Improving the performance of Portland Limestone Cement through utilizing nano-SiO_2-coated limestone

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Research significance

- Portland Limestone Cement (PLC):

5-15% limestone (wt.%)

- Limestone advantage:

Availability
Low environmental impact production

- Limestone disadvantage:

Very limited reactivity
Mechanical strength and durability issues

Research significance

SiO_2 nanoparticles performance in cementitious media:

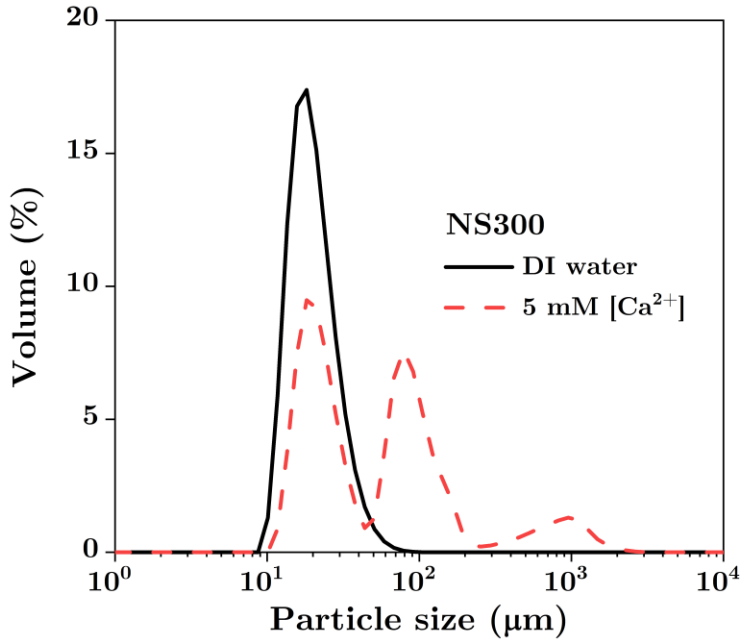
- High pozzolanic activity
- Acceleration of cement hydration
- Micro-filling effect

SiO_2 nanoparticles advantage:

- Improving mechanical strength & durability
- Early age improvement

SiO_2 nanoparticles disadvantage:

- Agglomeration in cementitious media
- Cost



Agglomeration of SiO_2 nanoparticles

Research significance

How to increase limestone content while improving the dispersion of SiO_2 nanoparticles?

Coating limestone particles with SiO_2 nanoparticles

Coating process:

- Low cost
- Low environmental impact
- Simplicity

Limestone particles: positively charged

SiO_2 nanoparticles: negatively charged

Electrostatic attraction!

Mix design

Materials

- Type I cement
- Limestone 98% purity & 3 µm (average)
- SiO_2 nanoparticles: Colloidal form & 300 m^2/g (NS300)

Three sets of samples

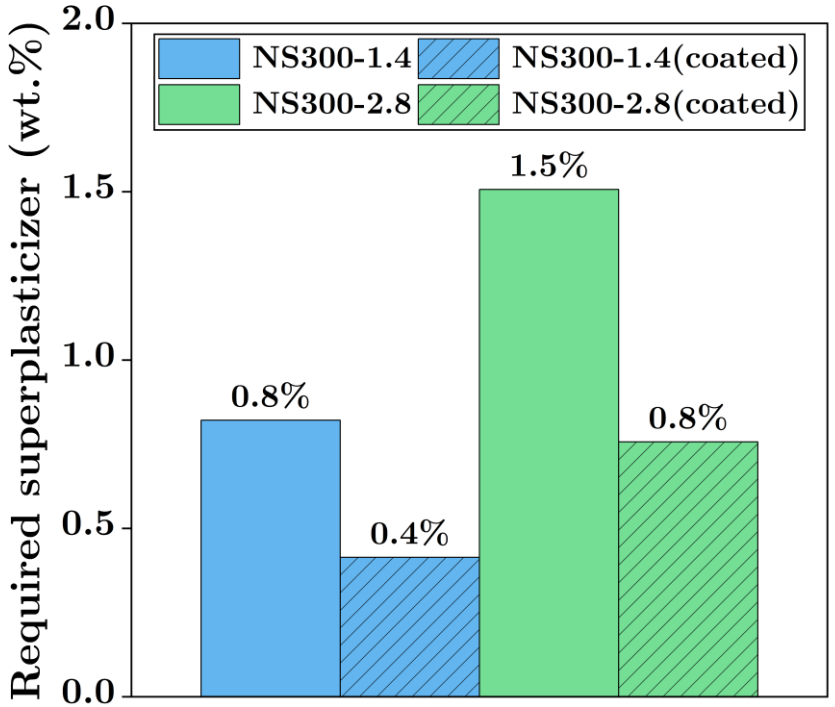
1. Cement (100%): Ref-LS-0
2. Cement (80%) + Limestone (20 wt.%): Ref-LS-20

3.1. Cement + Limestone (20 wt.%) + NS300
3.2. Cement + Limestone (20 wt.%) coated with NS300

NS300-A: A% NS300 & (80-A)% cement

NS300-A (coated): A% NS300 loaded on limestone & (80-A)% cement

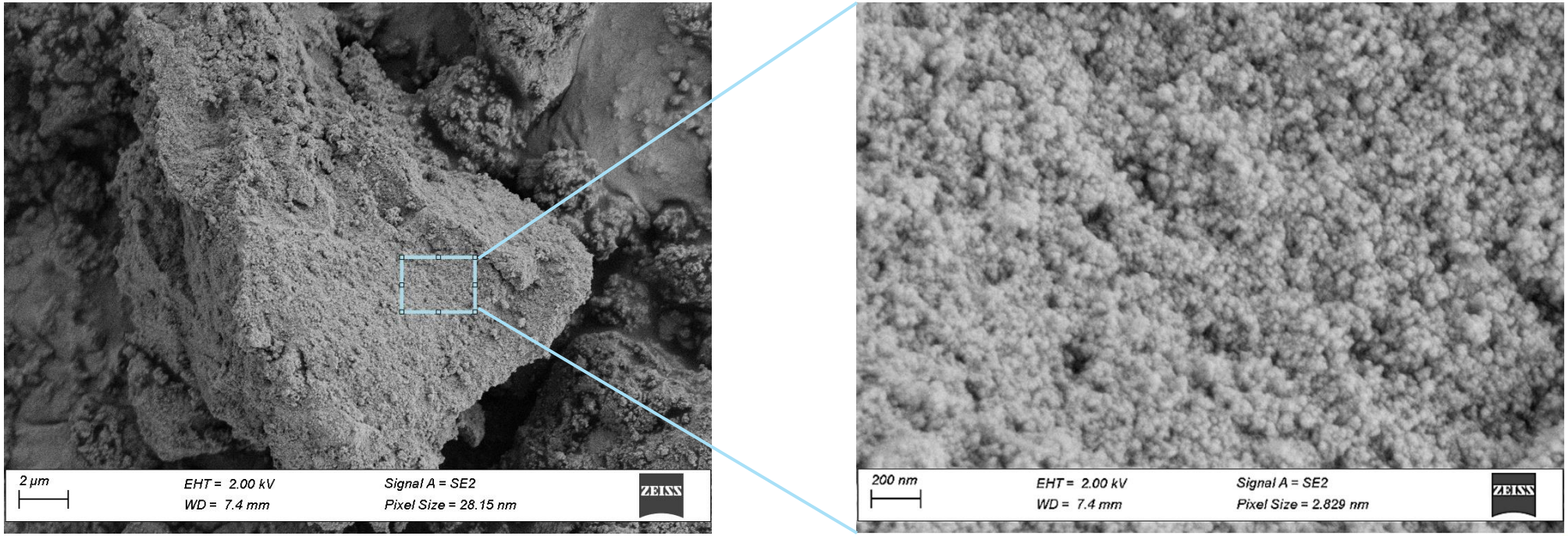
Superplasticizer to ensure similar flow diameter (75±5 mm)



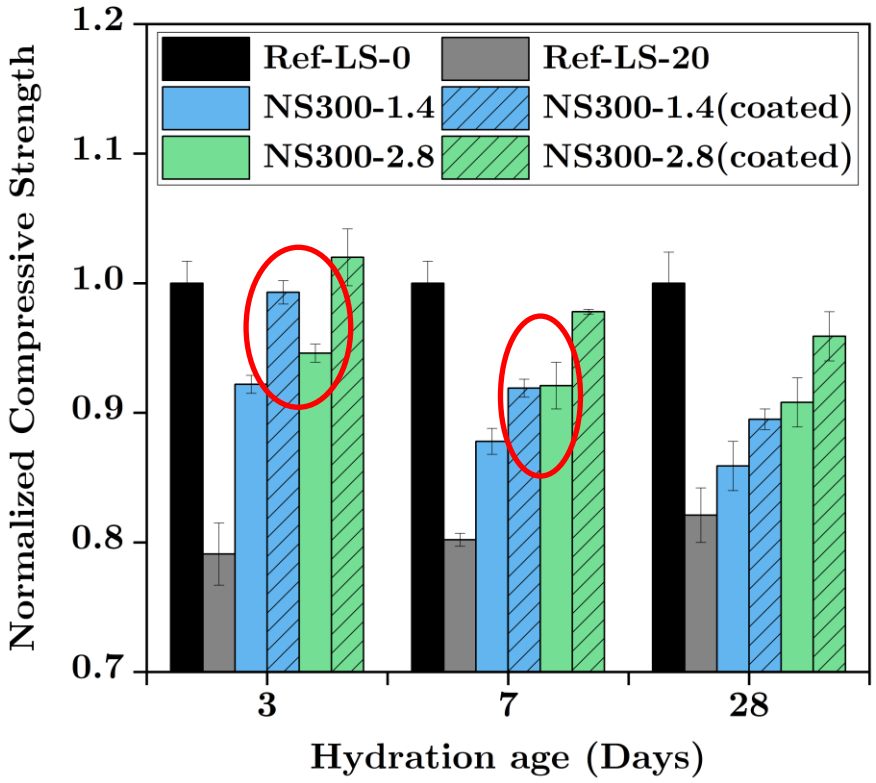
Significant reduction in the SP amount

Coated limestone particles (SEM)

- Loading content: 14% by weight of limestone



Compressive Strength



20% limestone: ~20% strength reduction

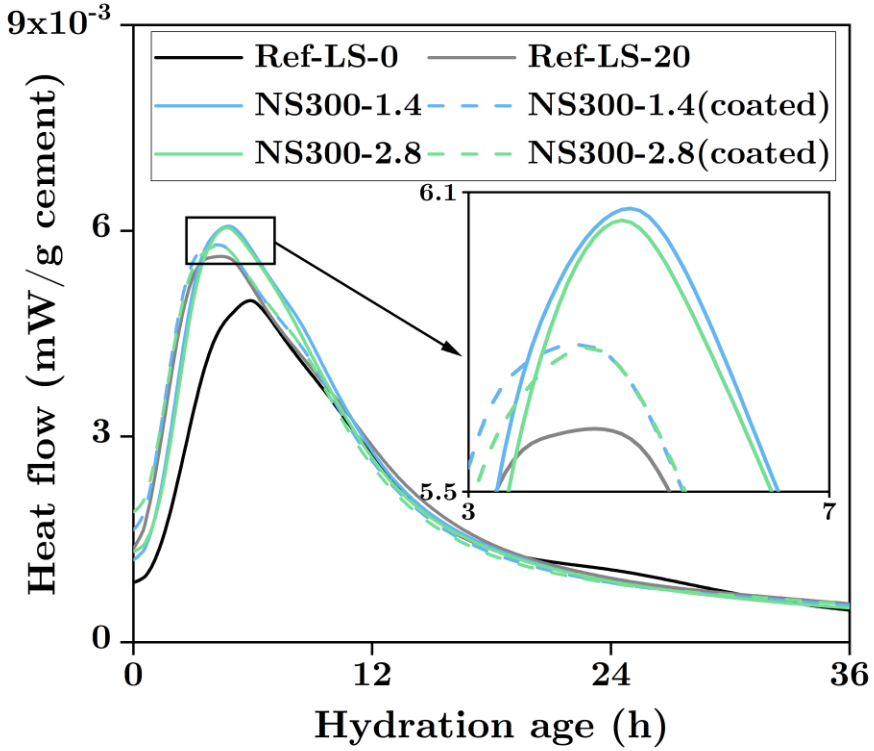
NS300: Strength ↑

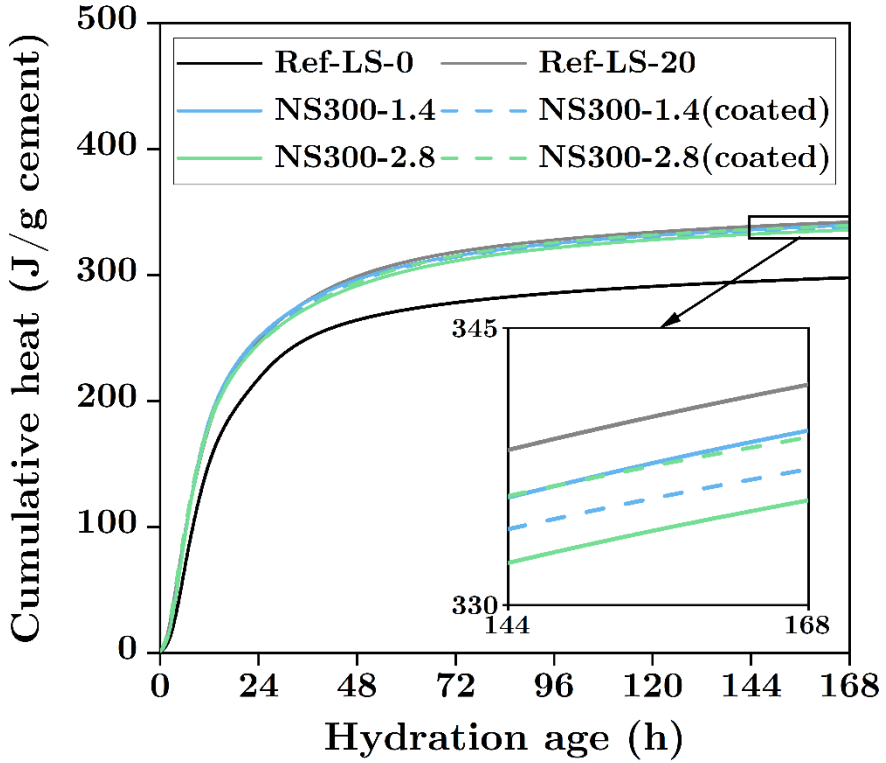
At later ages: NS300 effect ↓

Loading SiO_2 Nanoparticles:

- Loading 7% NS300 > 14% NS300 addition during mixing (early age)

Calorimetry



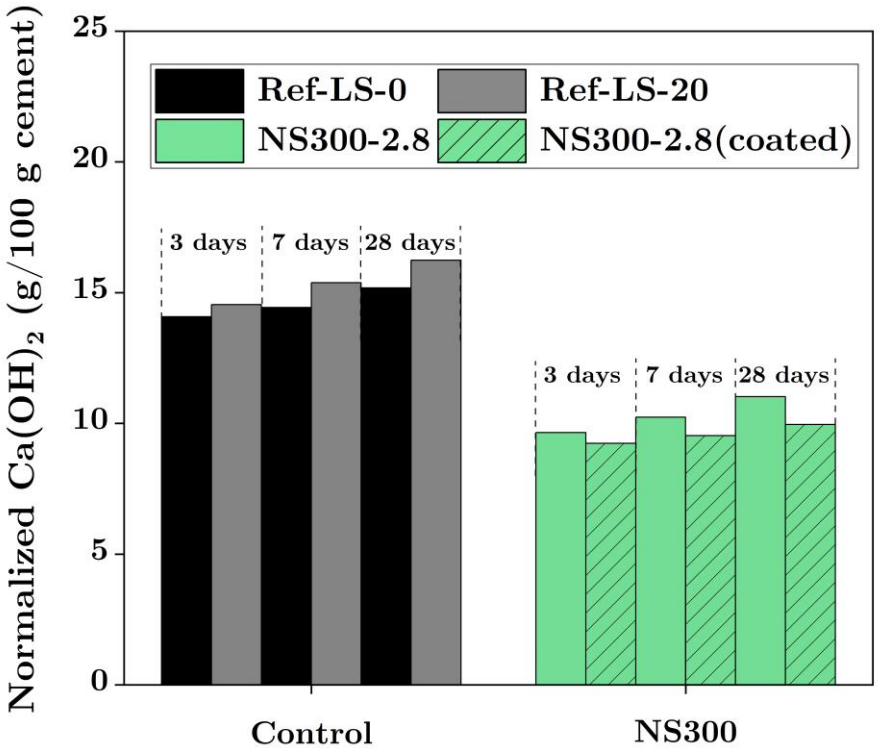


Not significant effect on total heat release!

Addition of fine limestone (20% wt.%) accelerated cement hydration

Loading SiO_2 nanoparticles decreased main peak (~ 5%)

$Ca(OH)_2$ content



20 wt.% limestone: CH ↑

SiO_2 nanoparticles decreased CH content (~ 30%-35%)

Loading SiO_2 nanoparticles further decreased CH!

Conclusion

SiO_2 nanoparticles-coated limestone composite:

Superplasticizer ↓↓ ⇒ Cost ↓

Compressive strength ↑↑

Pozzolanicity ↑

Cement replacement by limestone ↑↑ ⇒ Environmental impact ↓

Thank you for your attention!

Questions?