Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Freeze-thaw resistance of slag concrete

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Contents

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Approach for testing

Exposure classes for frost resistant concrete

- Freeze-thaw resistance (XF1, XF3)
- Salt freeze-thaw resistance (XF2, XF4)

Picture: Ahsan Iqbal

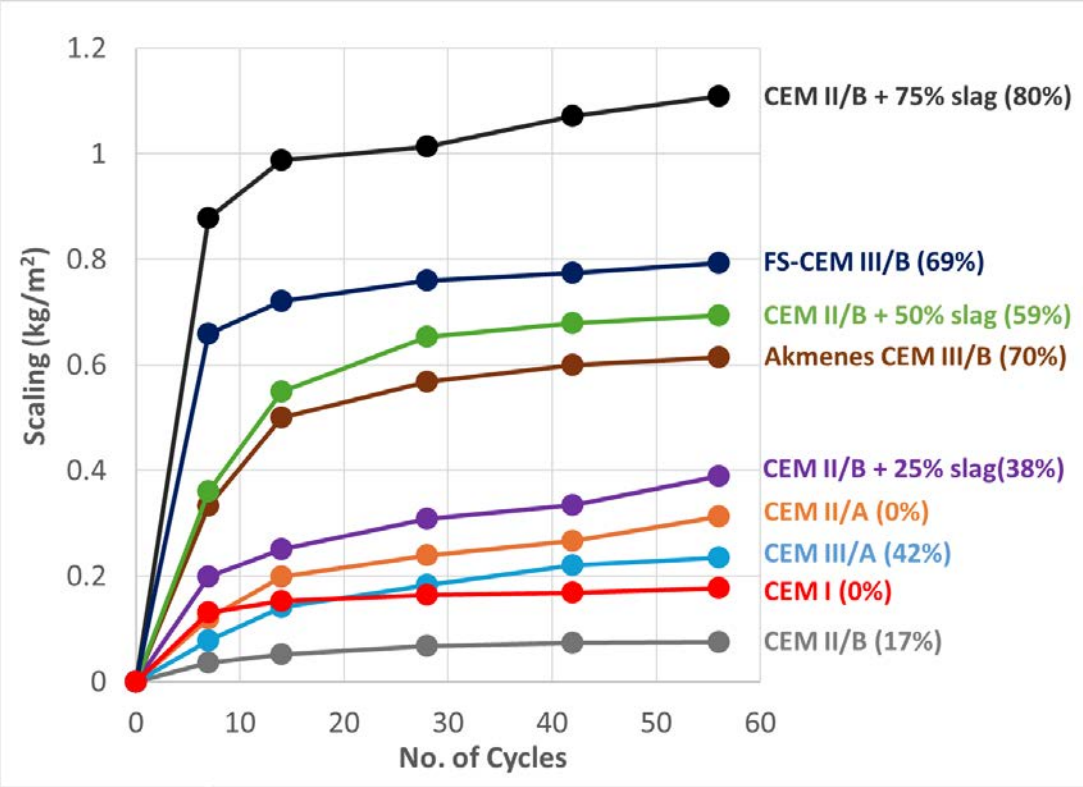
Frost Resistance

Direct approach ⟷ **Indirect approach**

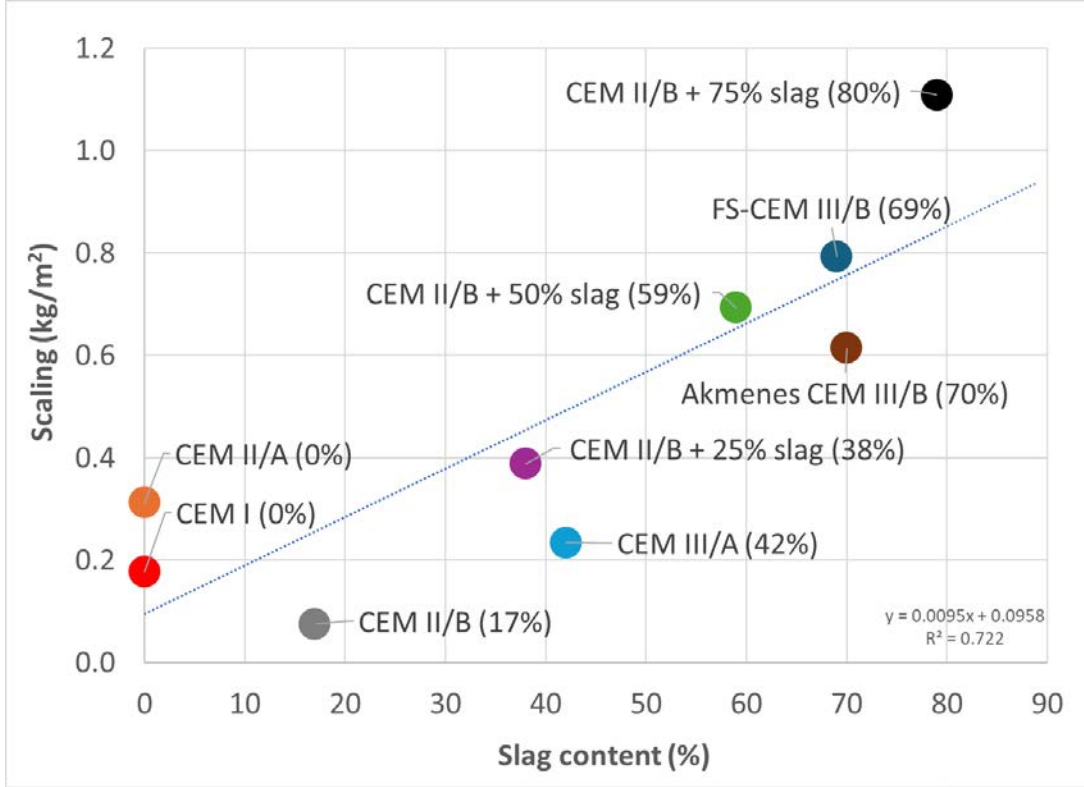
- **Slab test**
  - Scaling
  - UPV

- Based on known correlation between different parameters using empirical evidence.
  - X-ray computed tomography (XCT)
  - Capillary suction and pressure saturation test
  - Air-void analysis (thin / polished section)

Scaling resistance with chlorides (non-carbonated specimens)



Scaling rates over freeze-thaw cycles



Scaling after 56 freeze-thaw cycles

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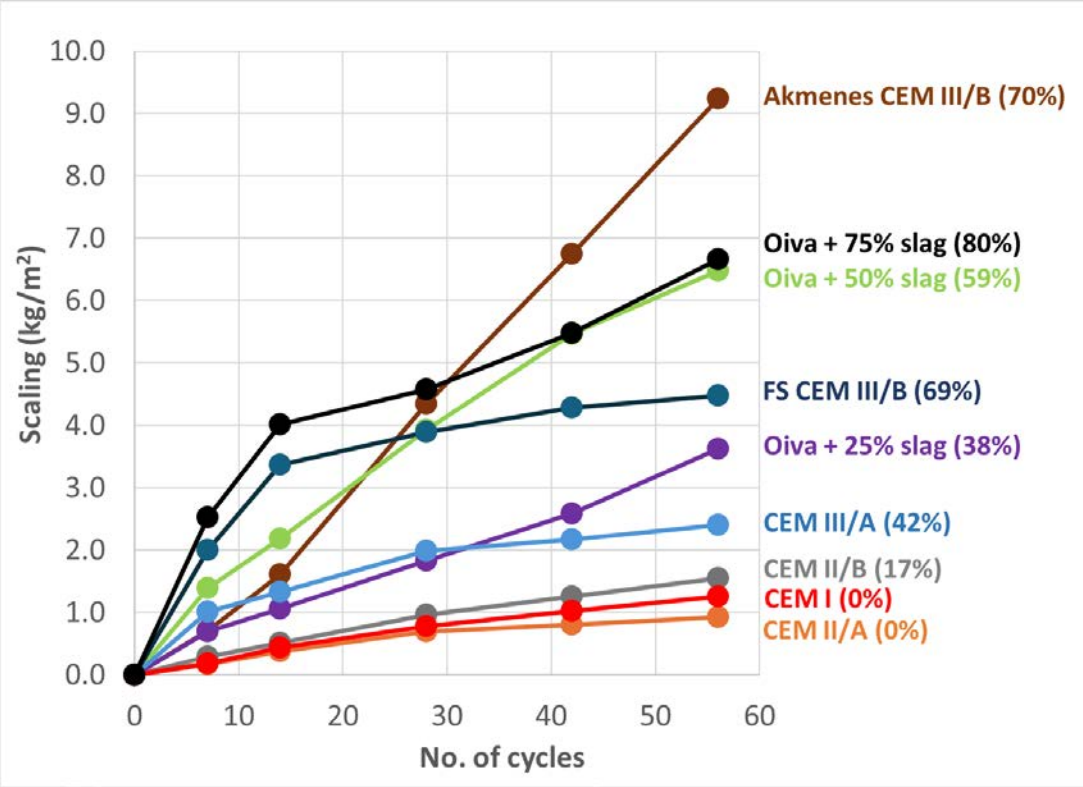
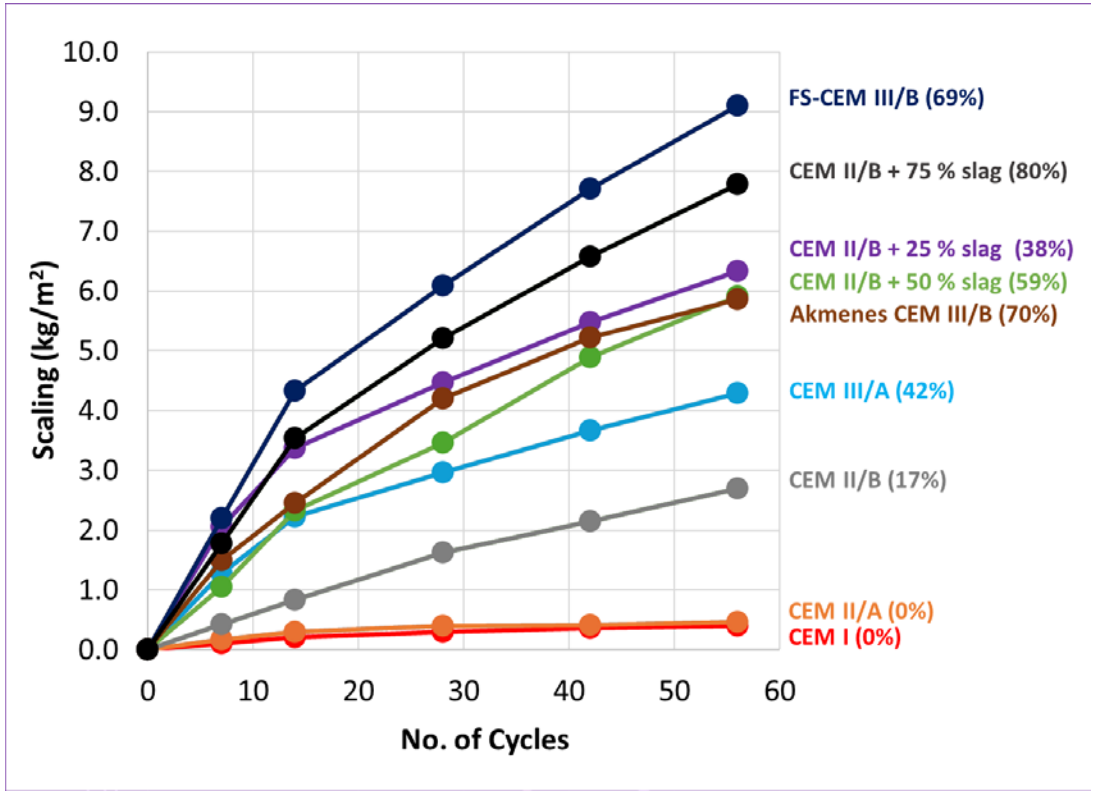
Scaling resistance with chlorides (carbonated specimens)



Scaling rates (2 months acc. Carbonation)



Scaling rates (1-year natural carbonation, 65% RH)

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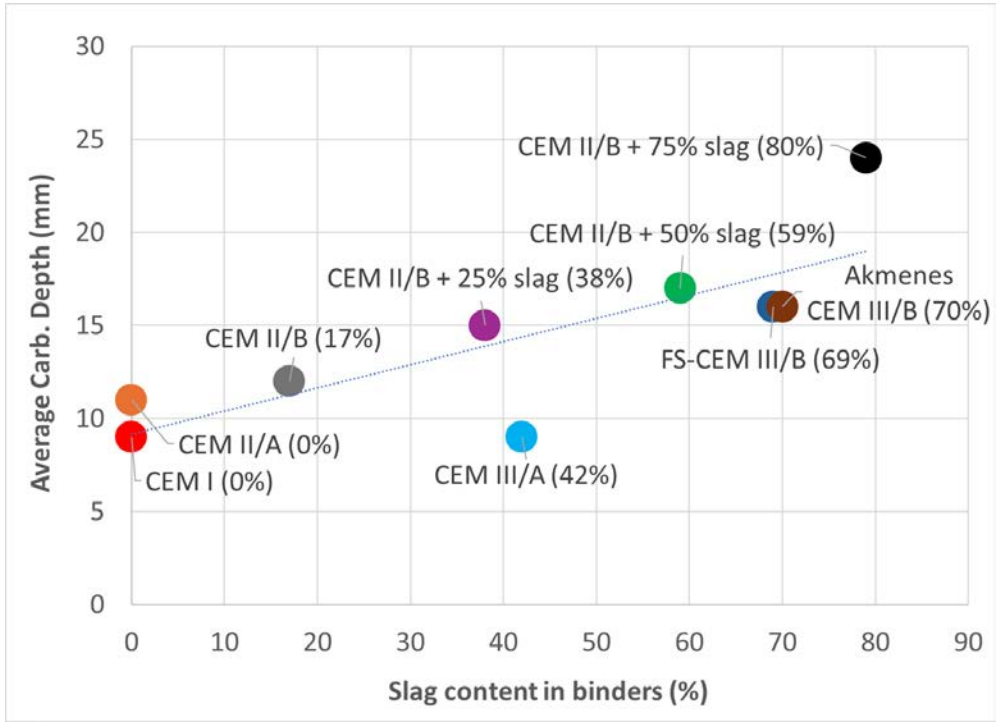
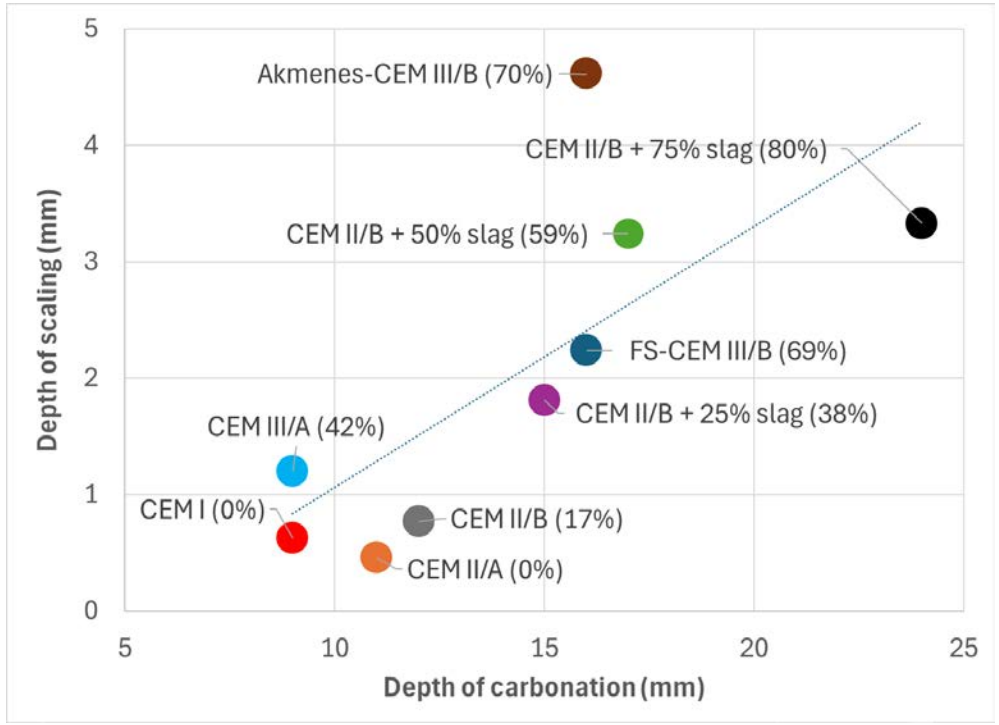
Carbonation depth



Effect of slag content



Effect of carbonation depth on scaling

Assumed density of scaled material 2000 kg/m^3

$$\text{CEM II/B (80\% slag)} = \frac{3{,}3\ mm}{24\ mm} = 14\%;\ carbonated\ zone\ scaled\ off.$$

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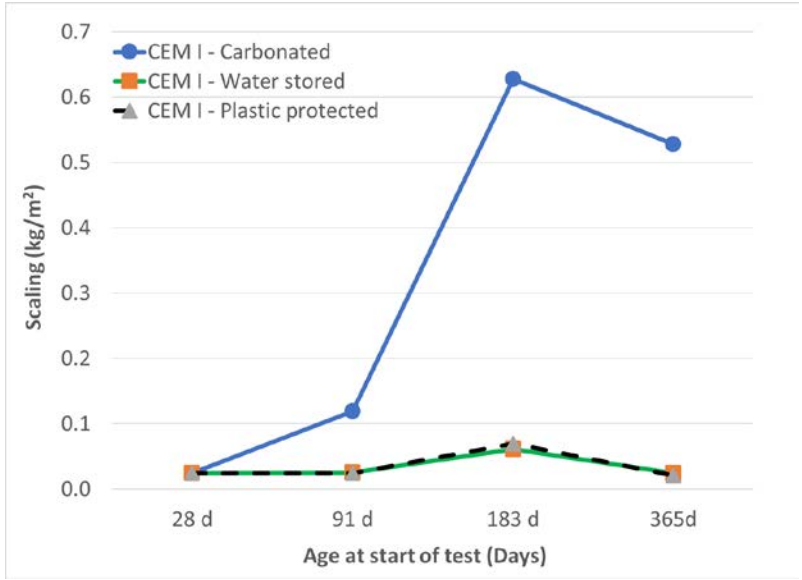
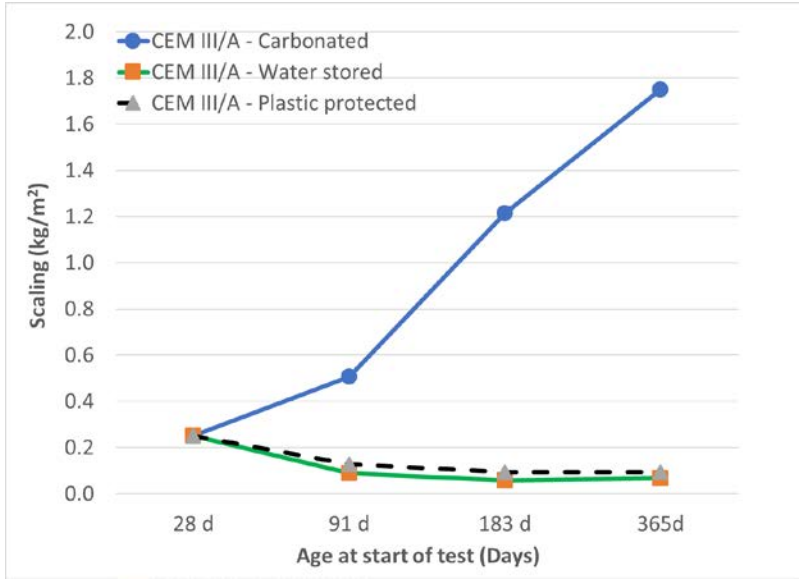
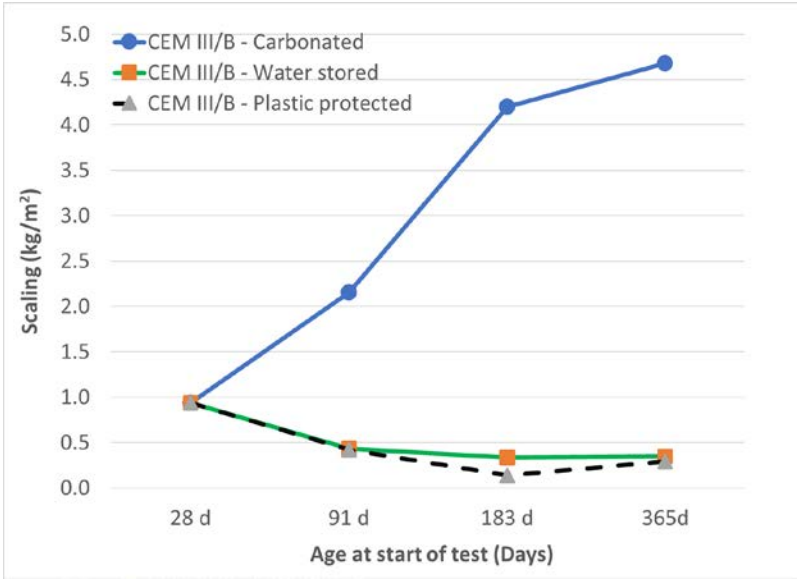
Effect of ageing and curing conditions on scaling resistance with chlorides







CEM I (0%)

CEM III/A (40%)

CEM III/B (70%)

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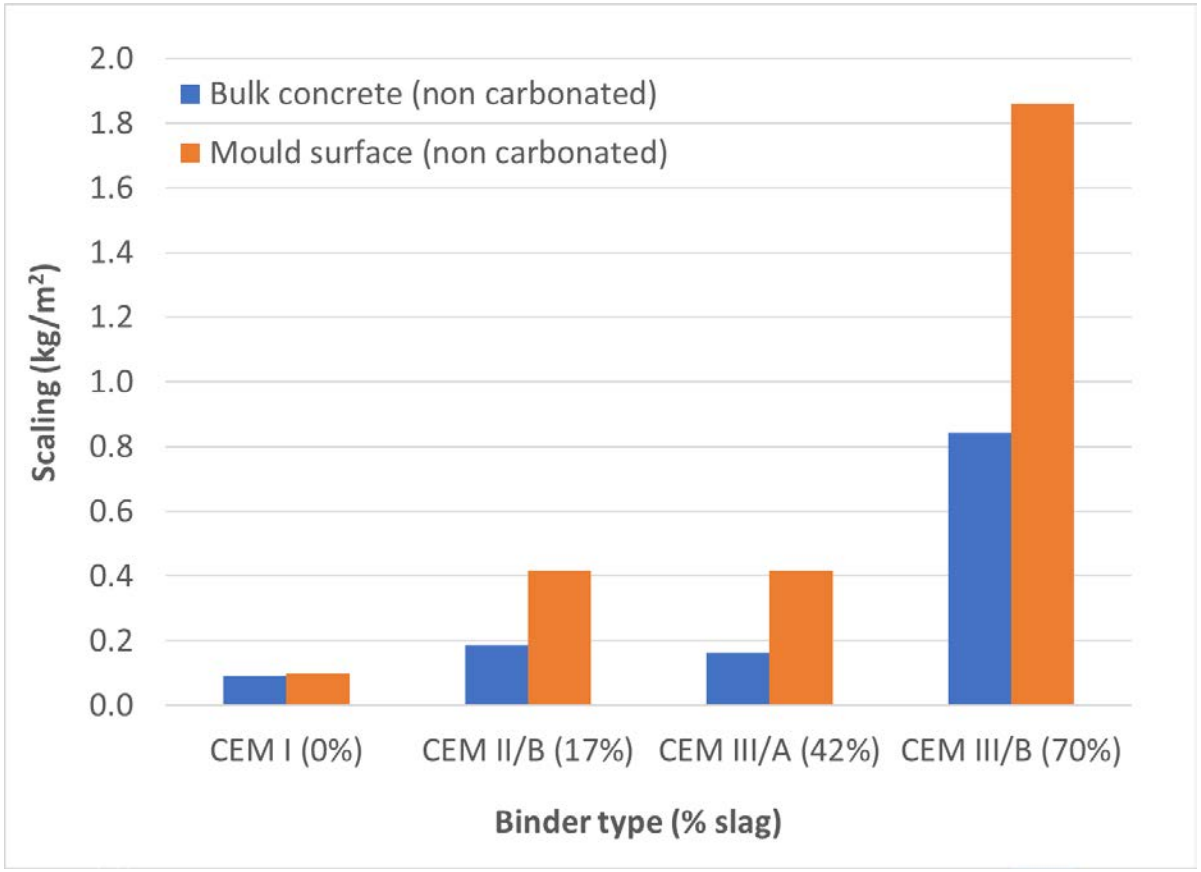
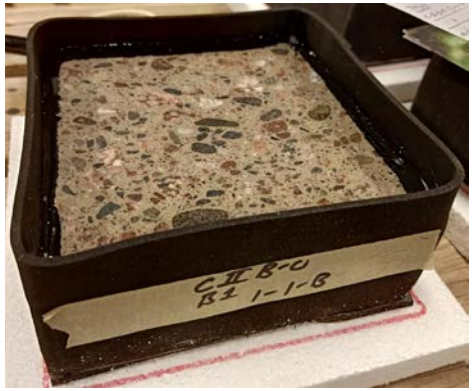
Mould vs. Bulk concrete: Effect on scaling





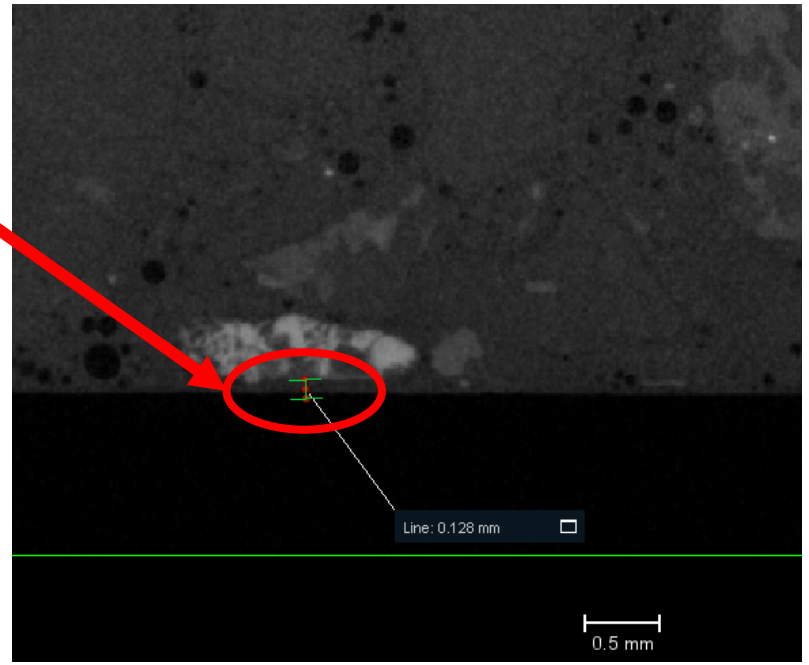
- Test surface of concrete with slag content has clear effect on surface scaling.

X-ray computed tomography

- Same specimen can be tested both before and after carbonation.
- X-ray resolution used **15 µm**.
- No surface effect could be detected (no excess cement paste visible near the surface).
- Effect of carbonation near concrete surface was not detectable.
  - Resolution of the test method is probably not enough small.

Ø 25 x 100 mm

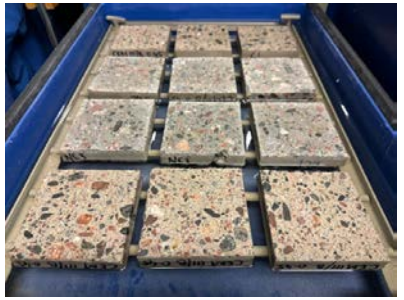
~100 µm / 0,1 mm



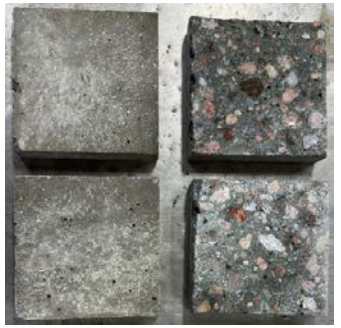
Current research

- The observed clear effect of carbonation on salt freeze-thaw resistance is most probably connected to coarsening of the pore structure.
  - The coarsening effect was not detected with X-ray CT.
- **Analysis continues:**
  - Capillary suction testing.
    - ❑ Suction porosity (effective **w/b ratio** of hardened concrete)
    - ❑ Air porosity (**entrained air** in hardened concrete)
  - X-ray CT,
  - XRD (possible chemical effects), ESEM?
  - ^{1}H NRM? TGA?

Picture: Ahsan Iqbal



Picture: Ahsan Iqbal

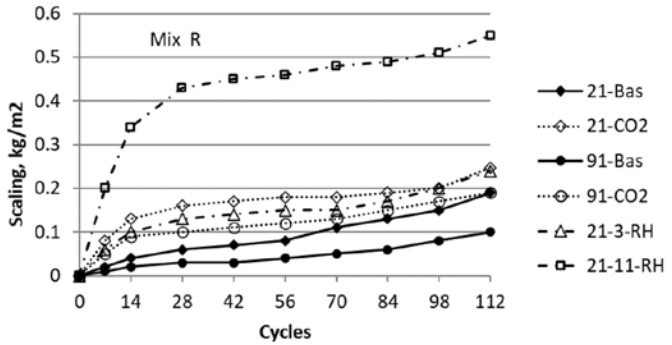


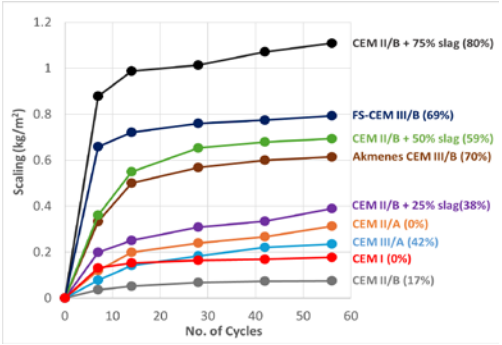
What's next?

- Aim is to clarify why carbonation has such a large effect on salt freeze-thaw scaling of slag concretes?
  - What is really happening in the slab test?
  - How critical is the pre-treatment of the specimens before the freeze-thaw testing (carbonation time, drying/wetting periods)?

Master's thesis

- "Critical evaluation of slab test method for salt freeze-thaw resistance of concrete"
  - Initial cycles of the slab test and the effects of the pre-treatment.





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Helsing E Utgenannt P: "Salt-Frost Scaling of Concrete with Slag and Fly Ash - Influence of Carbonation and Prolonged Conditioning on Test Results". *Nordic Concrete Research*, Vol., No. 63 – Issue 2, 2020, pp. 89-108.

Kiitos
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Kysymyksiä?
Kommenttia!

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