

# Improving Early Strength of Low Clinker Cements and Concretes



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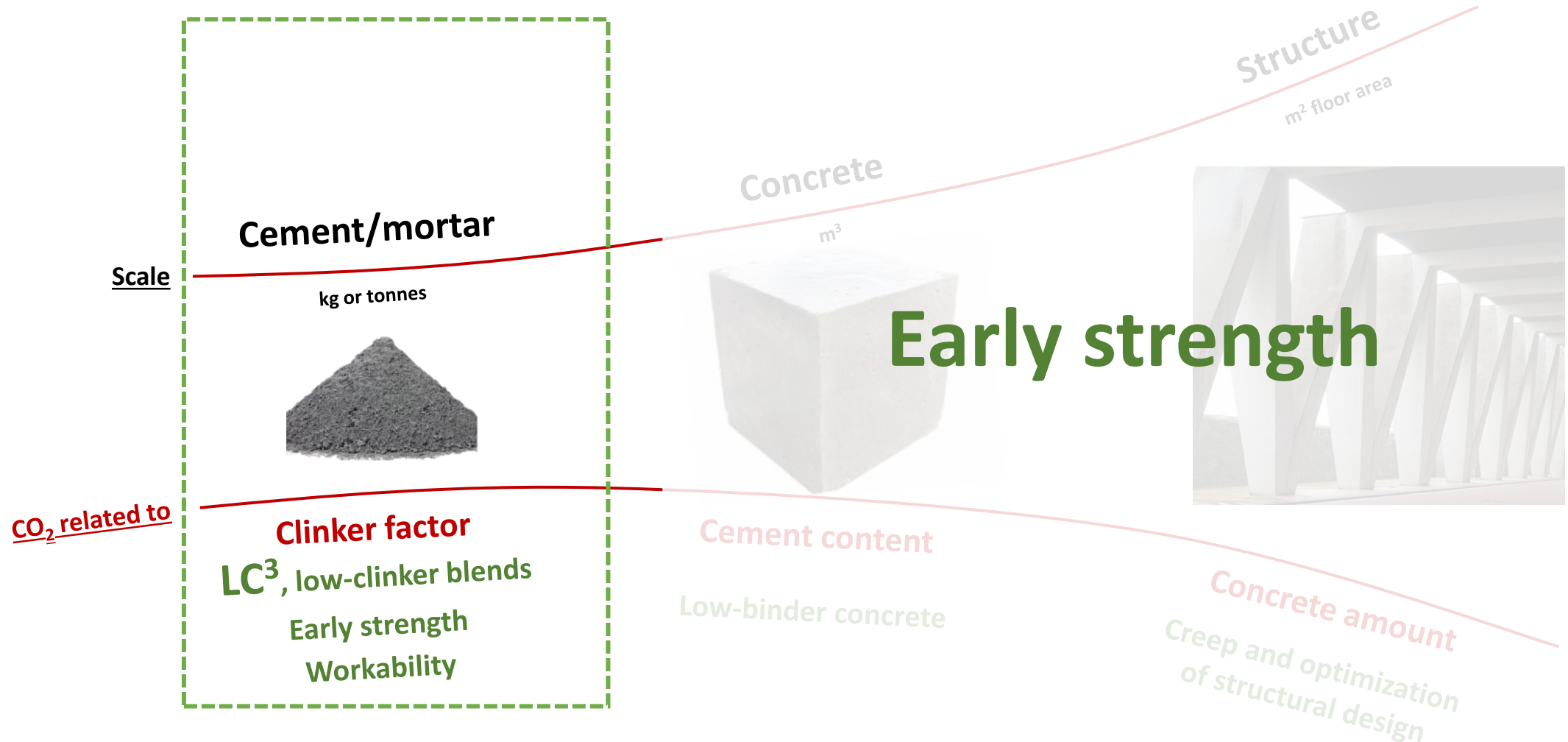
Dr. Beatrice Malchiodi

Prof. Karen Scrivener

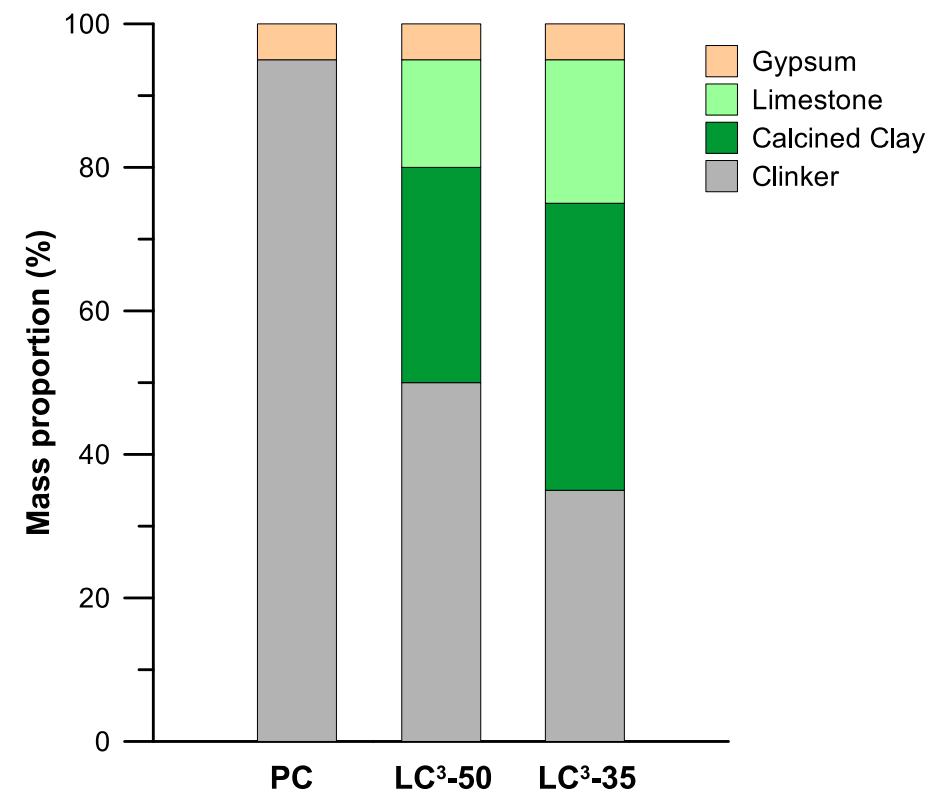
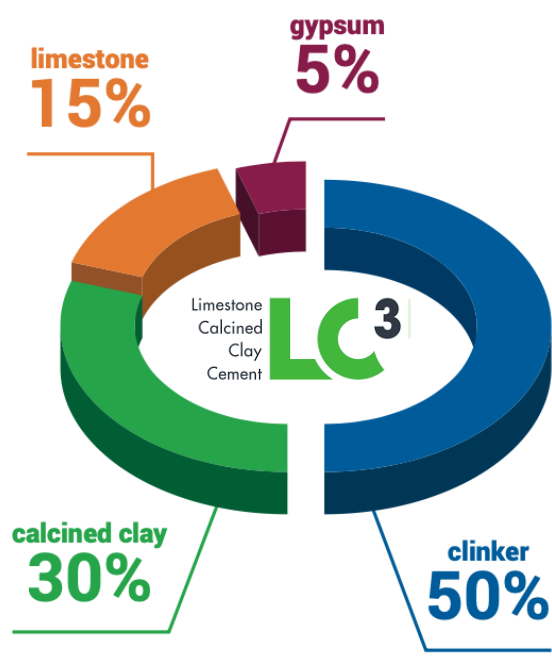
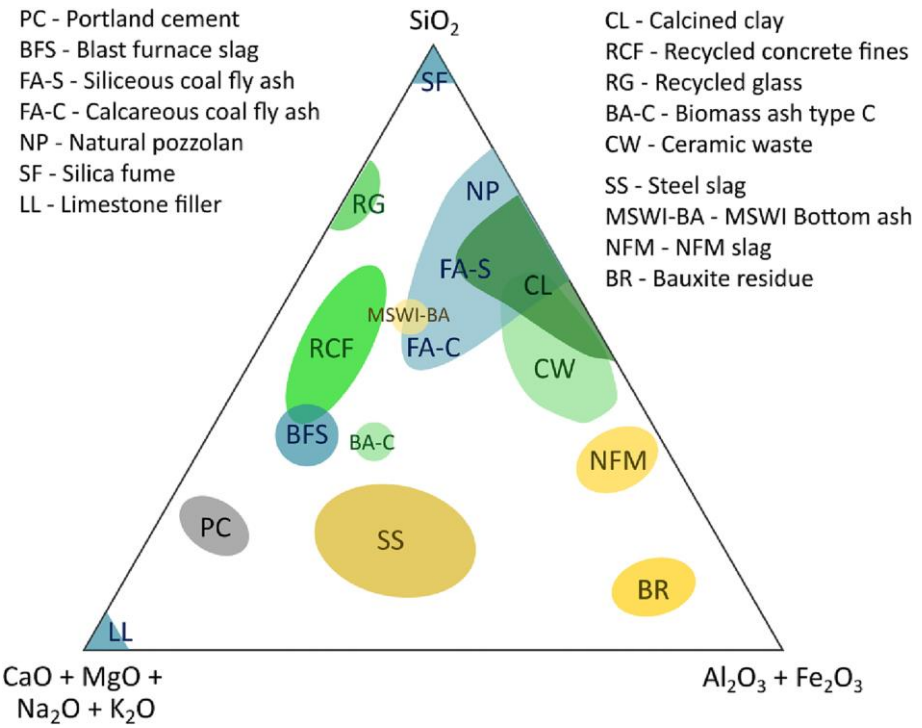
06th November, 2024



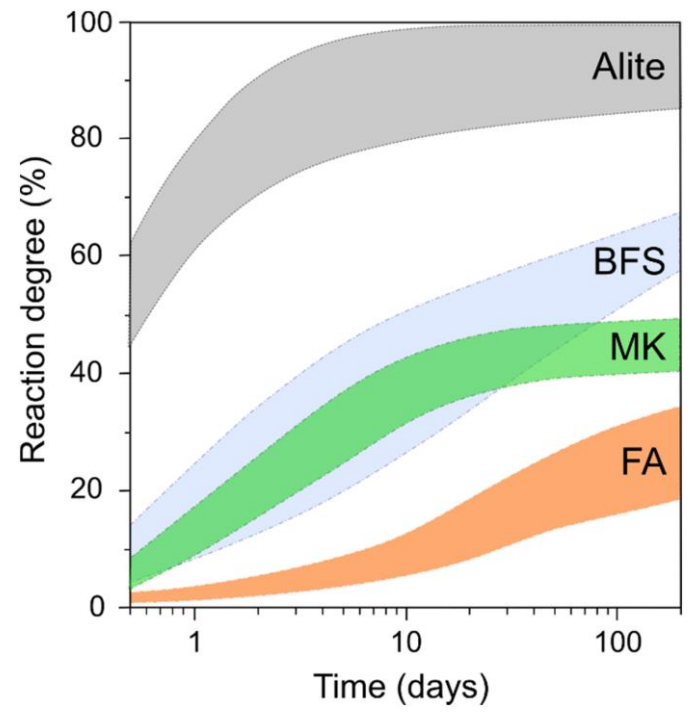
# A multidimensional approach towards net-zero



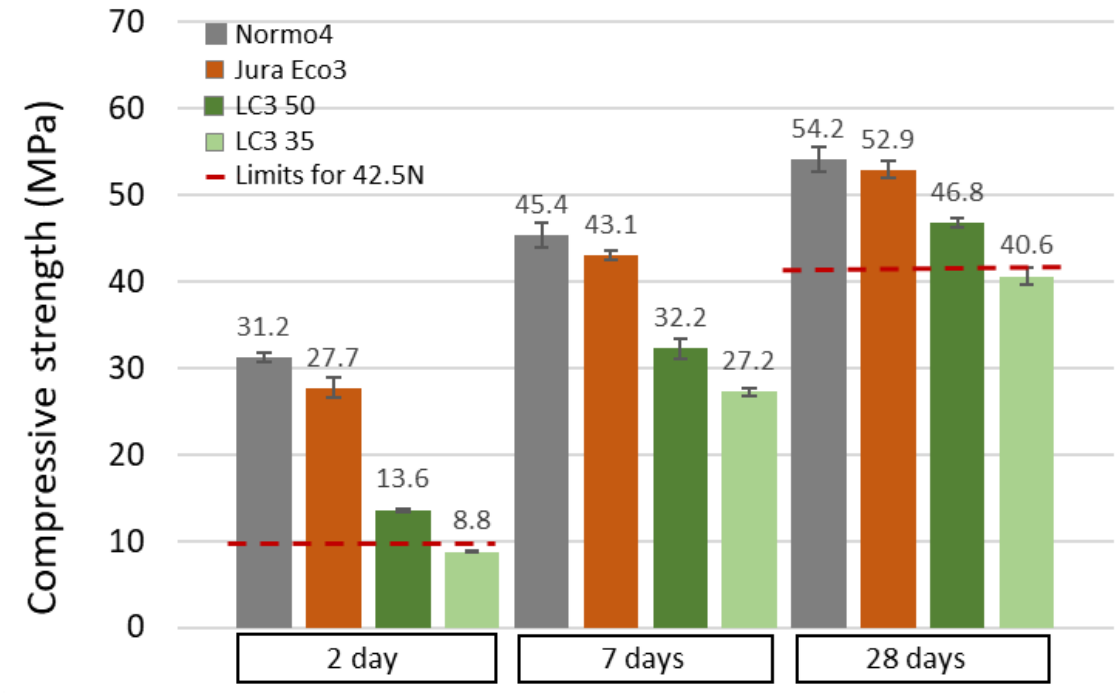
# Supplementary Cementitious Materials



# Low Clinker Cements - Early strength issues



Reaction degree envelopes with clinker substitution levels from 30 to 50 wt.%



Very low compressive strength at early ages compared to OPC and commercial blended cements (Jura Cement).

Jørgen Skibsted, Ruben Snellings, Reactivity of supplementary cementitious materials (SCMs) in cement blends, Cement and Concrete Research, 2019

(LMC results – Beatrice Malchiodi)



Early-age strength improvement

C-S-H Seeding

Commercial Seeds

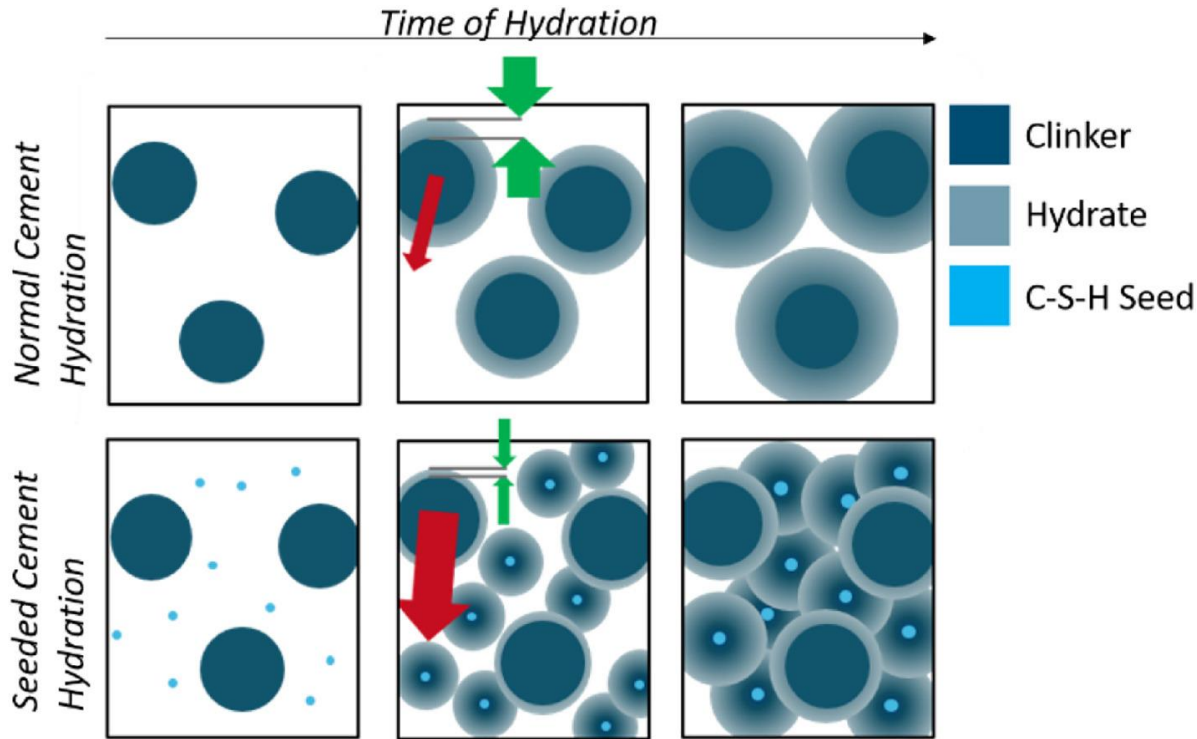


Limestone  
Calcined  
Clay  
Cement



# 1. C-S-H Seeding (1/3)

**Solution 1:** Addition of commercial C-S-H seeds



**Seeding:**  
**Master X-Seed® STE 54**

**Dosage:**  
**2%**

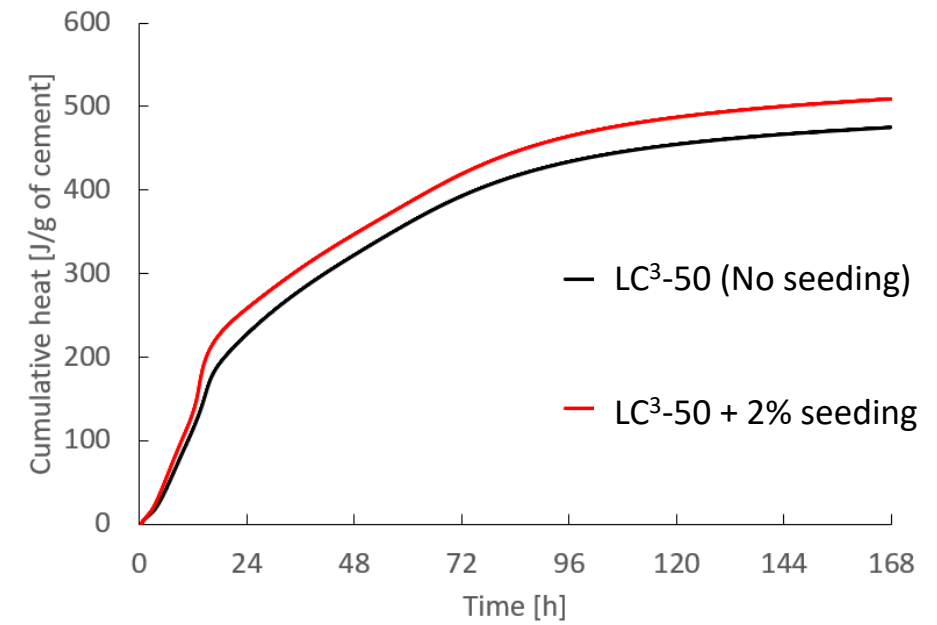
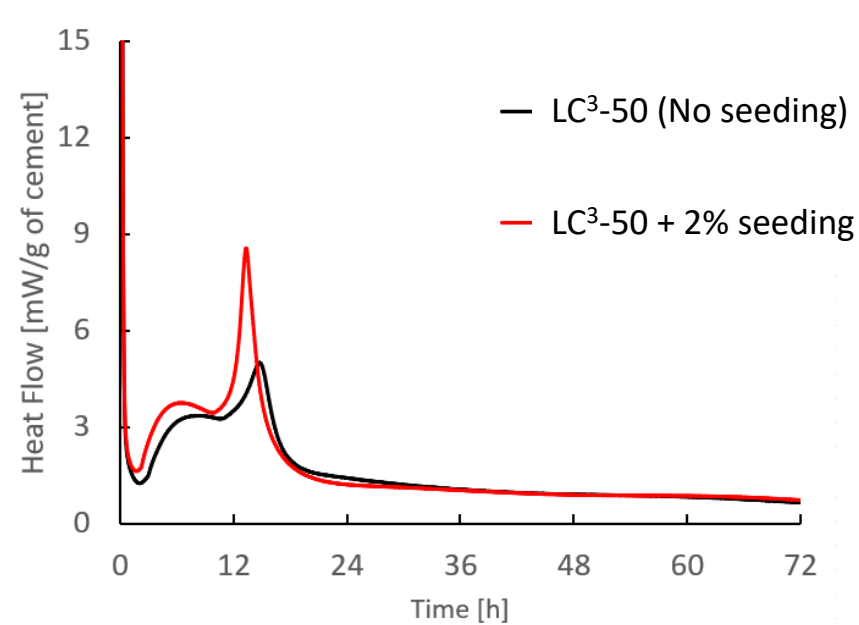


# 1. C-S-H Seeding (2/3)

## LC<sup>3</sup>-50

### Hydration kinetics:

- Accelerate 1<sup>st</sup> peak ↑
- Aluminate reaction ↑
- Early age cumulative heat ↑
- 7-day cumulative heat ↑

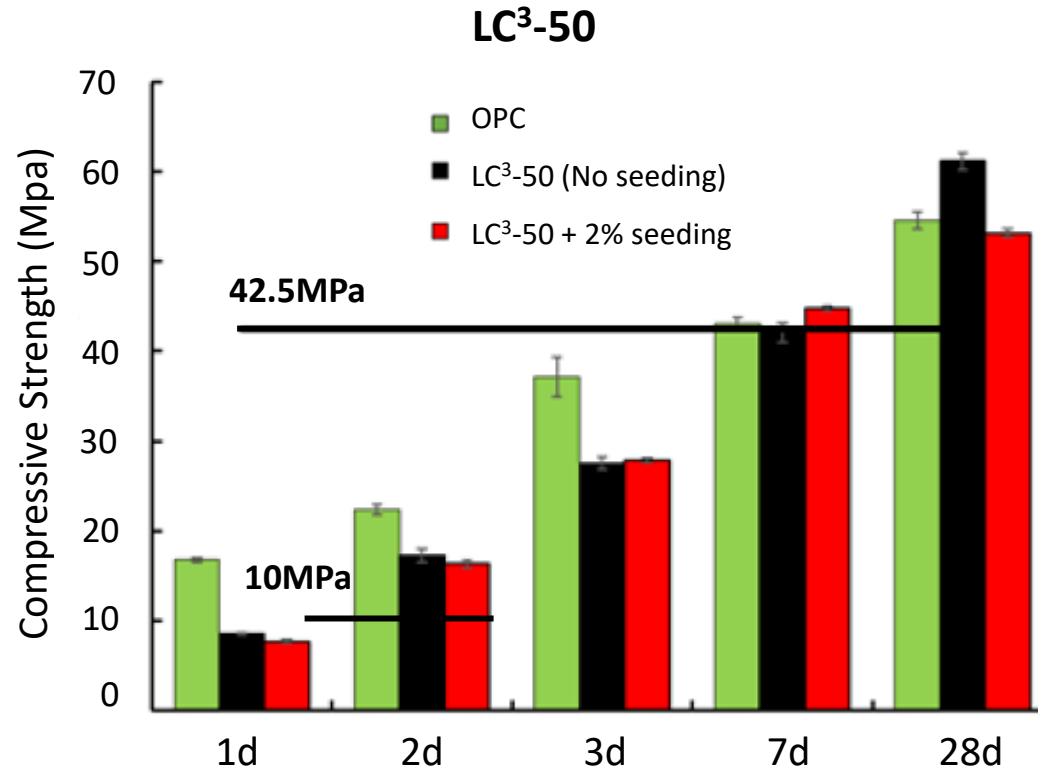




# 1. C-S-H Seeding (3/3)

## Compressive Strength:

- Early-age strength (up to 3d) ↓
- Early-age strength at 7d ↑
- Strength after 7d ↓







Early-age strength improvement

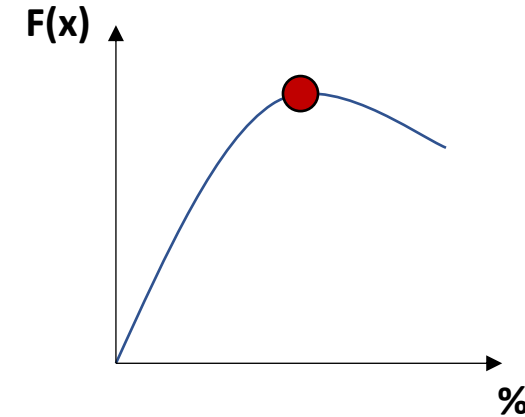
Alkanolamines + Alkali Sulphates

DEIPA +  $K_2SO_4$

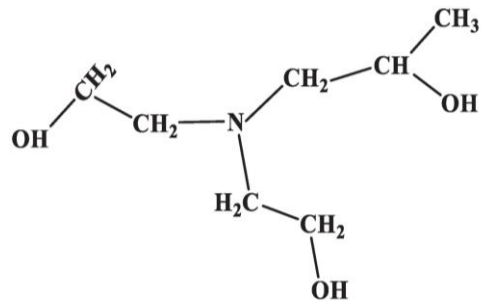
## 2. Alkanolamines + Alkali Sulphates (1/2)

**Solution 1:** Addition of alkanolamine grinding aids and alkali sulphates as accelerators (boosted if added in combination)

*M. Ben Haha 2021 Patent, M. Ben Haha 2023*



DEIPA (Diethyl isopropanol amine)



$K_2SO_4$  (Potassium Sulphate)

1

Ref mixes:

- OPC NORMO 4
- LC<sup>3</sup> 50 (LMC)

2

LC<sup>3</sup> 50 + DEIPA:

- DEIPA:
  - 0.025 %
  - 0.05 %
  - 0.10 %
  - 0.15 %
  - 0.20 %
- In mixing water

3

LC<sup>3</sup> 50 + DEIPA  
+  $K_2SO_4$ :

- $K_2SO_4$ :
  - 0.50 %
  - 0.75 %
  - 1.00 %
  - 1.25 %
  - 1.50 %
  - 1.75 %
- In dry mix

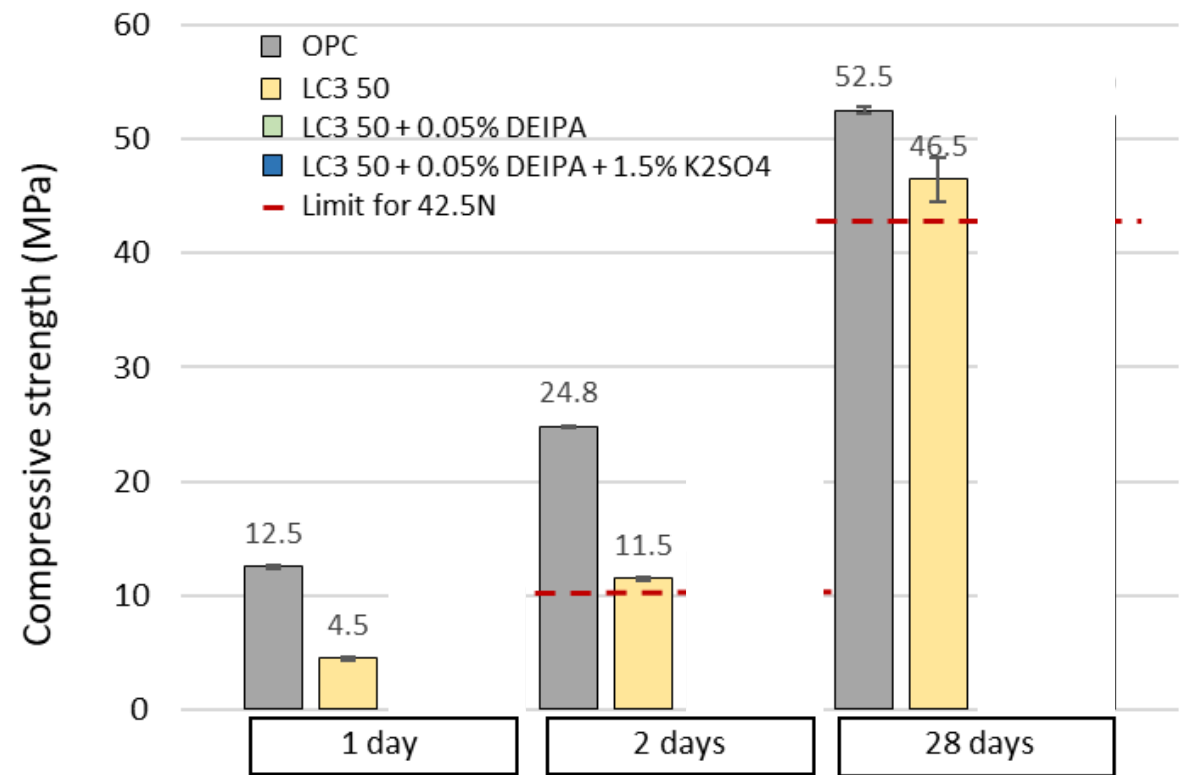


## 2. Alkanolamines + Alkali Sulphates (2/2)

OPC vs LC<sup>3</sup>50 vs LC<sup>3</sup>50 + DEIPA vs LC<sup>3</sup>50 + DEIPA + K<sub>2</sub>SO<sub>4</sub>

### Combined effect of DEIPA + K<sub>2</sub>SO<sub>4</sub>

- 1 day: +137% (+6.2 MPa)
- 2 days: +75% (+8.6 MPa)
- 28 days: No slow down!



(LMC results – Beatrice Malchiodi)



Early-age strength improvement

State-of-the-Art Grinding



LOW  
CARBON



LOW  
CAPITAL



HIGH  
PERFORMANCE



SCALABLE

# 3. State-of-the-Art Grinding (1/4)

**Solution 3:** FIDE Technology Low-Carbon Grinding Mill

Limestone  
Calcined  
Clay  
Cement

LC<sup>3</sup>



# 3. State-of-the-Art Grinding (2/4)

**Solution 3:** FIDE Technology Low-Carbon Grinding Mill

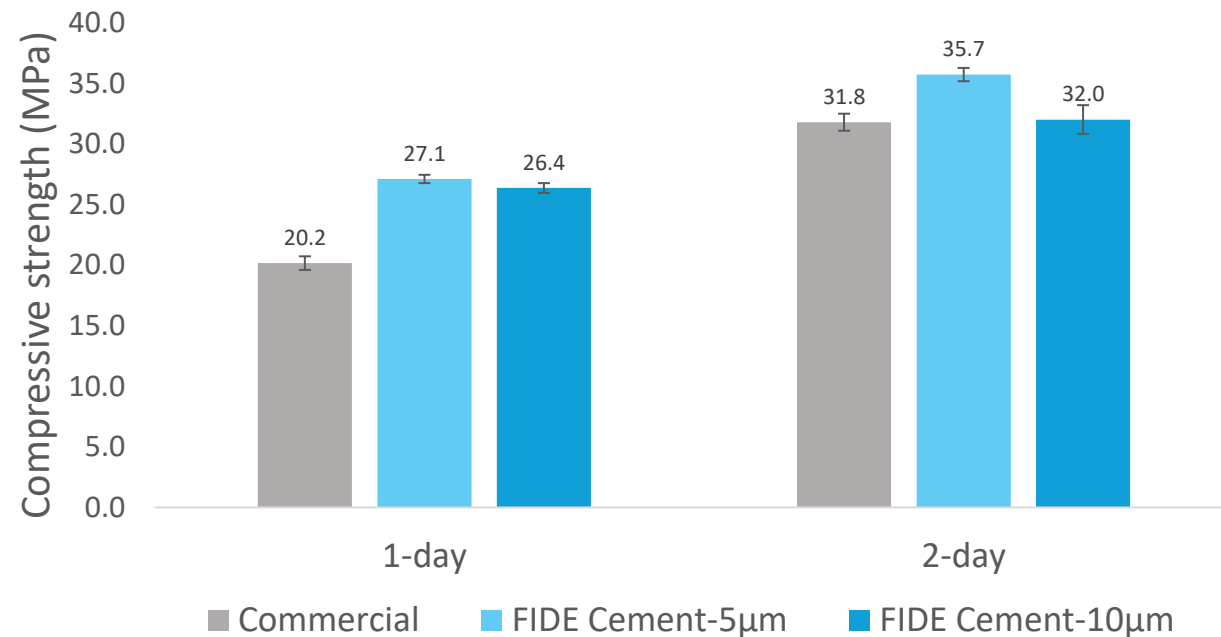
**FIDE**TECH  
NOLOGY



FIDE LC Mill Prototype at EPFL with a capacity of 150 kg per hour

[\(https://fidetechnology.com/\)](https://fidetechnology.com/)

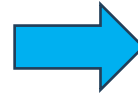
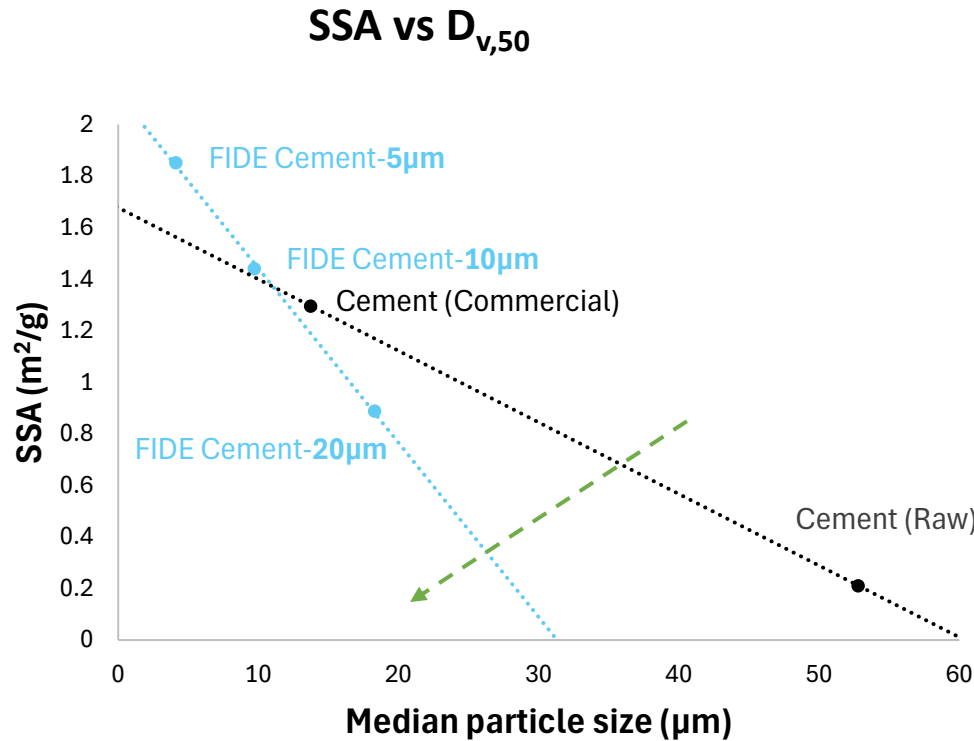
## Compressive Strength



(LMC results – Chloé Anaïs Marie Monin)



# 3. State-of-the-Art Grinding (3/4)



**Why is the SSA increase higher using FIDE LC Mill?**



# 3. State-of-the-Art Grinding (4/4)

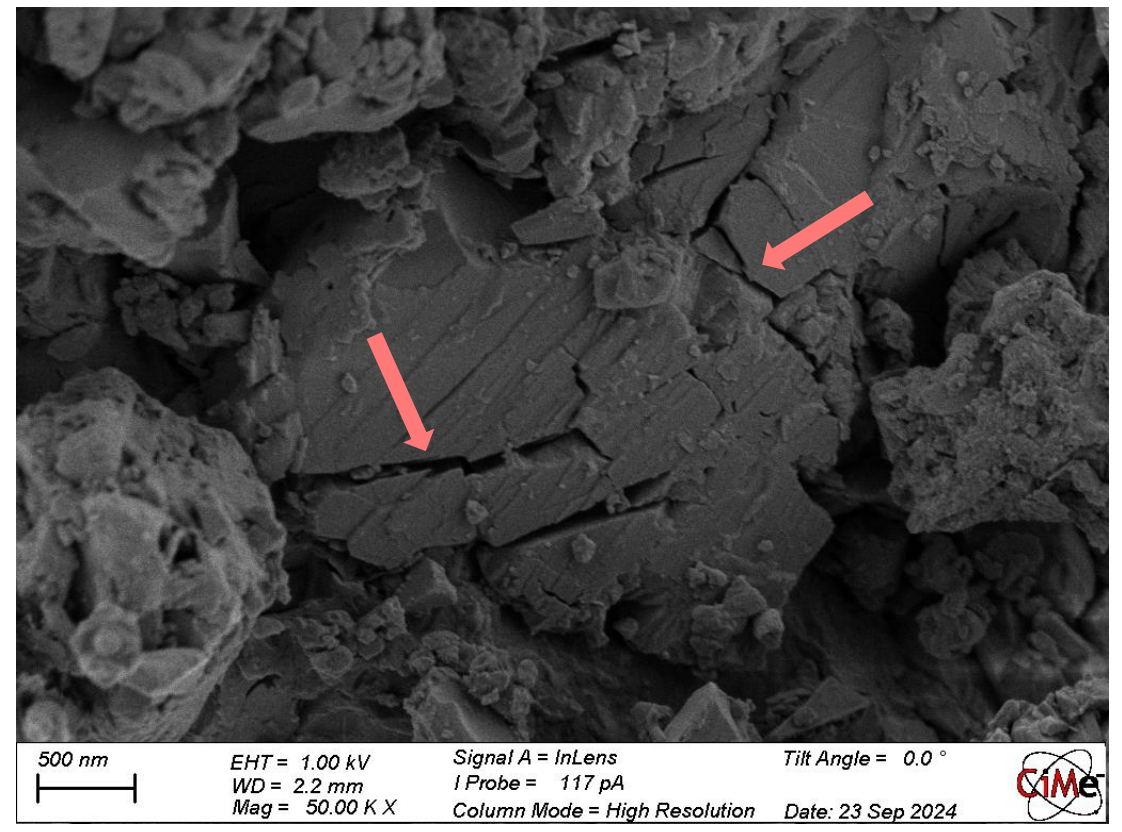
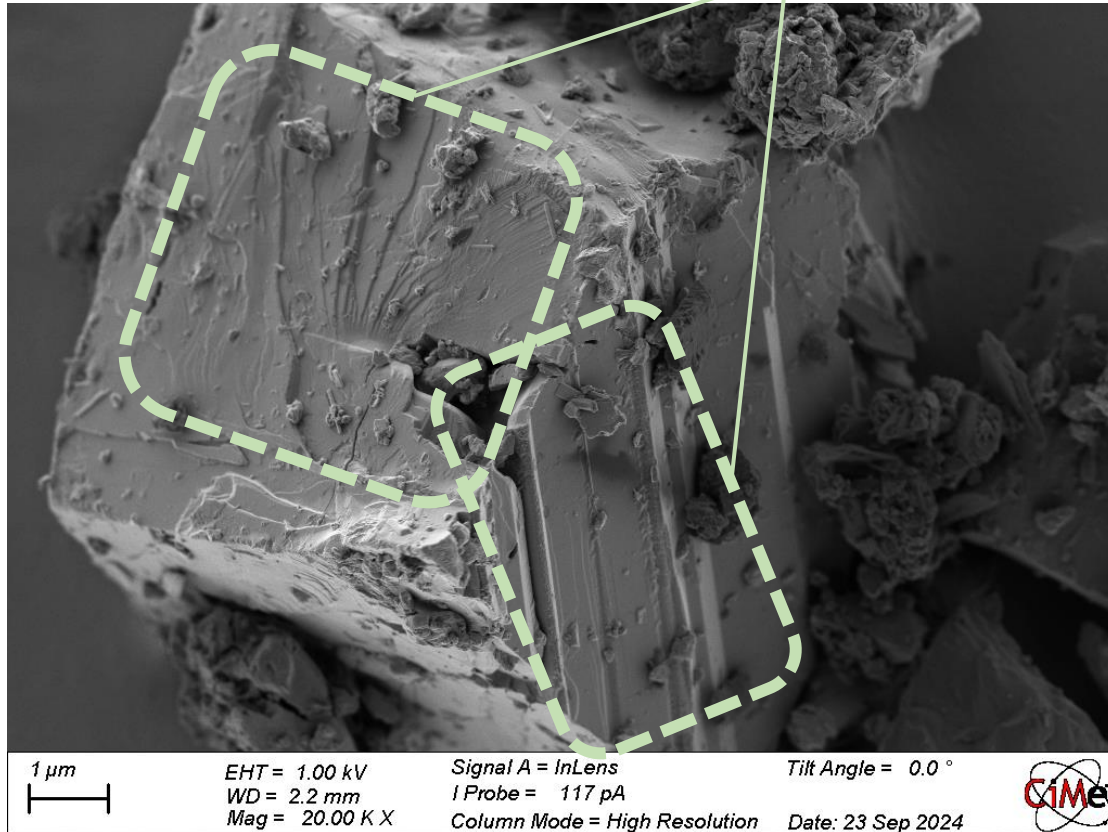
FIDE LC Milling

Shear Fracture

Traditional Milling



Impact Fracture



Limestone  
Calcined  
Clay  
Cement

**LC<sup>3</sup>**

# Conclusion



Early-age strength  
improvement

C-S-H Seeding

Commercial Seeds

Alkanolamines + Alkali  
Sulphates

DEIPA +  $K_2SO_4$

Grinding

**FIDE**TECH  
NOLOGY



# QUESTIONS?

# THANK YOU!

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