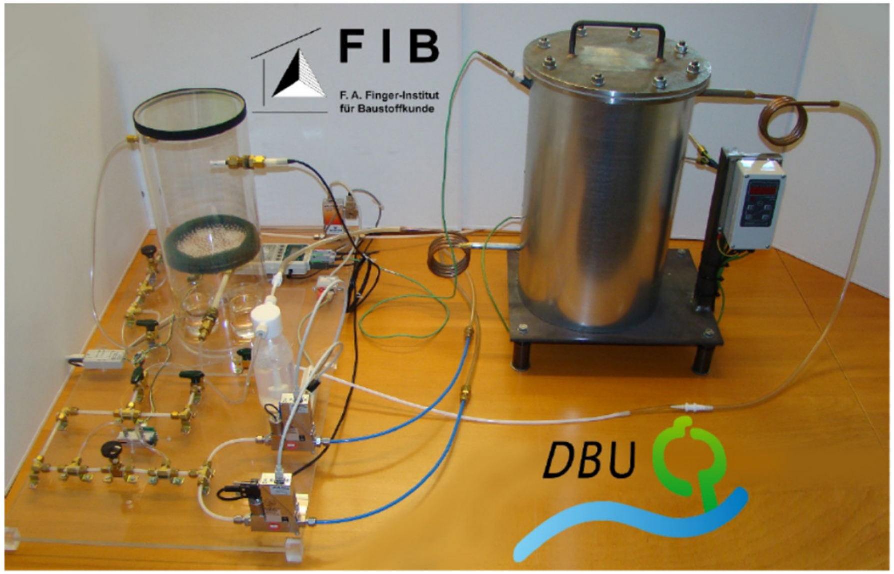
Biggest advantage of recycling of concrete rubble: The place of material extraction and the place of material use are moving closer together!

- Less transports
- Less CO_2



Fine aggregates < 2 mm: Upgrading the recycled fine aggregates for the concrete production

- Reduction or modification of cement paste content by special methods of treatment
- Utilization of the rapid CO_2 uptake of the CH- and CSH-phases of the sands to densify the microstructure



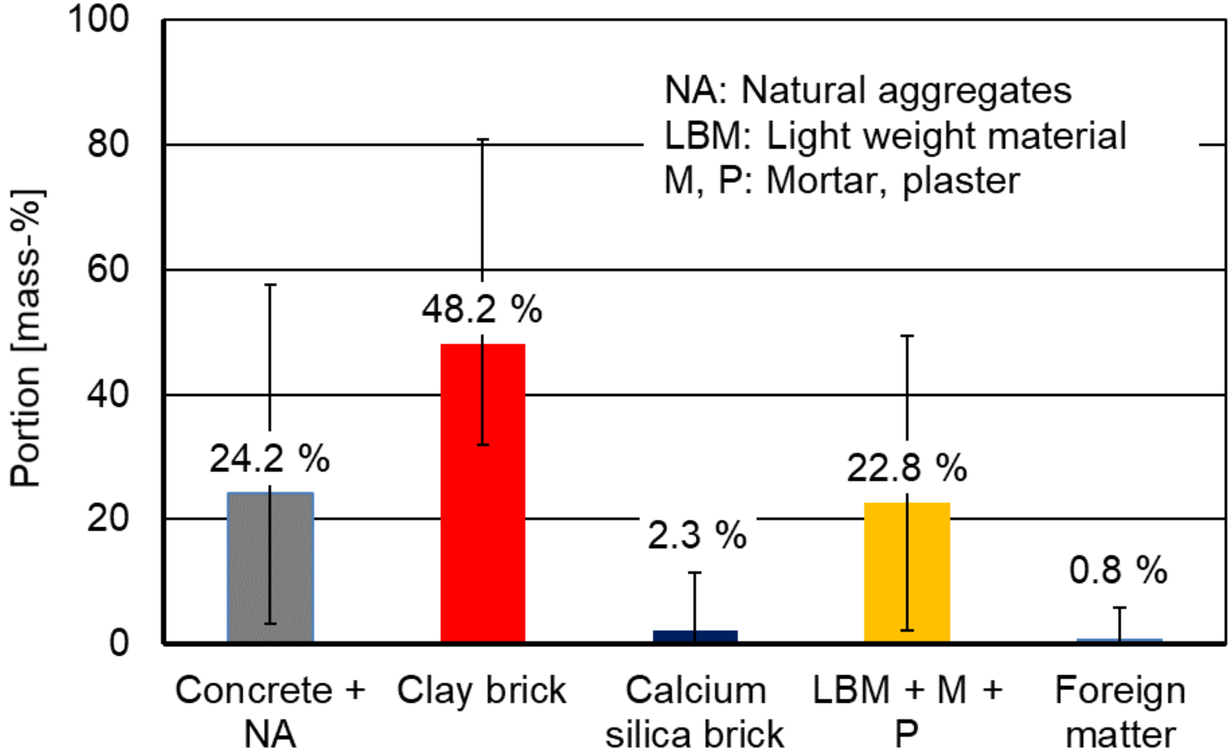
Seidemann, M. 2019

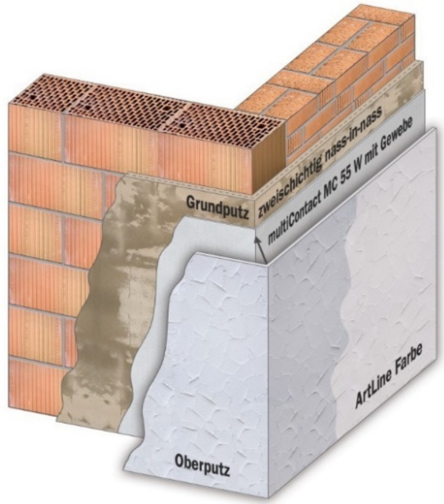
Masonry as raw material resource

Masonry as raw material resource

Main characteristics

- Masonry in its initial state: Composite of (clay) brick + mortar + plaster
- Masonry from CDW after processing: Material with 50 mass-% of brick in average

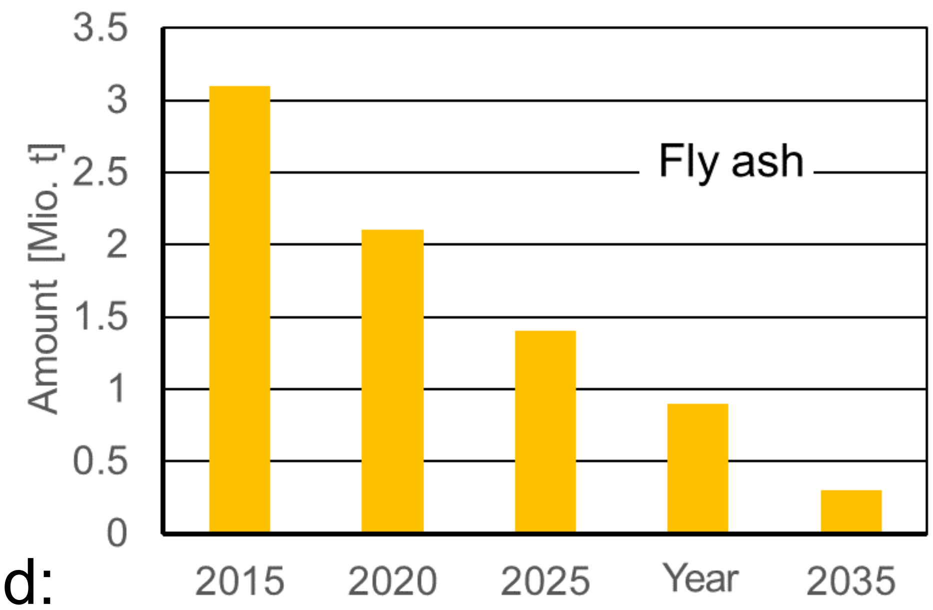




Bauhandwerk 3/2010

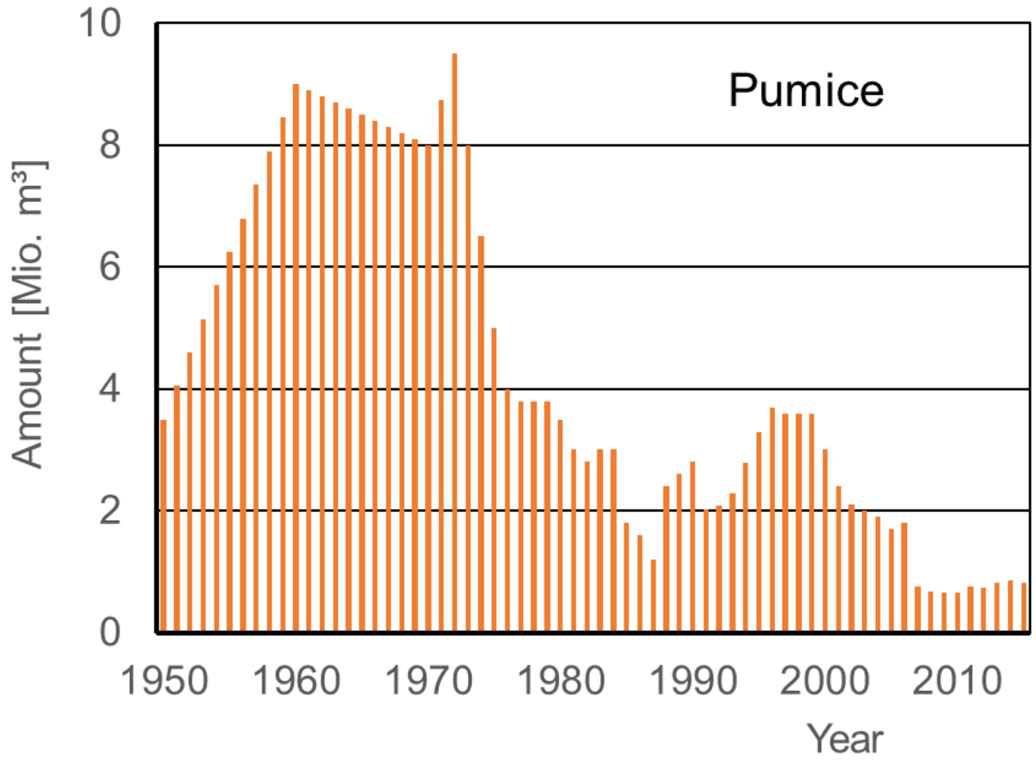
Source materials for SCM at present: Fly ash, granulated blast furnace slag

- Material availability: Decreasing due to the decrasing use of fossil fuels for power generation and changes in the pig iron production process



- Substitutes mostly investigated:
  - Residues from industrial processes such as steel slags or petrochemical catalysts as well as by-products from various combustion processes of organic matter
  - Calcined clays
  - Brick powders

- Source materials for LWA at present: Pumice, expandable clay, sintered fly ash
- Raw material availability of pumice in Germay: Decreasing because of the depletion of the deposits
- Raw material availability of expandable clay: Only at very few locations in Germany

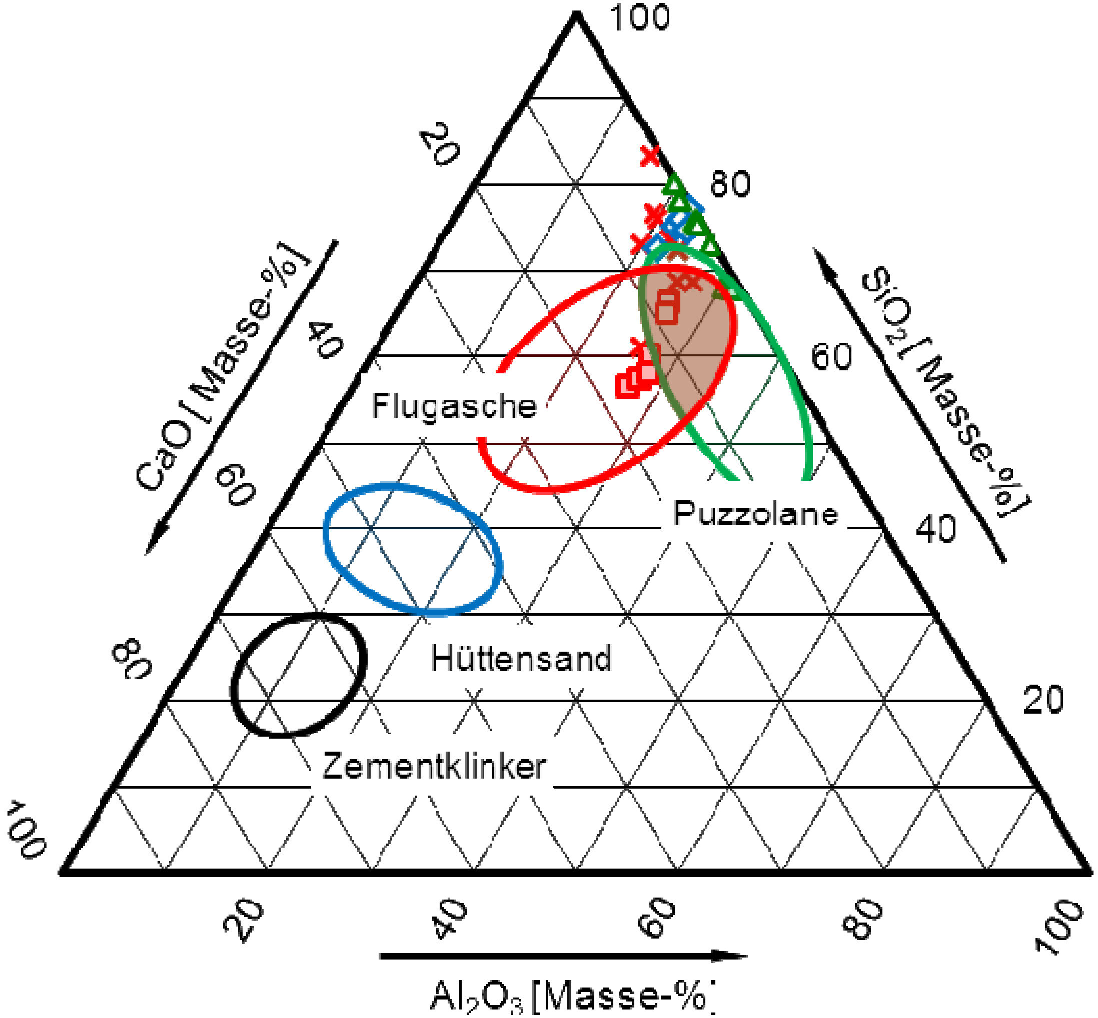


Masonry rubble as resource for SCM

Masonry rubble as resource for SCM

Main requirements on masonry as supplementary cementitious material

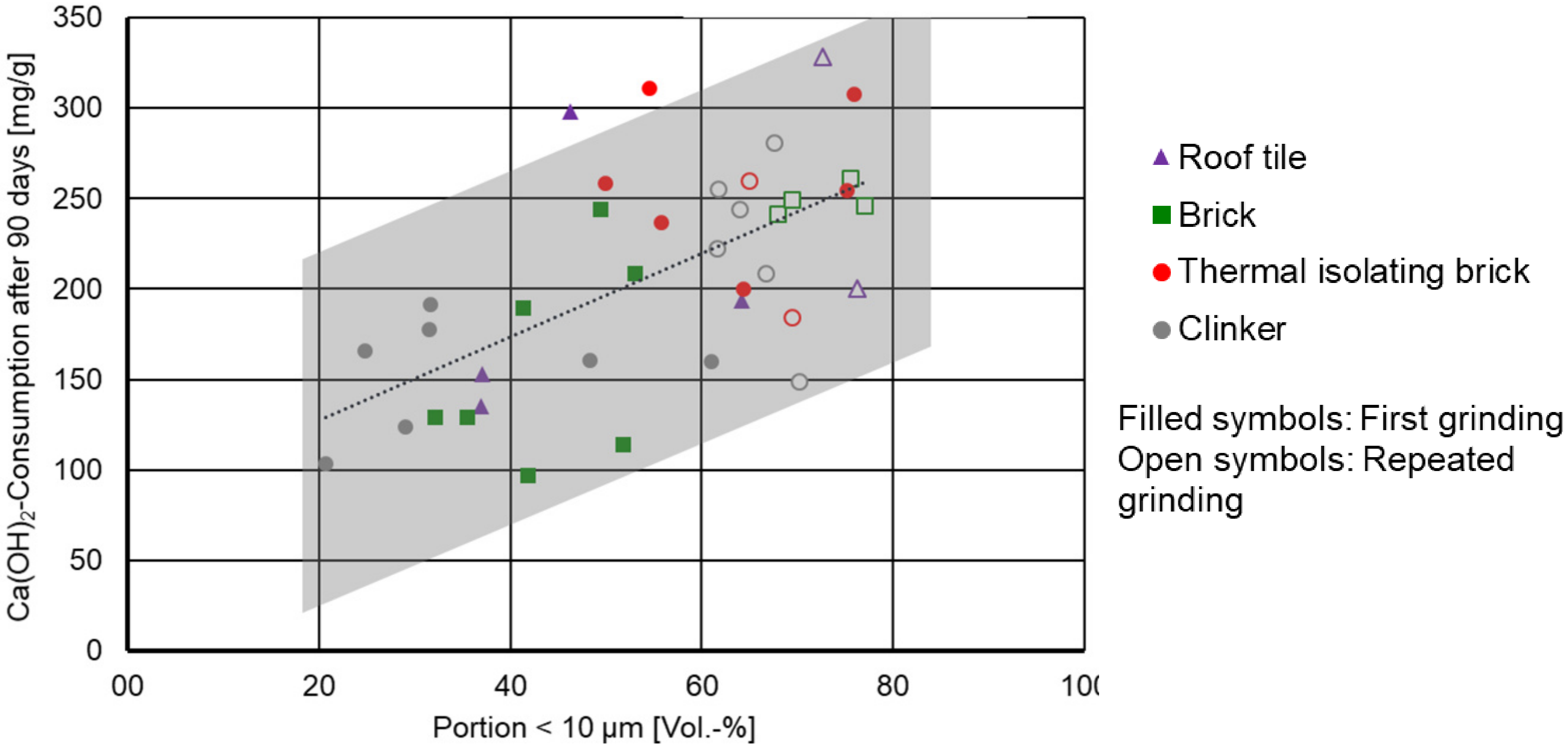
- Chemical composition
- Amorphous phase content
- Particle size distribution



Masonry rubble as resource for SCM

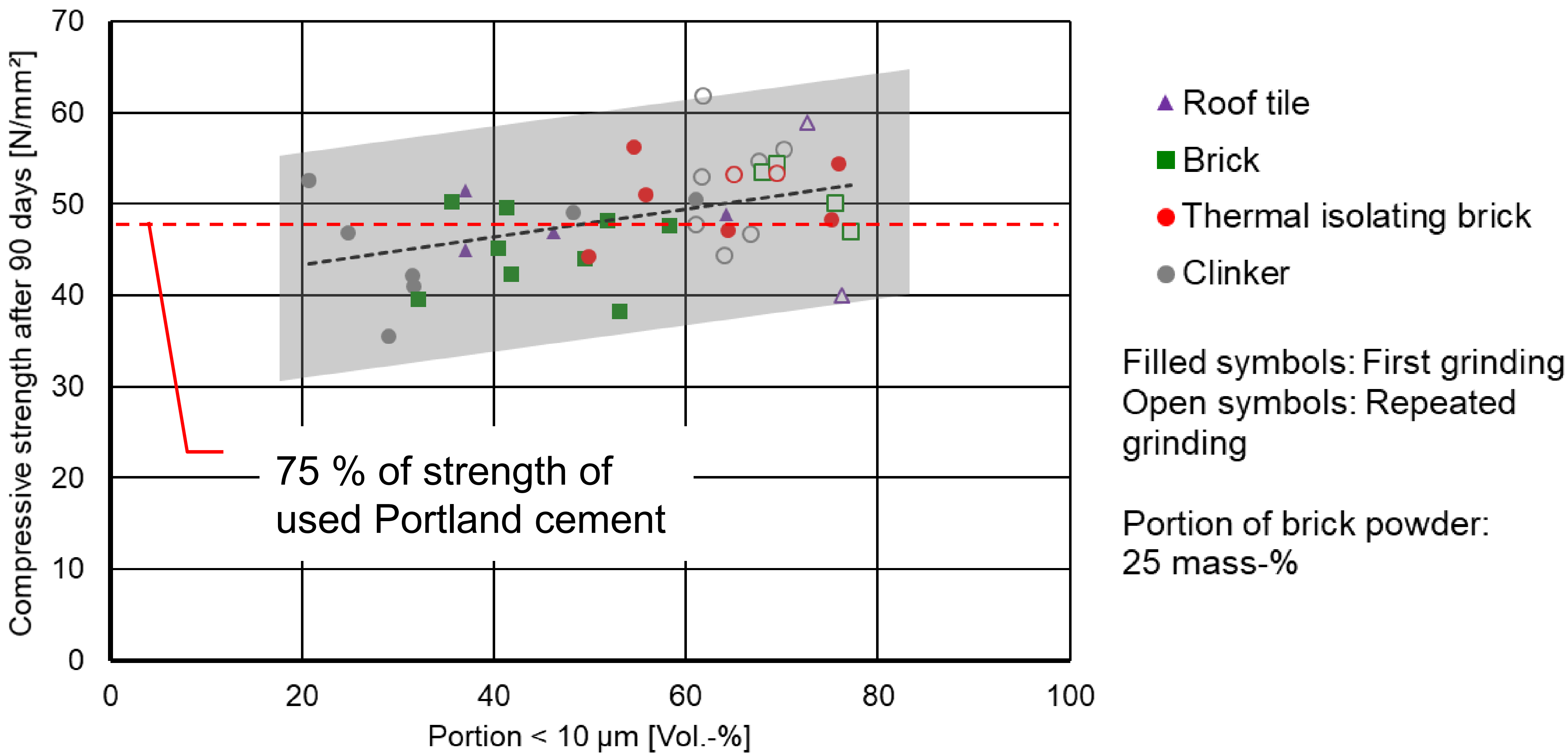
Results from experiments with pure bricks

- Reactivity: Influence of the portion < 10 µm on Portlandite consumption measured with the Chapelle Test



Masonry rubble as resource for SCM

- Compressive strength: Only with high fineness participation in strength formation



Masonry rubble as resource for SCM

Challenge: Generation of pure brick powder from masonry rubble

Comminution to breakdown the compounds consisting of brick and mortar/plaster

↓

Screening in fractions

↓

Sorting in the particle size range < 4 mm

↓

Grinding

Used sorting device

Masonry rubble as resource for SCM

Sorting experiments

- Mixtures of 50 mass-% concrete + 50 mass-% brick
- Used brick: From soft burnt bricks to hard burnt clinker
- Used concrete (instead of mortar): 3 different types
- Particle fractions: 0,063/0,5 mm; 0,5/1,0 mm; 1,0/2,8 mm

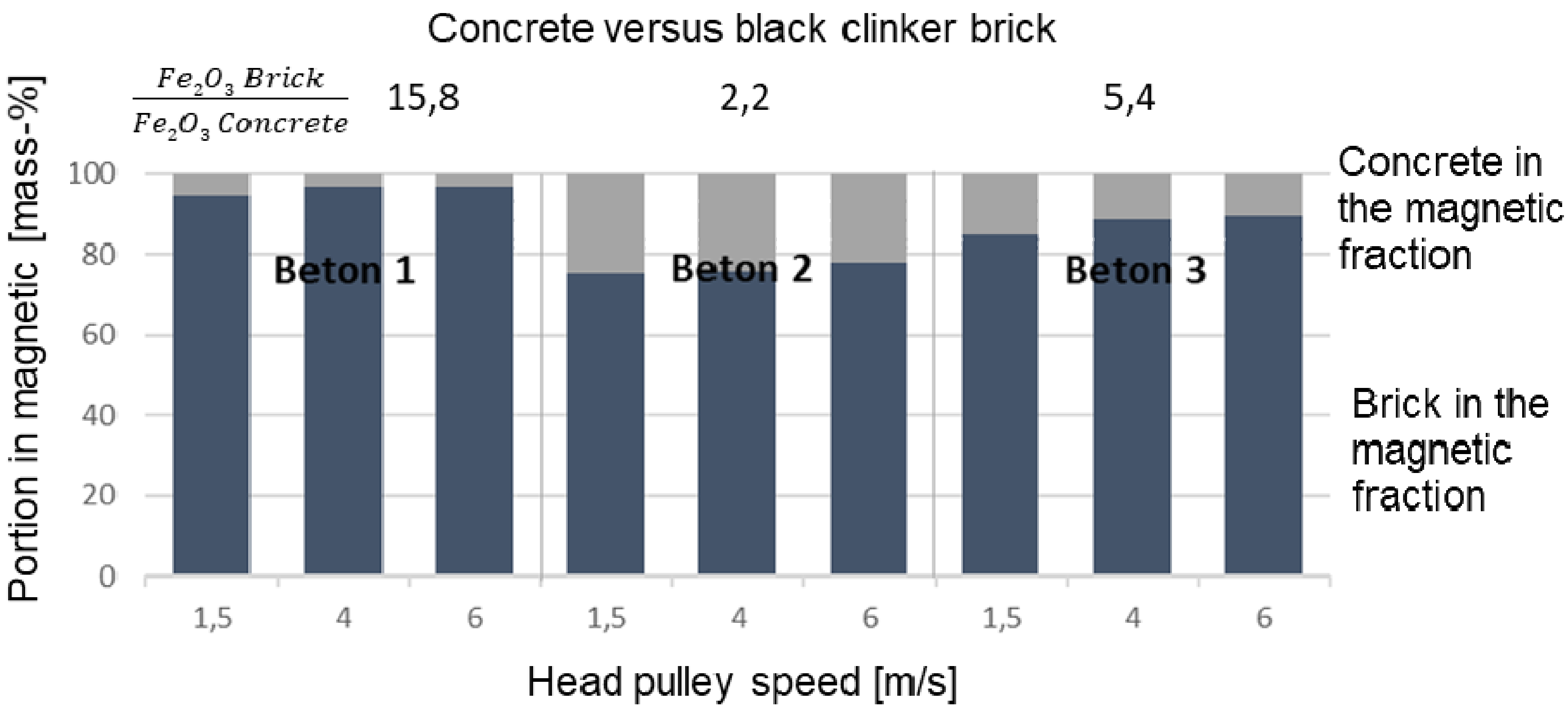
Evaluation of achieved separation by

- Lost of ignition
- Counting of the grey and red paricles
- Colour analyses

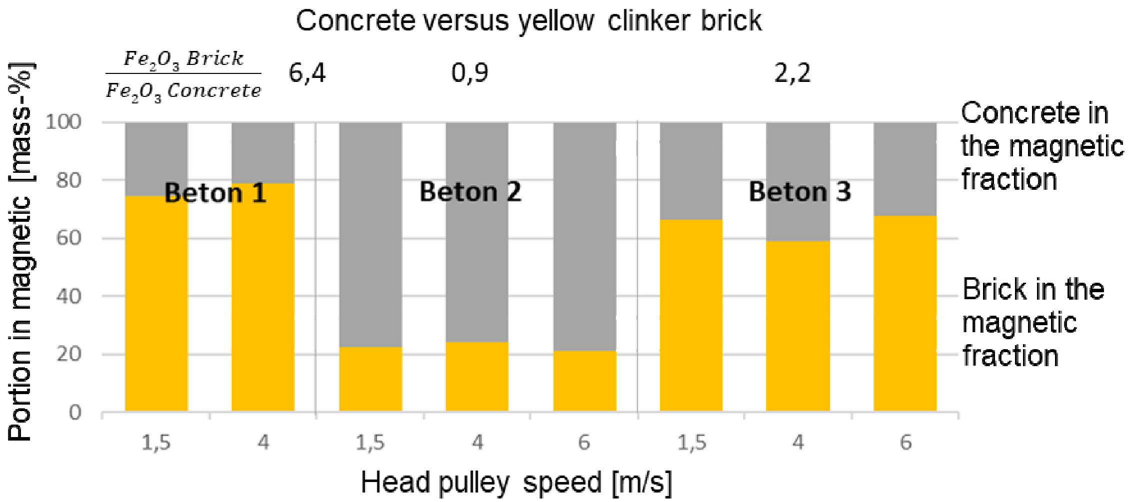
Masonry rubble as resource for SCM

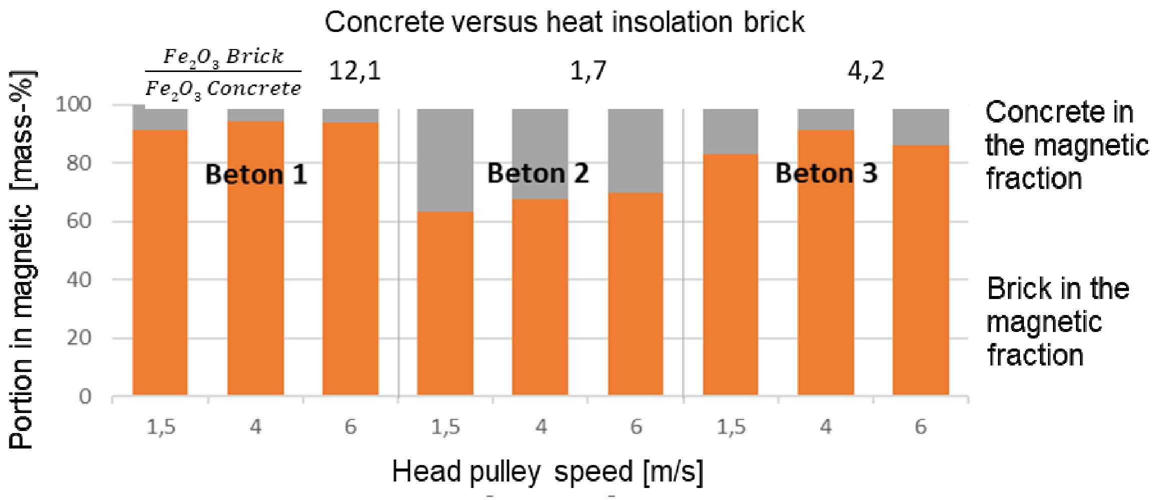
First results on sorting of the fraction 1/2.8 mm

- Enrichment of the brick in the magnetic fraction
- Clear influencing factor: Fe_2O_3-ratio
- Further influence: Particle size
- Low influence: Head pulley speed



Confirmation of the statements by the results on other types of bricks





Research will be continued!

Masonry rubble as resource for LWA

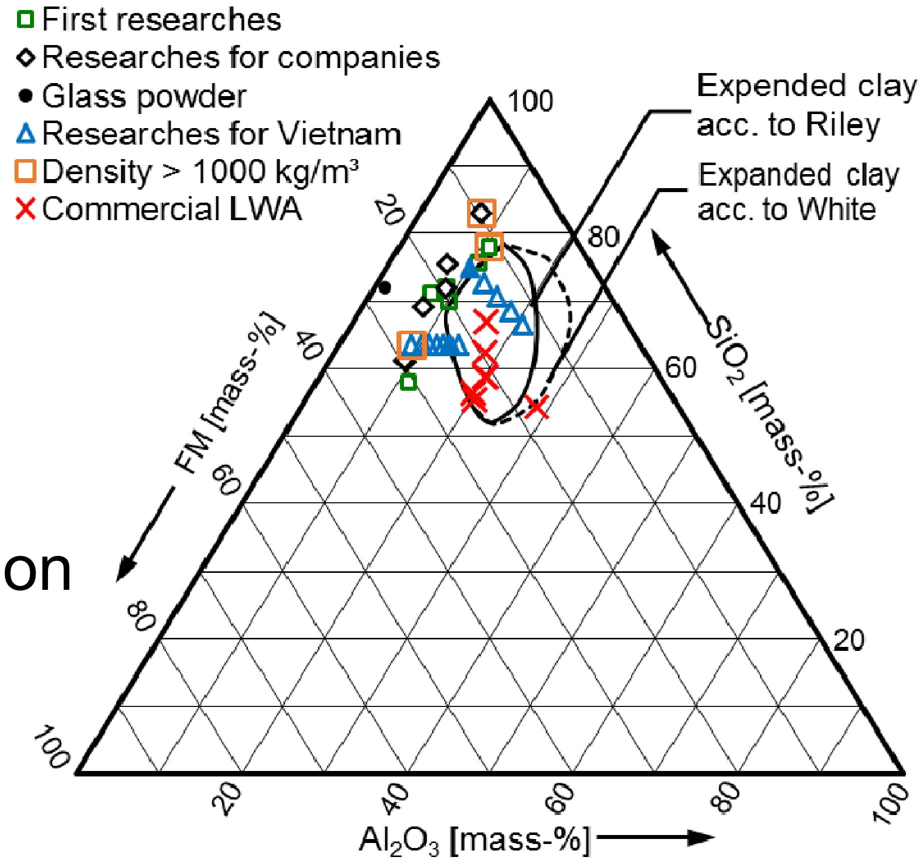
Masonry rubble as resource for LWA

Masonry as raw material ressource for lightweight aggregates?

First formulation of the question in 2000 as "A lone voice in the wilderness"

Working hypothesis:

- In the production of LWA the replacement of clay by brick or masonry is possible, because their chemical composition are comparable
- The mineralogical composition is of minor importance
- But: A suitable expanding agent must be added



Masonry rubble as resource for LWA

Confirmation of the working hypothesis in researches on LWA from construction and demolition wastes

- First tests on feasibility
- Studies on technology and conditions of manufacture
- Investigations on a broad range of raw materials to derive requirements on composition, particle size…
- Design, erection and operation of a pilot plant
- Estimations on economic feasibility (in progress)

1999 - 2001	Granulates from aerated autoclaved concrete und clay brick rubble
2009 - 2012	Production of high-quality structural lightweight aggregates from secondary raw materials based on heterogeneous construction and demolition waste
2009 - 2012	Lightweight aggregates from rock wool
2011 - 2013	Lightweight aggregates from fine fractions of shale processing
2015 - 2017	Development of a process for the production of lightweight aggregates based on CDW/other inorganic residues from Vietnam
From 2015	Studies for the recycling industry, tests with raw materials of different companies
2019	First successful production of LWA in the pilot plant
2020/2021	Processing of gypsum-containing masonry rubble

Masonry rubble as resource for LWA

A current research project: Pilot plant experiments on the production of lightweight aggregates from sulfate containing masonry rubble with simultaneous recovery of the gypsum

Used raw materials

Mixtures of

Roof tile rubble

+

Concrete rubble

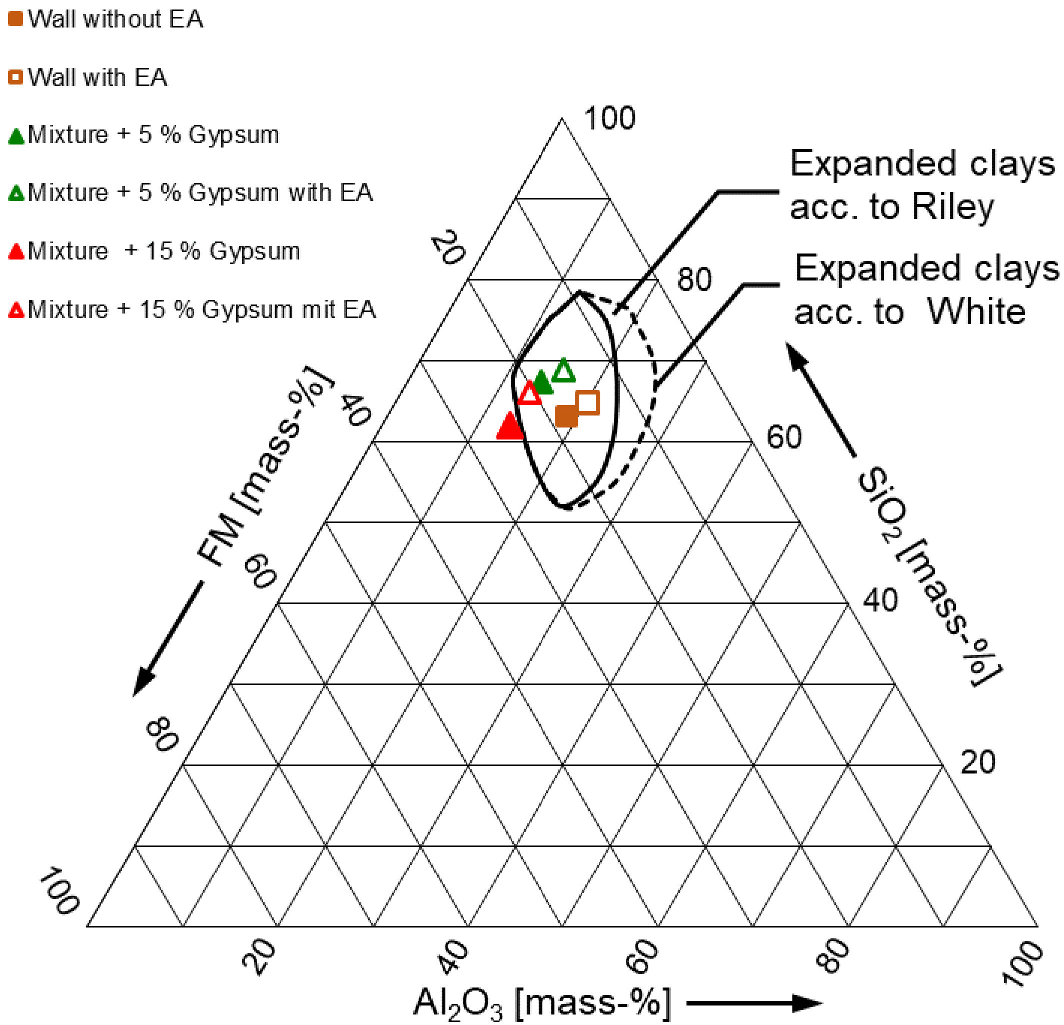
+

Gypsum

Brick wall plastered with gypsum

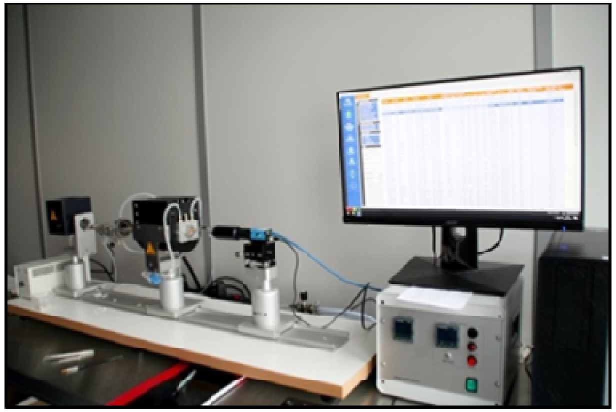
Masonry rubble as resource for LWA

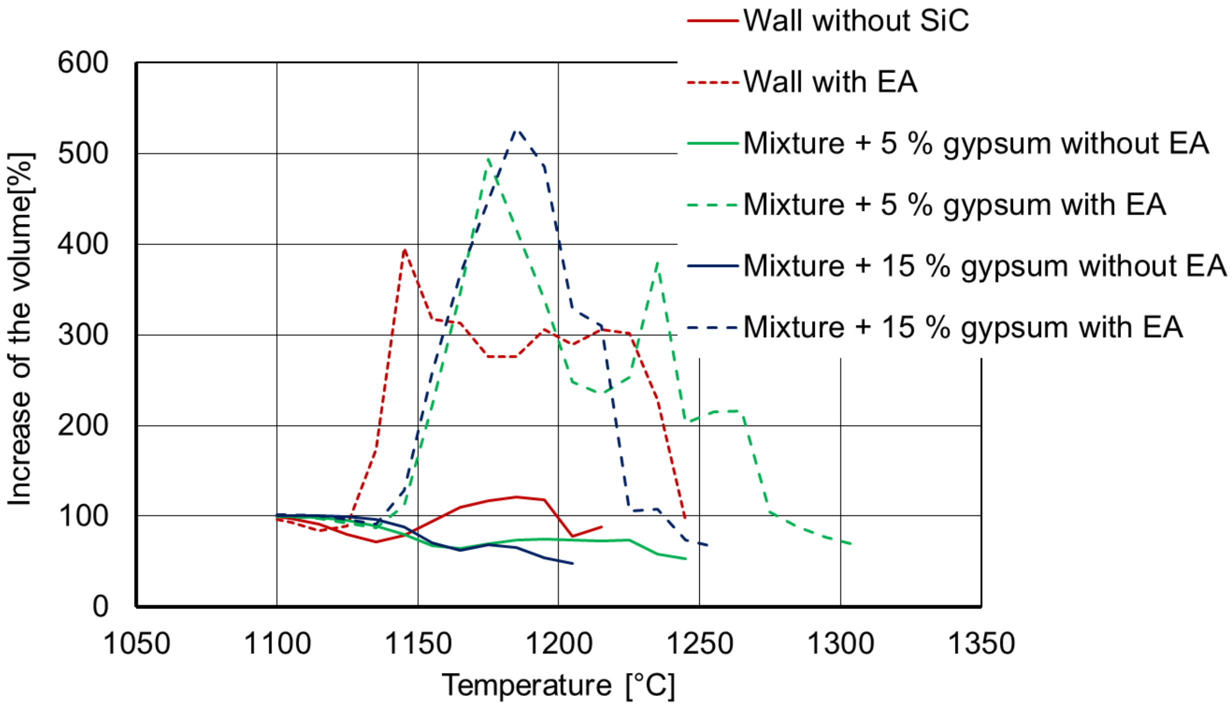
Sequence of the test run
First step: Measurement of chemical composition



Masonry rubble as resource for LWA

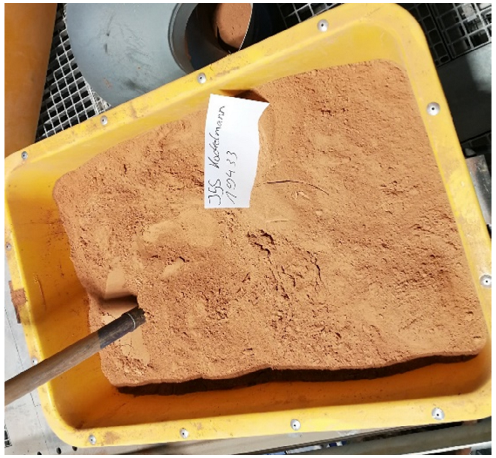
Second step: Control of the melting behavior with a heating microscope

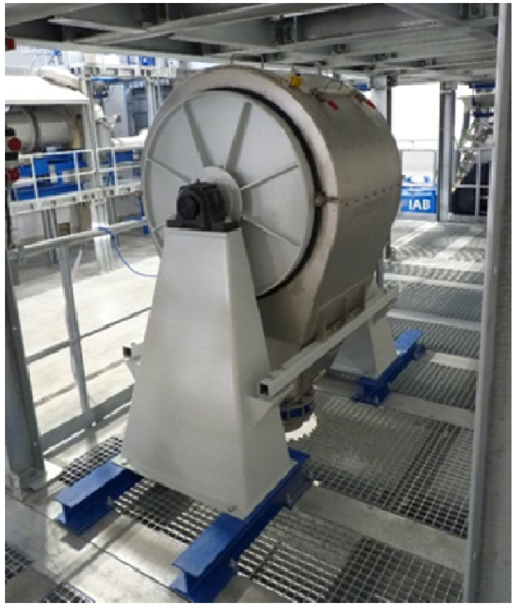




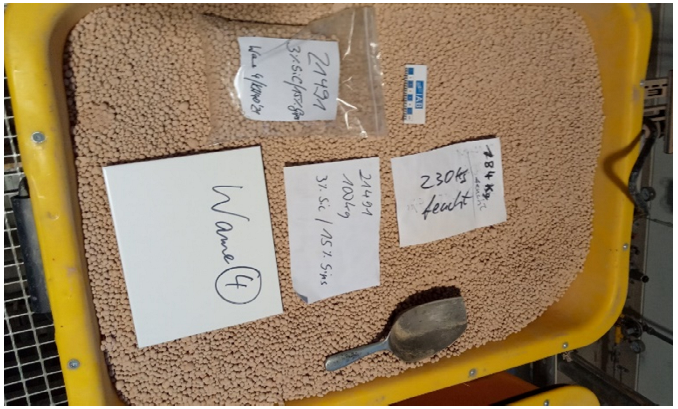
Masonry rubble as resource for LWA

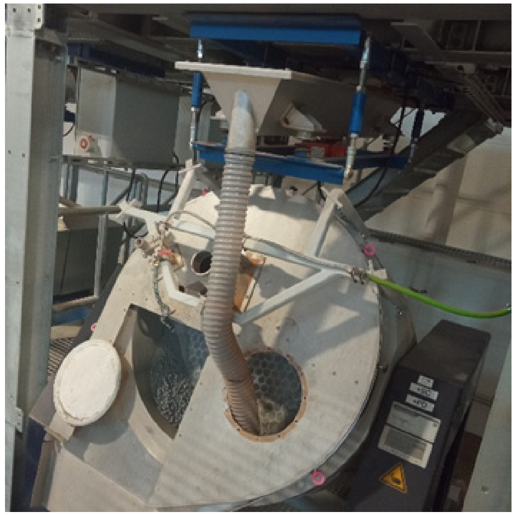
<u>Third step</u>: Assemble of the mixtures and grinding





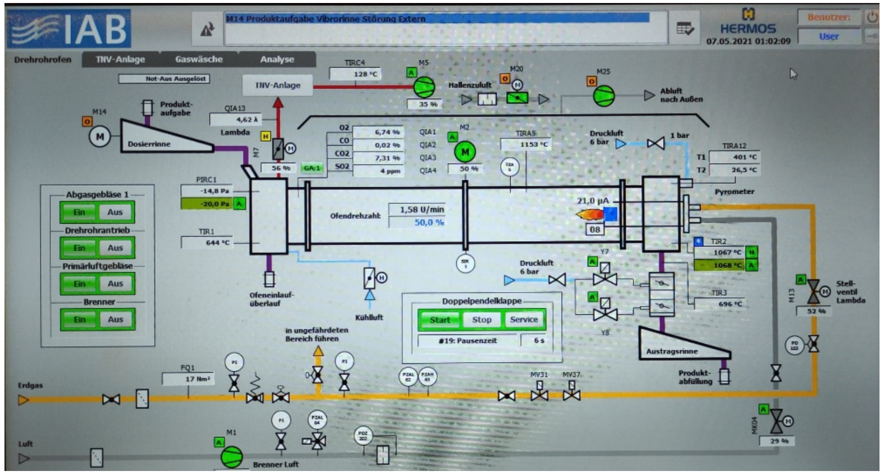
<u>Fourth step</u>: Forming granulates and drying the green granulates





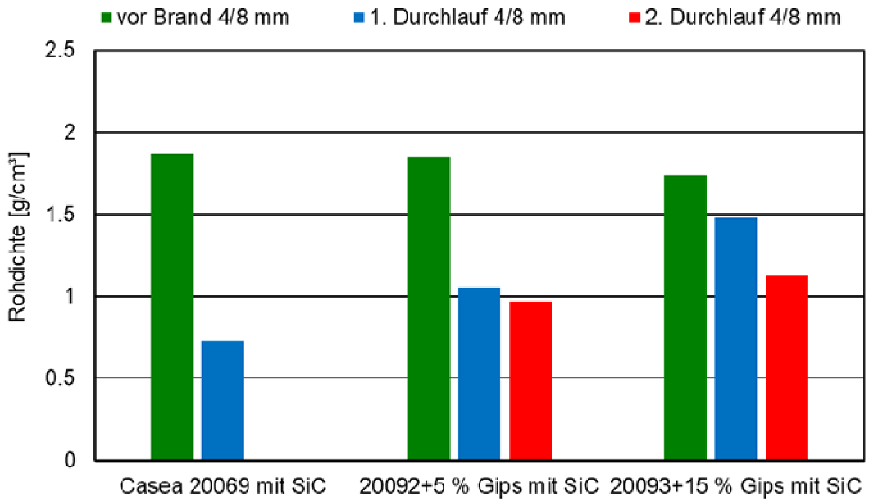
Masonry rubble as resource for LWA

<u>Fifth step</u>: Burning



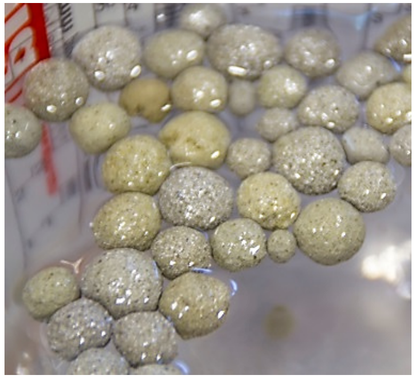
Masonry rubble as resource for LWA

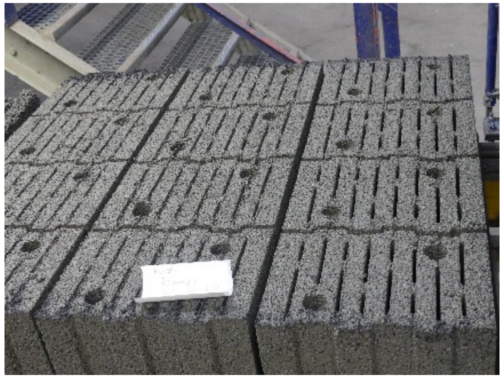
Properties of the LWA from the gypsum containing raw material



Application of the produced lightweight aggregates

- Thermal insulation fills or panels
- Lightweight aggregates for precast concrete parts and concrete blocks
- Aggregates for gradient concrete
- Road and path construction on ground with low bearing capacity
- Substrats for hydroponic cultivation
- Granulates for lightweight renders

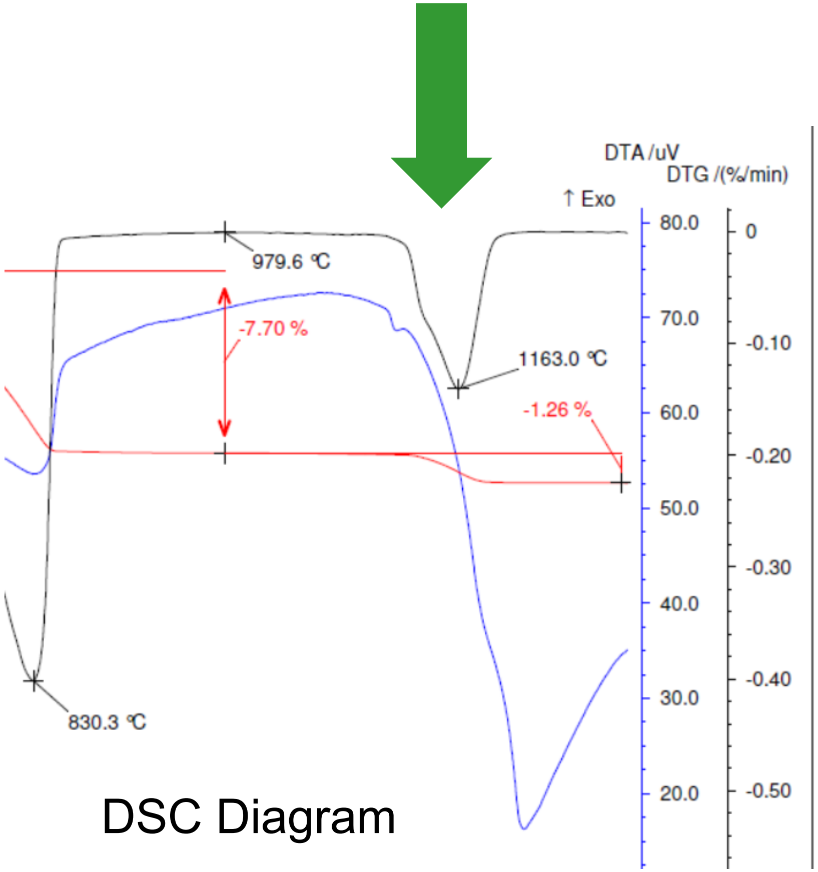




What about the gypsum in the input material?

- Gone away!
  Reduction from more than 10 mass-% in the input material to less than 0.8 mass-% in the product
- Reason: Dissociation of $CaSO_4$ in a temperature range from 1100 to 1200 °C in presence of SiO_2, Fe_2O_3 and/or Al_2O_3

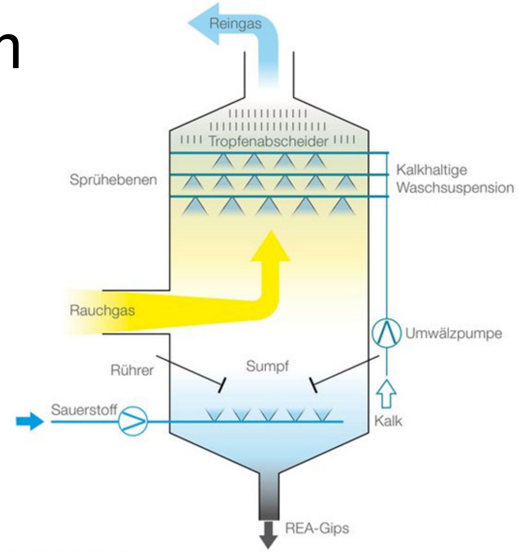
$CaSO_4$-Disoziation at 1163 °C
Transfer of SO_2/SO_3 in flue gas



DSC Diagram

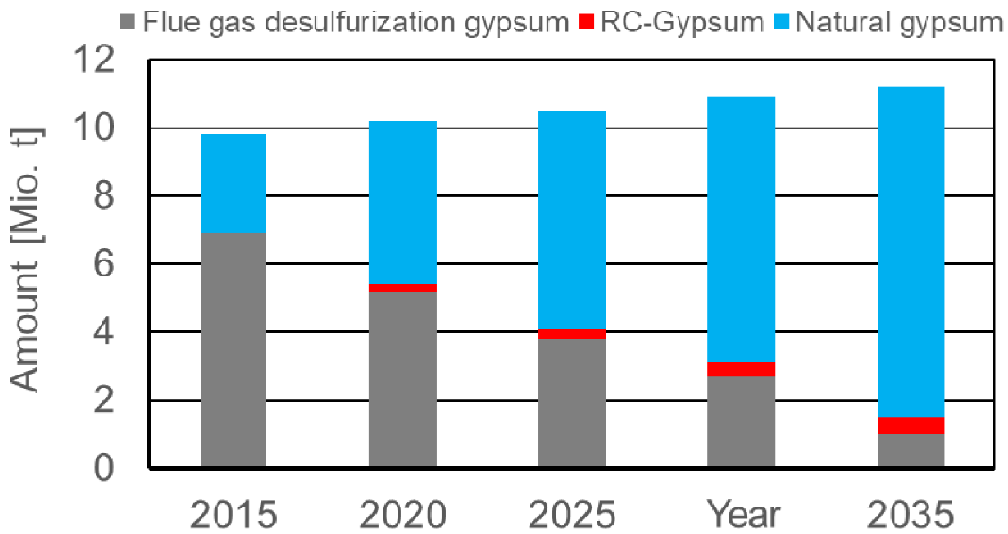
Masonry rubble as resource for LWA

Next step: Recovery of the SO_3 from the flue gas as flue gas purification gypsum



Generated gypsum can contribute

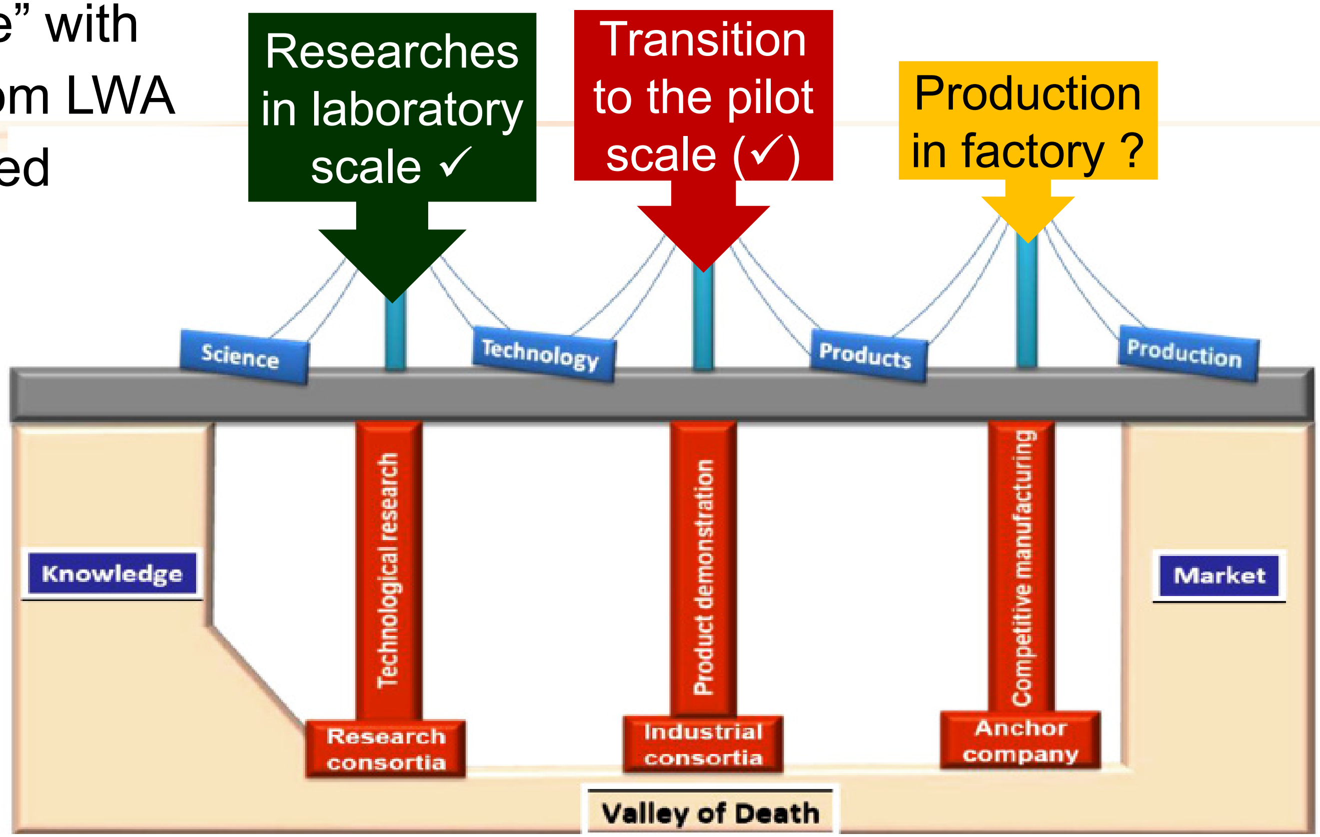
- to close the “gypsum gap” due to “energy turnaround”
- to reduce the expansion of mining of natural gypsum



Recycling of masonry: Use as raw material for lightweight aggregates

Next steps to overcome the Death Valley between knowledge and market

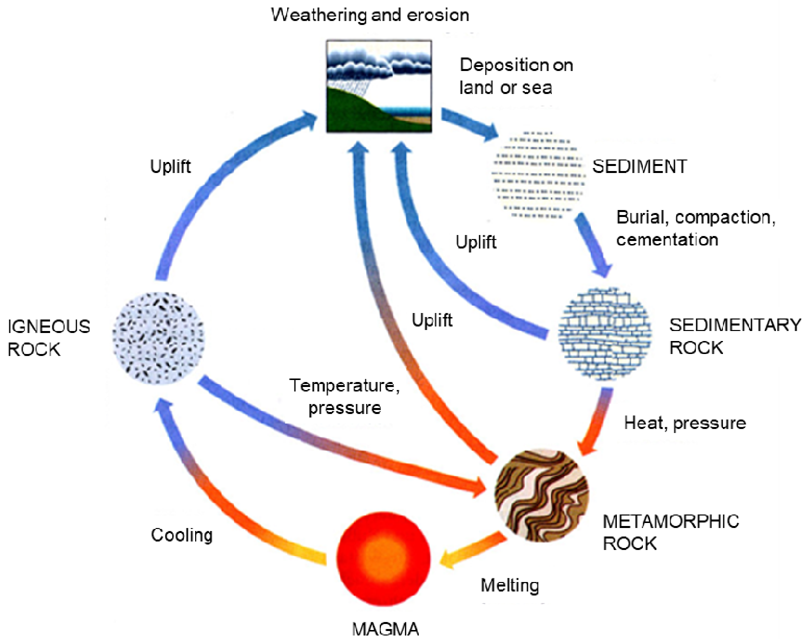
- Summarizing all laboratory results
- Experimental determination of the technological parameters as temperature profile, residence time, heat consumption in the pilot plant
- Create a "showcase" with
- diverse products from LWA
- Looking for interested investors



Pacheco-Torgal, 2014.

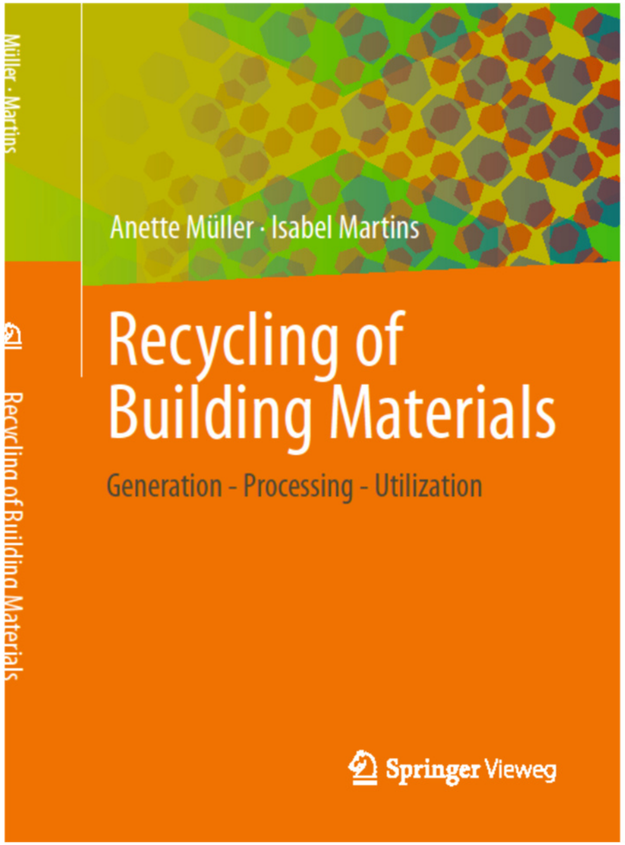
My two most used farewell images as role models for a circular economy!

Wikipedia, the free encyclopedia



Press, F.; Siever, R.: Allgemeine Geologie. Spektrum Akademischer Verlag 3. Auflage. Heidelberg, Berlin 2003.

Thank you to my colleges
Dr. Anett Lipowsky and
Dipl.-Ing. Steffen Liebezeit!



Thank you for your attention !

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