

25.02.2026

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# **POLYMER–LIQUID–BINDER INTERACTIONS AND THEIR IMPACT ON RHEOLOGY IN LIMESTONE CALCINED CLAY CEMENT (LC<sup>3</sup>)**

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## Environmental matters

8% global

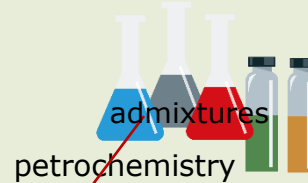


clinker



SCMs → LC<sup>3</sup>

**!** Increased surface area causes rheological problems



admixtures  
petrochemistry

Bio-based alternatives

**!** Quality scatter



## Costs

Despite the low wt.% required, the cost is still considerable high

Local supply chain



# MATERIALS: BIO-ADMIXTURES

Available in nature..

**Gum Arabic**



**Water hyacinth**



**Procedure:**

**Dissolve**

**Gum Arabic**



**Dry**

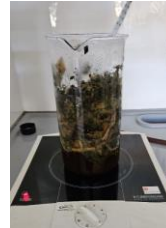


**Grind**



**Boil**

**Water hyacinth**



**Extract liquid**



# MATERIALS: BIO-ADMIXTURES

Available in nature..

**Gum Arabic**



**Water hyacinth**



Available on the market..

**Xanthan gum**



**Sodium alginate**



vs.

**Polycarboxylate ether (PCE)**



**LC<sup>3</sup> - 35**

**liapor**

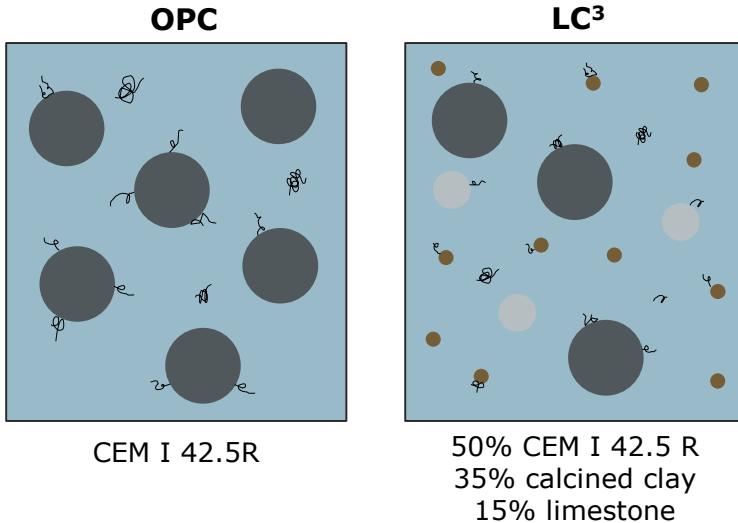


vs.


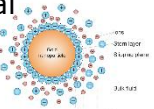
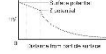


**CEM I 42.5R**

# BACKGROUND: binder-polymer-liquid phase interactions



Depends on...

- Polymer concentration
  - Size ratio of polymer to binder
  - Binder-binder interaction
  - Binder-polymer interaction
  - Liquid phase-polymer interaction
  - Temperature
  - Particle concentration
  - Time
  - ...
- ➔ Hydrodynamic radii
- ➔ Zeta potential
- ➔ TOC
- ➔ ICP-OES
- ➔ Rheology on liquid phase
- 
- 
- 

## Dynamic light scattering

Zetasizer Nano-zs:



- Hydrodynamic radii and Zeta potential;
- Solvent: water,  $\text{Ca}(\text{OH})_2$ , and aqueous phase from calcined clay.

## TOC

Multi N/C 3100:



- Liquid from OPC and  $\text{LC}^3$ : centrifuge;
- Different admixture dosages.

## ICP-OES

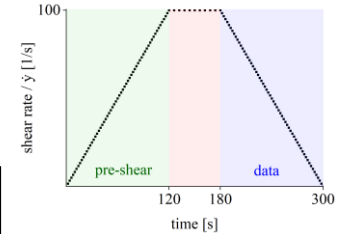
iCAP 6000 Series  
ICP Spectrometer:



- Liquid from OPC and  $\text{LC}^3$ : centrifuge;
- Influence of the admixture.

## Rheology:

MCR 502 WESP:



- Liquid phase: OPC and  $\text{LC}^3$
- Paste: OPC and  $\text{LC}^3$

## Early hydration:

- 48 hours

TAM AIR:



# RESULTS: Hydrodynamic radii

## Water

	Peak (d.nm)	Vol (%)	Peak (d.nm)	Vol (%)
GA	3.8	98	19.2	2
WH	57.4	100	-	-
XG	17.9	97	210	3
AL	479.3	73	55.8	27
PCE	6.8	96	42.5	4

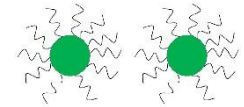
## Ca(OH)<sub>2</sub>

	Peak (d.nm)	Vol (%)	Peak (d.nm)	Vol (%)
GA	23.5	93	238.7	7
WH	214.5	100	-	-
XG	50.0	100	-	-
AL	1036	100	-	-
PCE	229	100	-	-

## Aqueous phase from calcined clay

	Peak (d.nm)	Vol (%)	Peak (d.nm)	Vol (%)
GA	25.4	100	-	-
WH	528.8	100	-	-
XG	1333	97	87.4	3
AL	407.3	100	-	-
PCE	8.8	96	57.2	4

- Polymer association.
- Influence in steric stabilization:



# RESULTS: Zeta potential

## Water

	pH	Zeta Potential (mV)
Gum Arabic	7.08	-33.70
Water Hyacinth	8.49	-21.93
Xanthan gum	7.39	-77.17
Alginate	8.85	-58.20
PCE	7.96	-9.26

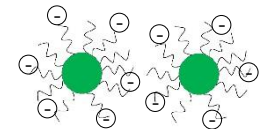
## Ca(OH)<sub>2</sub>

	pH	Zeta Potential (mV)
Gum Arabic	12.34	-14.60
Water Hyacinth	12.35	-15.10
Xanthan gum	12.55	-21.07
Alginate	12.88	-16.14
PCE	12.38	-5.11

## Aqueous phase from calcined clay

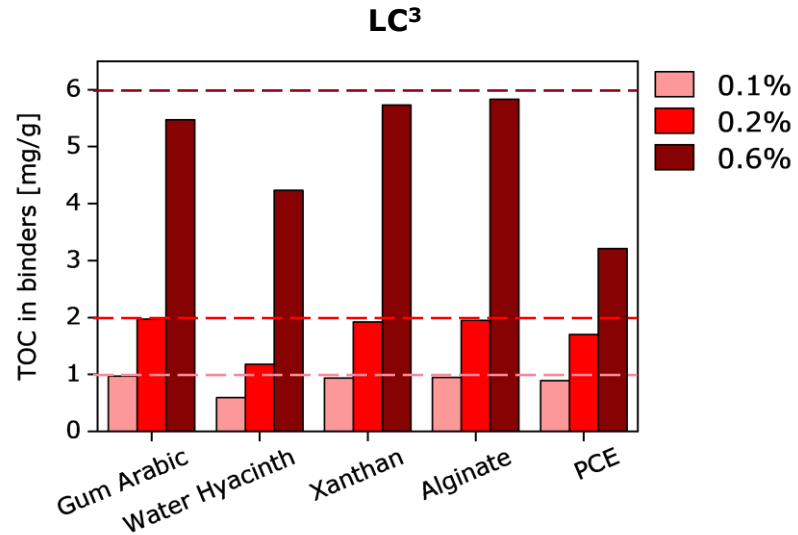
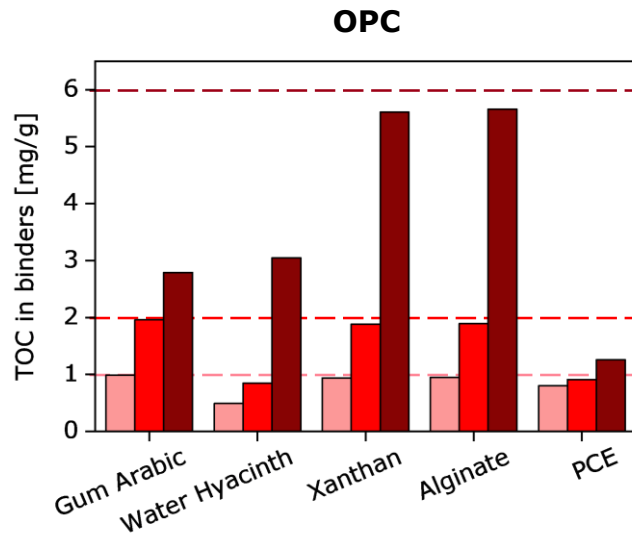
	pH	Zeta Potential (mV)
Gum Arabic	8.30	-8.12
Water Hyacinth	7.65	-12.06
Xanthan gum	7.27	-15.3
Alginate	8.17	-19.5
PCE	8.18	-3.97

➤ Influence in electrostatic stabilization:

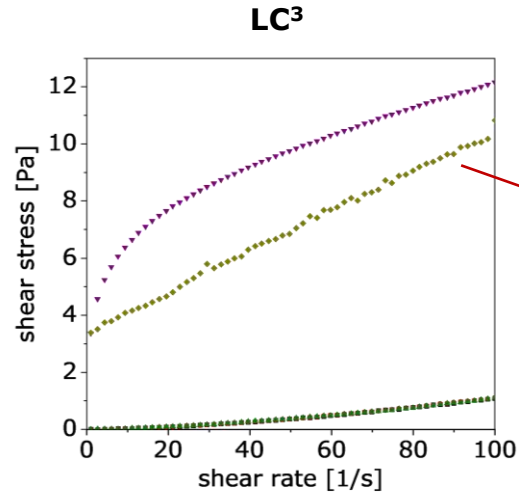
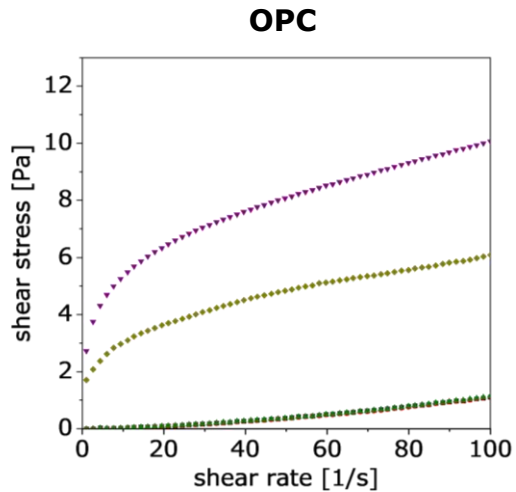


➤ Influence on polymer–binder adsorption

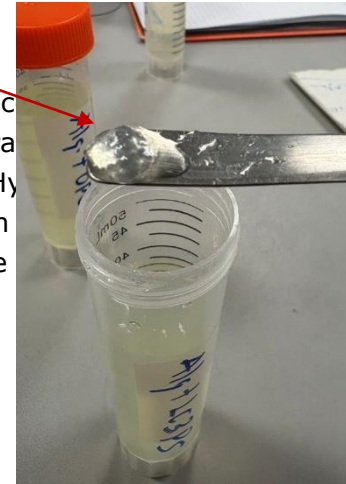
# RESULTS: TOC



# RESULTS: Rheology on liquid phase



- Reference
- Gum Ara
- ▲ Water Hy
- ▼ Xanthan
- ◆ Alginate



# RESULTS: ICP-OES

## OPC

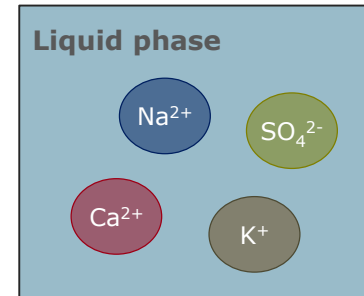
	Ref (mmol/l)	+GA (mmol/l)	+PCE (mmol/l)
<b>Ca</b>	46	139	59
<b>Na</b>	801	1190	867
<b>K</b>	321	507	402
<b>S</b>	66	72	34

## LC<sup>3</sup>

	Ref (mmol/l)	+GA (mmol/l)	+PCE (mmol/l)
<b>Ca</b>	34	74	67
<b>Na</b>	215	558	415
<b>K</b>	117	248	207
<b>S</b>	10	24	19

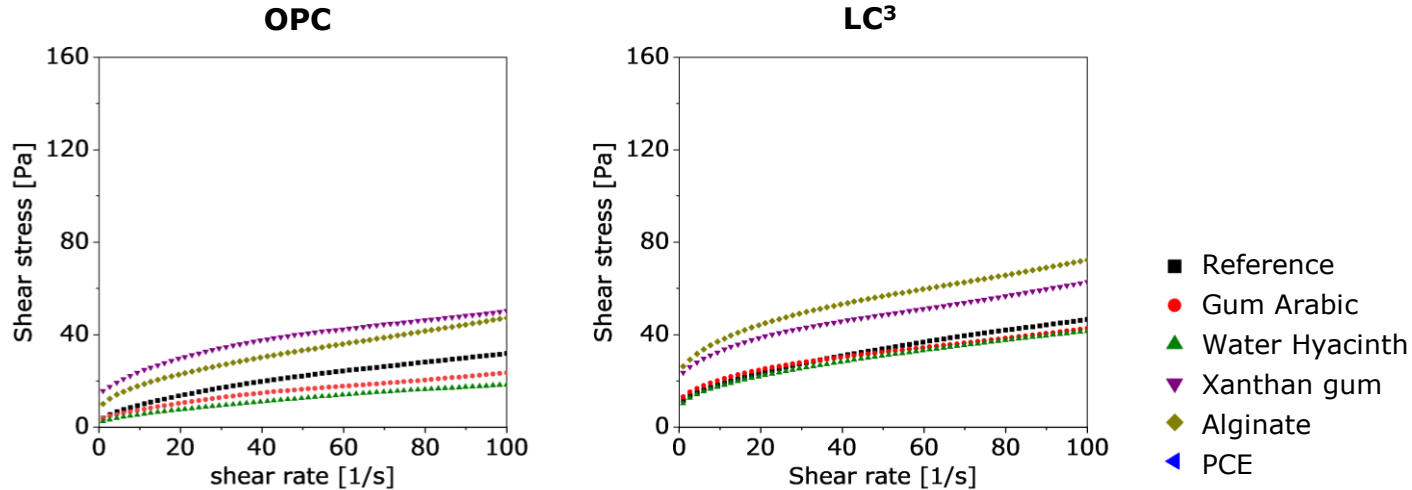
### Alginate:

NaOH  
Na<sub>2</sub>SO<sub>4</sub>  
KOH  
K<sub>2</sub>SO<sub>4</sub>  
Ca(OH)<sub>2</sub>  
CaSO<sub>4</sub> } Gel!!



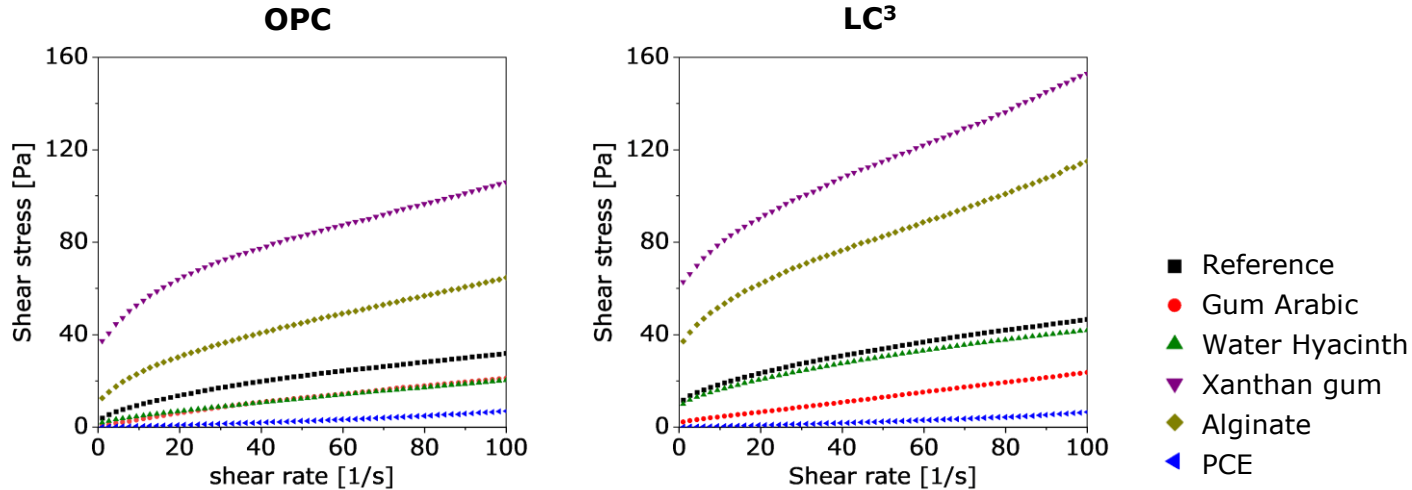
# RESULTS: Rheology on paste

**DOSAGE: 0.2%**



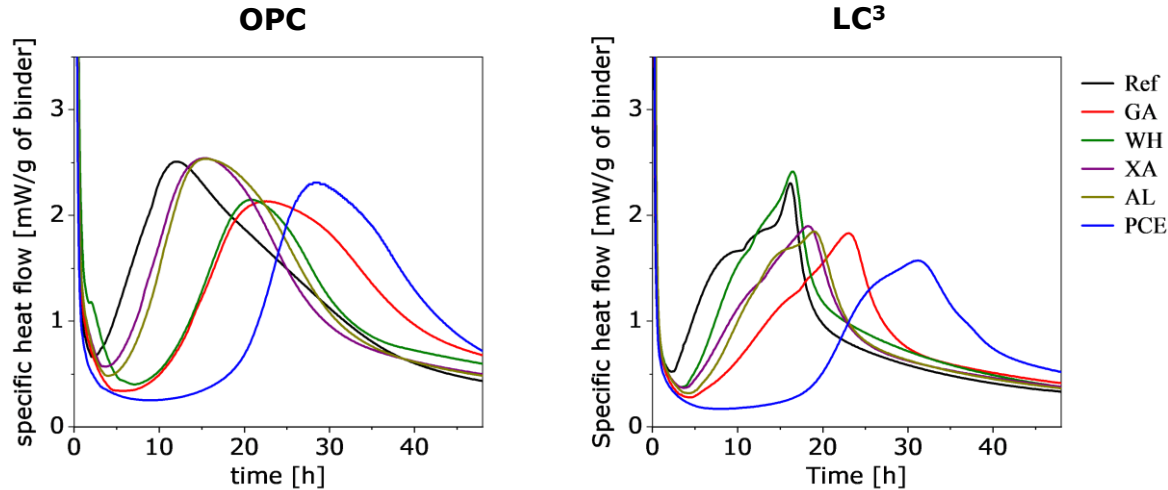
# RESULTS: Rheology on paste

DOSAGE: 0.6%



# RESULTS: Early hydration

**DOSAGE: 0.6%**



1. Xanthan gum and sodium alginate act as stabilizers, while gum Arabic and water hyacinth act as plasticizers;
2. High Hydrodynamic radii and high negative zeta potential can be correlated with good performance in stabilization;
3. Alginate tends to form gel more in LC<sup>3</sup> than in OPC.
4. Admixtures increases ions content in liquid phase.
5. Gum Arabic and water hyacinth behaved similarly in OPC, but showed a much more differentiated behavior in LC<sup>3</sup>, where each admixture produced distinct rheological and early hydration effects.



**THANK YOU!**



Nairobi, Kenya

## **80<sup>th</sup> RILEM Week 2026 in Conjunction with the 3<sup>rd</sup> ACCTA International Conference**

Advances in Climate-Friendly Construction Technologies in Africa



September 5 -11, 2026

25.02.2026

**THANK YOU!**

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Wolfram Schmidt

**ACKNOWLEDGEMENTS:**

