INTERNATIONAL CONFERENCE
SUSTAINABLE PRODUCTION AND USE OF CEMENT AND CONCRETE

Innovative recovery of anhydrous phases from hydrated cement based on microwave-induced heating

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Cement production is not only energy-intensive but also causes high CO_2 emissions. Recycling of old concrete can be an alternative energy-saving solution, avoiding the CO_2-producing precursor by addressing the binding properties of recycled cement and substituting to an extent the fresh cement content in concrete. **Microwave heating (MW)** is successful for weakening concrete and separation of individual constituents. Yet, not much work is known on the potential to recycle the cementitious binder by thermal reactivation. Here, we present an **innovative technique** to break down hydrated cement into the original anhydrous components by performing **microwave heated dehydration**. The successful **reproduction of original phases –** C2S (Belite) and C3S (Alite) - from hydrated ordinary Portland Cement (HOPC, water cement ratio 0.4) forms the foundation to **study cement recycling of old concrete**.

1. Procedure

Recycling after different aging times (days): D2, D3, D7, D14 and **D28** of w/c 0.4 CEM I 52.5N

Before MW: *For all aging times:*

1. Hydration stoppage → XRD
2. Compression tests

→ **MW** →

After MW: *For all aging times:*

→ XRD

Rehydration samples: MWC + water

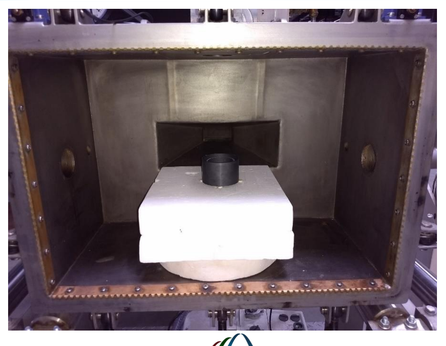
→ **+H_2O** →

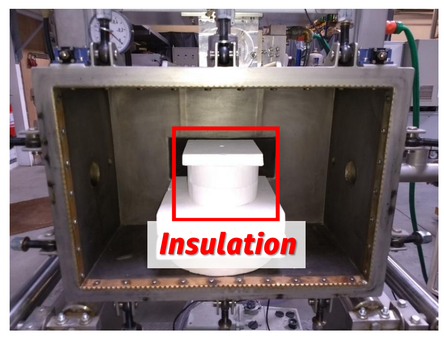
After rehydration: *For all aging times:*

1. Hydration stoppage → XRD
2. Compression tests

Investigate potential of re-using microwave treated cement (**MWC**) from hydrated ordinary Portland cement (**HOPC**)

2. Microwave technology



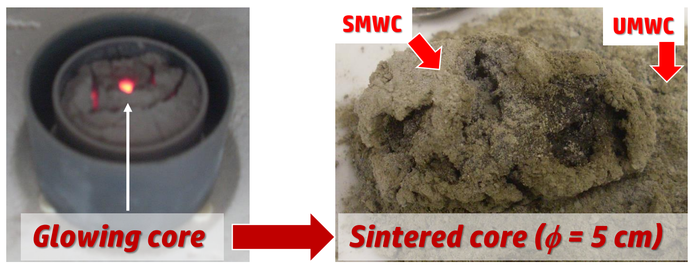


- Multimode MEAM - ***Explorer***
- **Power** (P) and **temperature** (T) logger
- Vacuum pump to avoid condensation
- **100 g HOPC** in MW-transparent quartz glass
- Thermal insulation

3. Microwave results

Power input 600-700 W up to 900°C:

Unsintered powder (UMWC) + sintered core (SMWC)

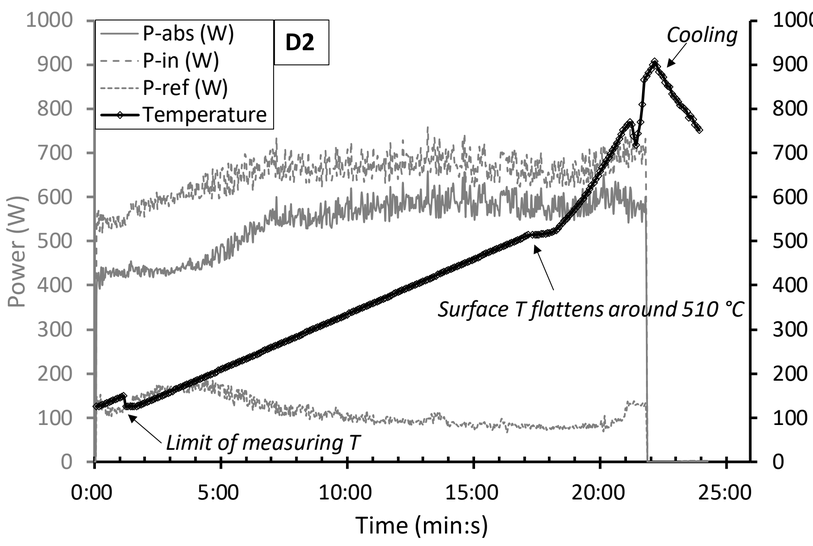


- All aging times give a **similar T increase** at the surface
- Mass loss **28-29%** → **full dehydration**
- In 20-25 min sintered core (**>1300 °C**)
- P_{abs} = 400-600 W → **80-90%** of power is absorbed
- **Plateau $T_{surface}$** around **500 °C** for D2, D3 and D28 (not observed for D7, D14) → related to phase change?
- **T-rate increase** due to surface crack → core **T** measured

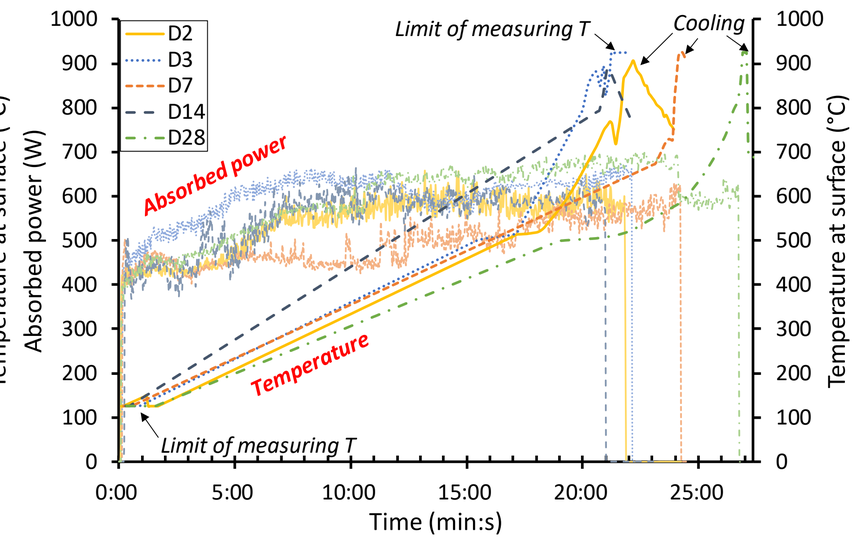
Cement couples with microwaves: *volumetric heating* (in contrast to conventional furnace heating)

$P_{absorbed}$ (abs) = P_{input} (in) – $P_{reflected}$ (ref): → **plotted with time and temperature T measured at sample surface**

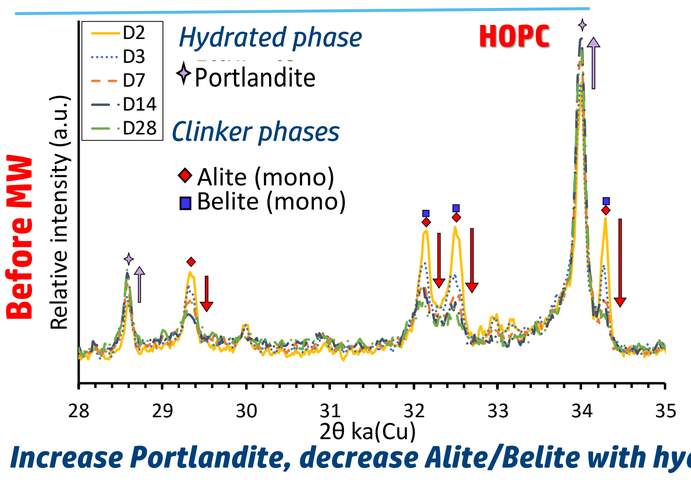
After 2 days of aging:



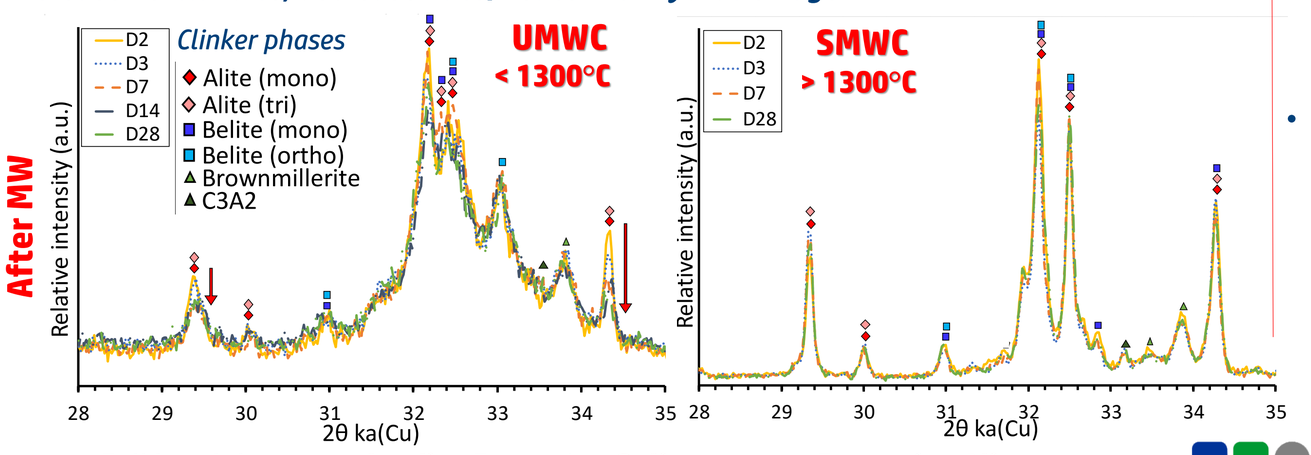
For all aging times:



4. Analysis and discussion



Increase Portlandite, decrease Alite/Belite with hydration age



- Full breakdown ***portlandite***, Formation ***Belite***
- ***No formation Alite*** (hydration age 'inherited' in alite peaks at 29.4° and 34.3°)
- ***Formation Alite***
- No influence hydration age

X-ray diffraction

UMWC:

Aging time prior to MW matters!

*the older, the more **Alite** reacted away*

SMWC:

Aging time does not matter!

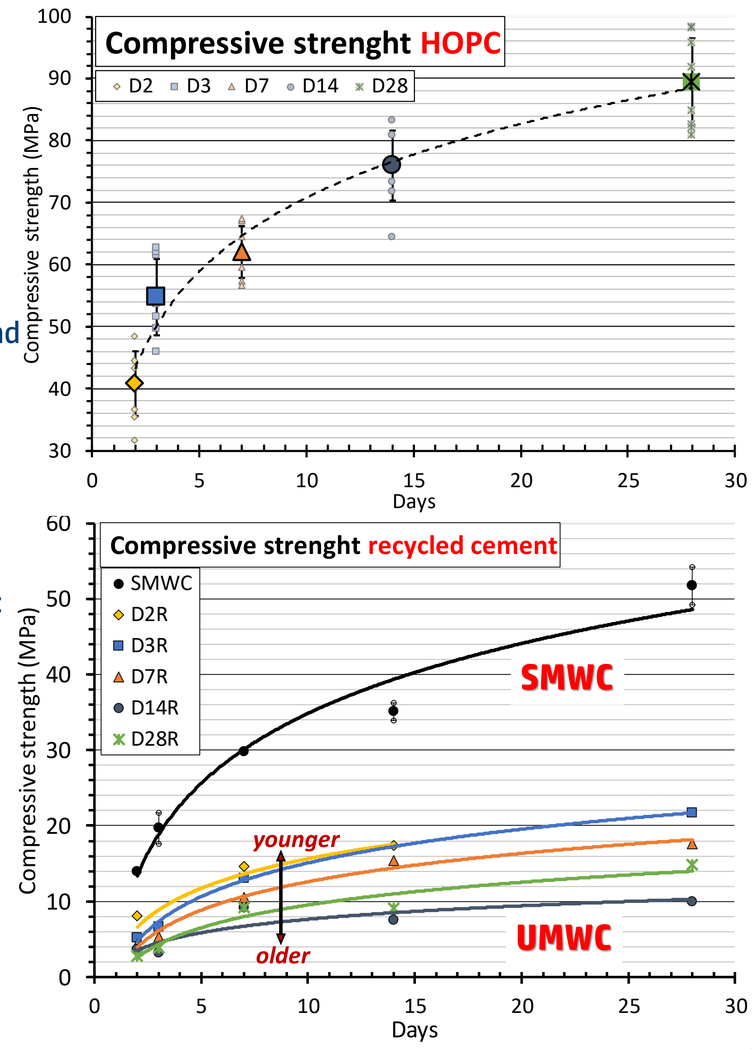
*new formation of **Alite***

The effect of **Alite on strength**

Compression tests

- Cubes: 2x2x2 cm^3
- Mixing with water:
  - ***HOPC*** w/c 0.4
  - ***UMWC*** w/c 0.6 (lower no mixing possible)
  - ***SMWC*** w/c 0.4
- No direct comparison of fresh and recycled cement possible:
  - MWC is much coarser! (too little for proper grinding)
  (OPC: blaine = 4000 cm^2/g)
  (MWC: D_{50} = 500 – 700 µm)
- But relative comparison of MWC:
  - ***SMWC*** gives higher strength than ***UMWC***
  - ***Younger UMWC*** gives higher strength than ***older UMWC***

The amount of Alite matters!



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