Effects of Hydroxyethyl Cellulose on Hydration, Rheology, and Strength in Various Cement Blends

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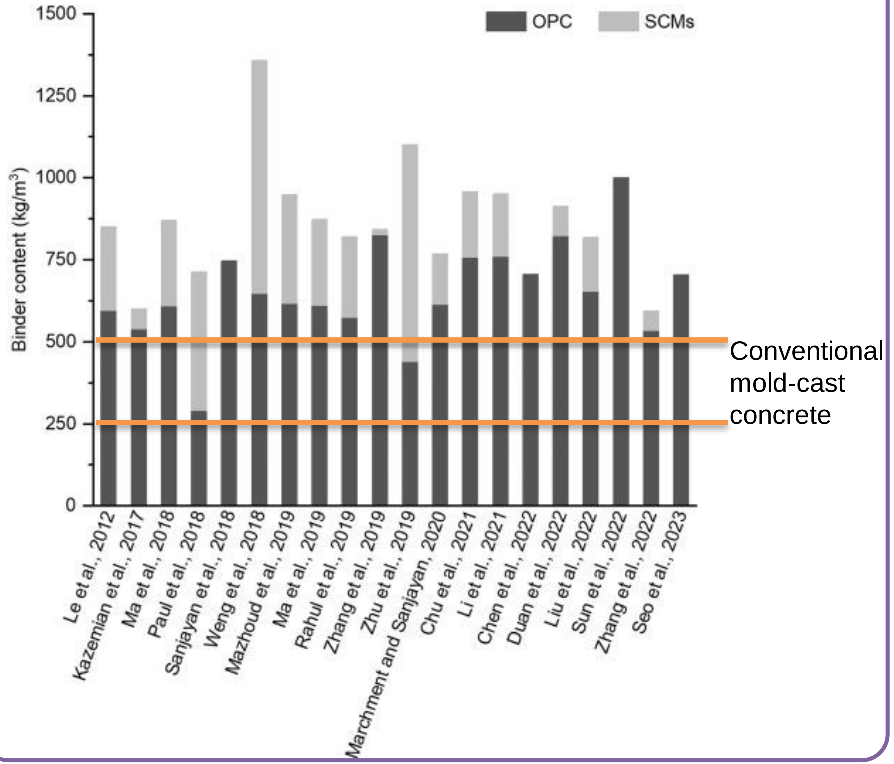
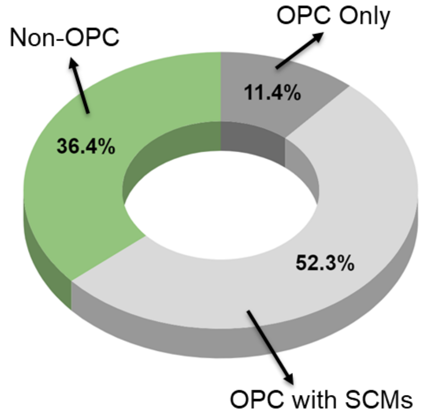
Development and Characterization of 3D Printable Materials with Low-Carbon Cements

Introduction

Binder content of 3D printable cementitious mixtures*



3D printable binders applied in publications



OPC with SCMs: fly ash, silica fume, ground granulated blast-furnace slag (GGBS), limestone, calcined clay, **Limestone calcined clay cement (LC³)**, etc.

Non-OPC: alkali-activated binders, calcium sulphoaluminate (CSA) cement, **Reactive magnesium oxide cement (RMC)**, etc.

* S.H. Bong, H. Du, Sustainable additive manufacturing of concrete with low-carbon materials, in: Sustainable Concrete Materials and Structures, Elsevier, 2024: pp. 317–341.

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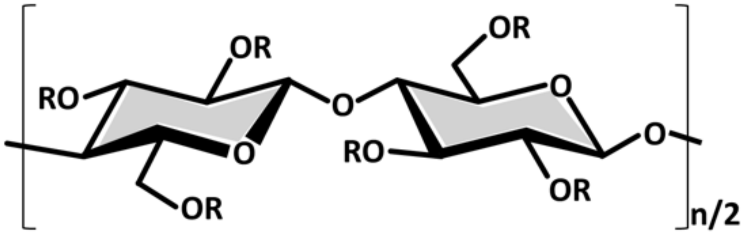
Introduction

Structure of cellulose ethers



Cellulose ethers	R groups
Methyl cellulose (MC)	H, CH_3
Hydroxyethyl cellulose ether (HEC)	H, CH_2CH_2OH
Hydroxyethyl methyl cellulose ether (HEMC)	H, CH_3, $[CH_2CH_2O]_nH$
Hydroxypropyl methyl cellulose ether (HPMC)	H, $[CH_2CH(CH_3)O]_nH$


HEC powder

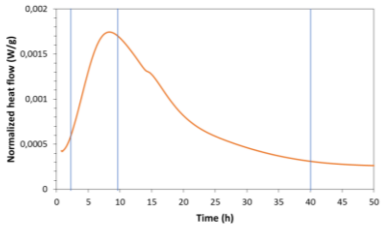
- Cellulose ether (CE), is one of the most used chemical **thickeners**
- Achieve remarkable **water retention** ability and **improve cohesion** with a traces amount (0-0.5%)
- Increase **viscosity**, enhance **yield stress,** limit **deformation** and extend **open time**
- Applications such as tile adhesives, self-compacting concrete (SCC), repairing mortars, and underwater concrete
- Lead to a delay in the setting of OPC and hinders its hydration process

Experimental Design

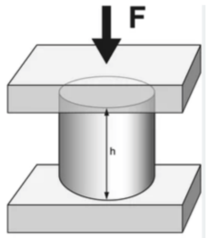
Mix compositions (wt. %)

Mix	Water to binder ratio	HEC to binder ratio
OPC OPCHEC	0.4	0.5
LC3 LC3HEC		
RMC RMCHEC		

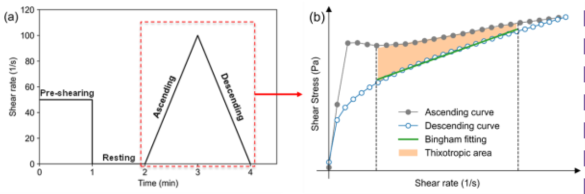
LC3			
Clinker	Calcined clay*	Limestone	Hemihydrate
50	30	15	5



Isothermal calorimetry



Compressive strength

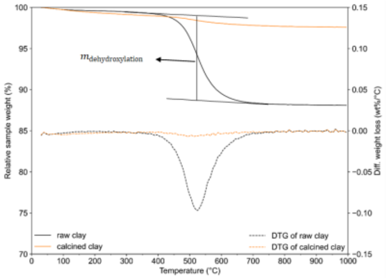


(a) Test protocol for measuring **dynamic yield stress, plastic viscosity**, and **thixotropic area**

(b) typical flow curve using the test protocol

Rheometer

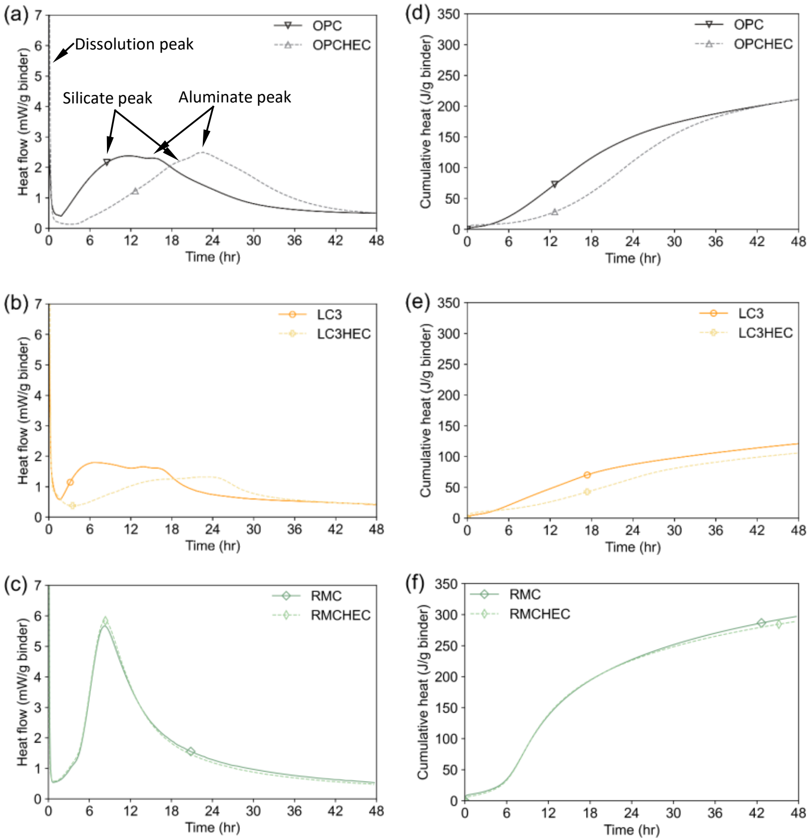
Rheology (plastic viscosity, static/dynamic yield stress and thixotropic area)



Thermogravimetric analysis (TGA)

* Raw clay had a kaolinite content of 72.4% determined by TGA

Results



Isothermal calorimetry results (a)-(c): heat flow normalized to total binder content; (d)-(f): cumulative heat normalized to total binder content

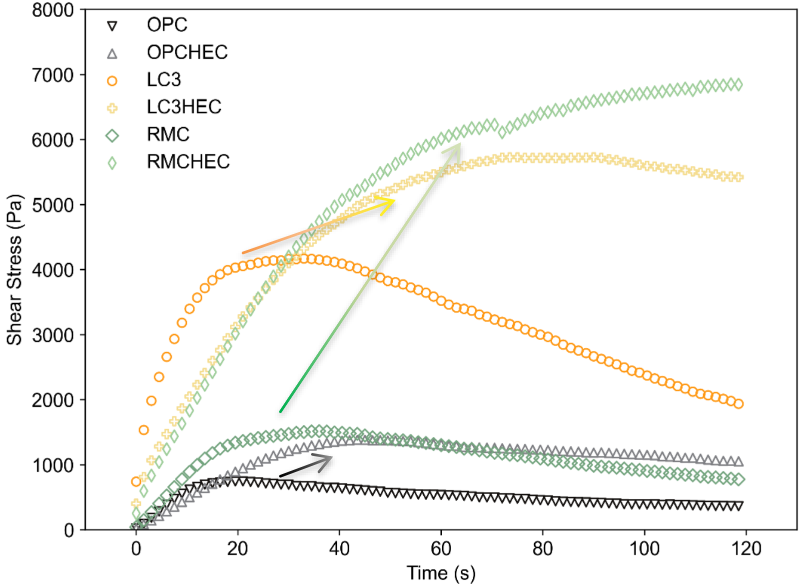
Isothermal Calorimetry

- Rate of heat release: RMC > OPC > LC^3
- HEC delayed the hydration of OPC and LC^3, but had no effect on the total hydration heat of OPC
- **No retardation for RMC system**

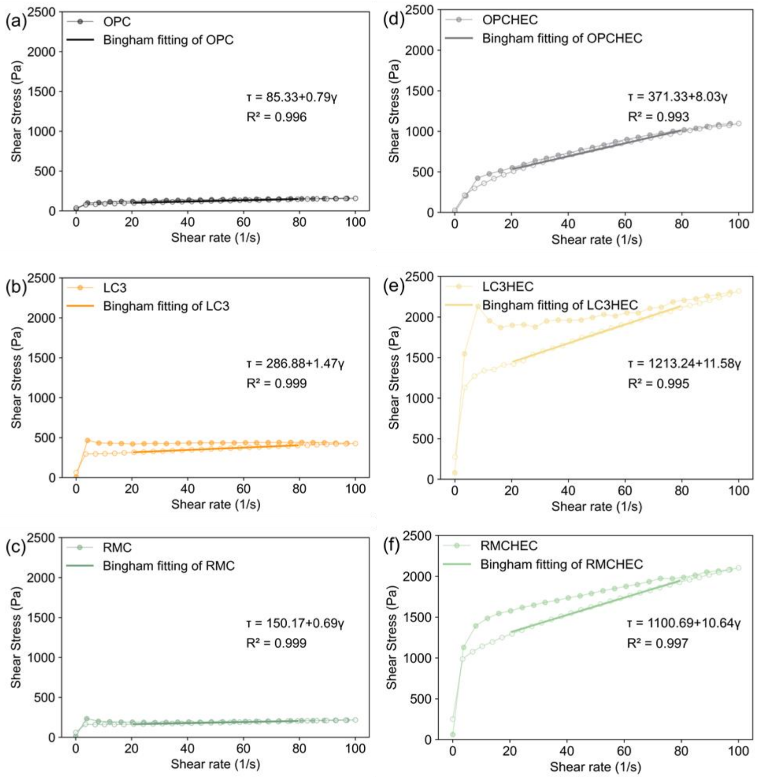
Results

Rheology

Stress growth results

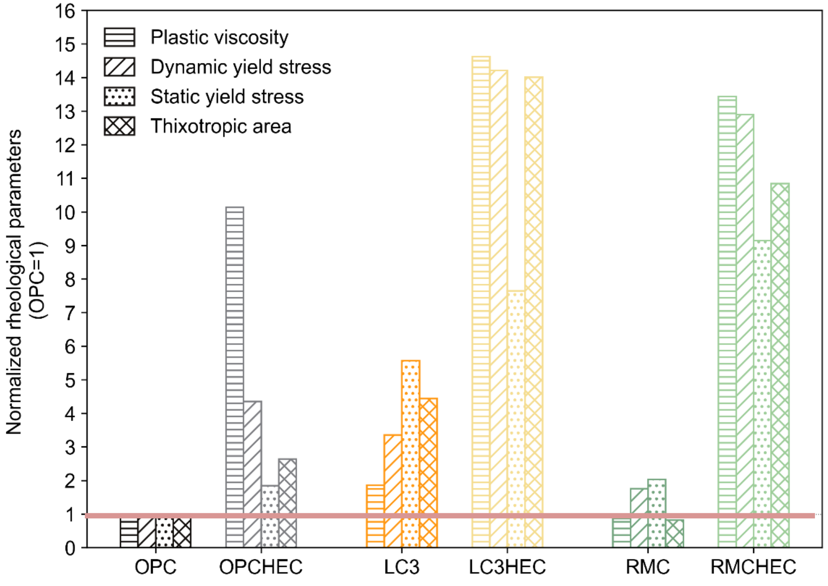


Samples were under a constant shear rate (0.1 1/s) over time

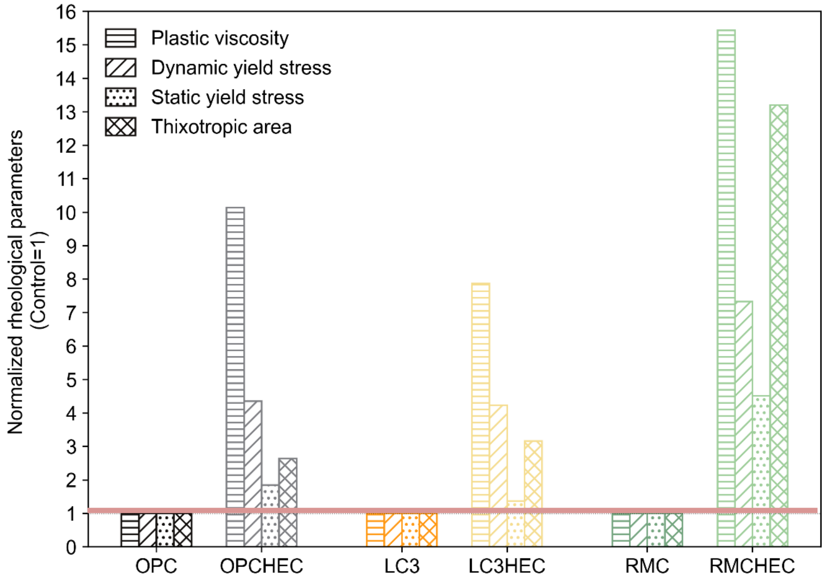


Flow curves and the Bingham model fitting results

Rheology



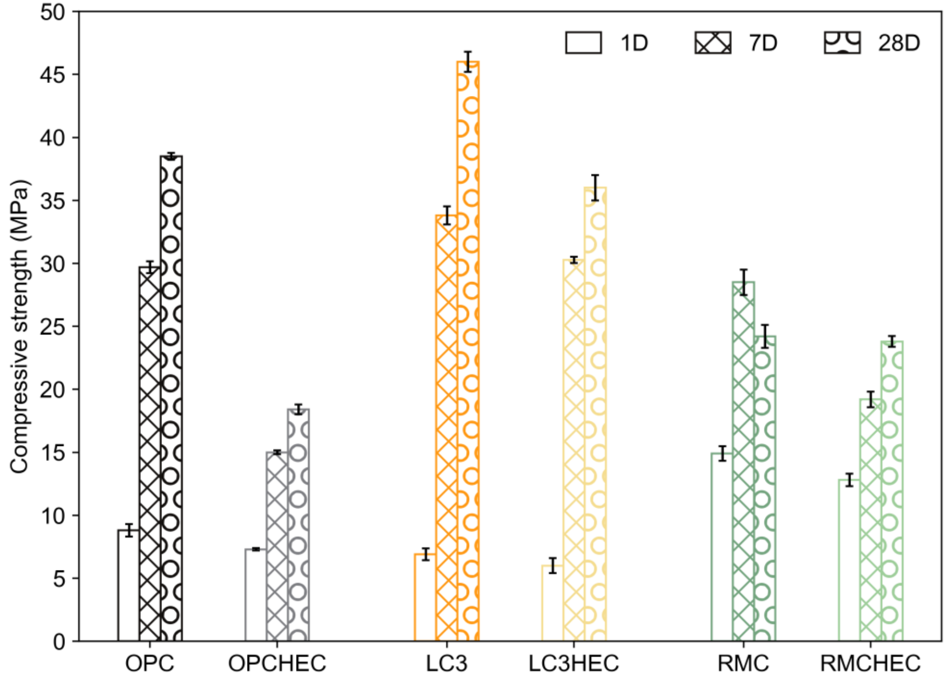
Rheological parameters normalized to the corresponding parameters of OPC (**OPC = 1**)



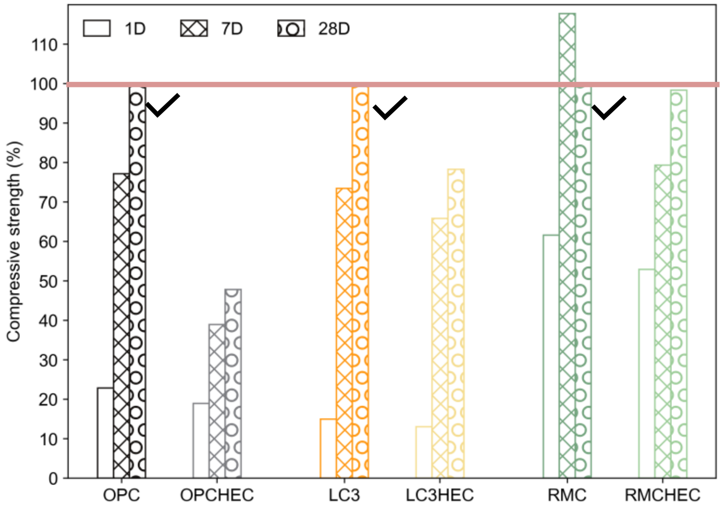
Rheological parameters normalized to the corresponding parameters of the corresponding control pastes (**Controls = 1**)

Results

Compressive strength



OPC and LC3 : Air Curing
RMC : 20% CO_2, 30℃ , RH 80%



(**Control 28D = 100%**)

- The modified pastes showed a **decrease in compressive strength** at all ages
- Reduction in compressive strength could be attributed to the **air entrainment** introduced by HEC

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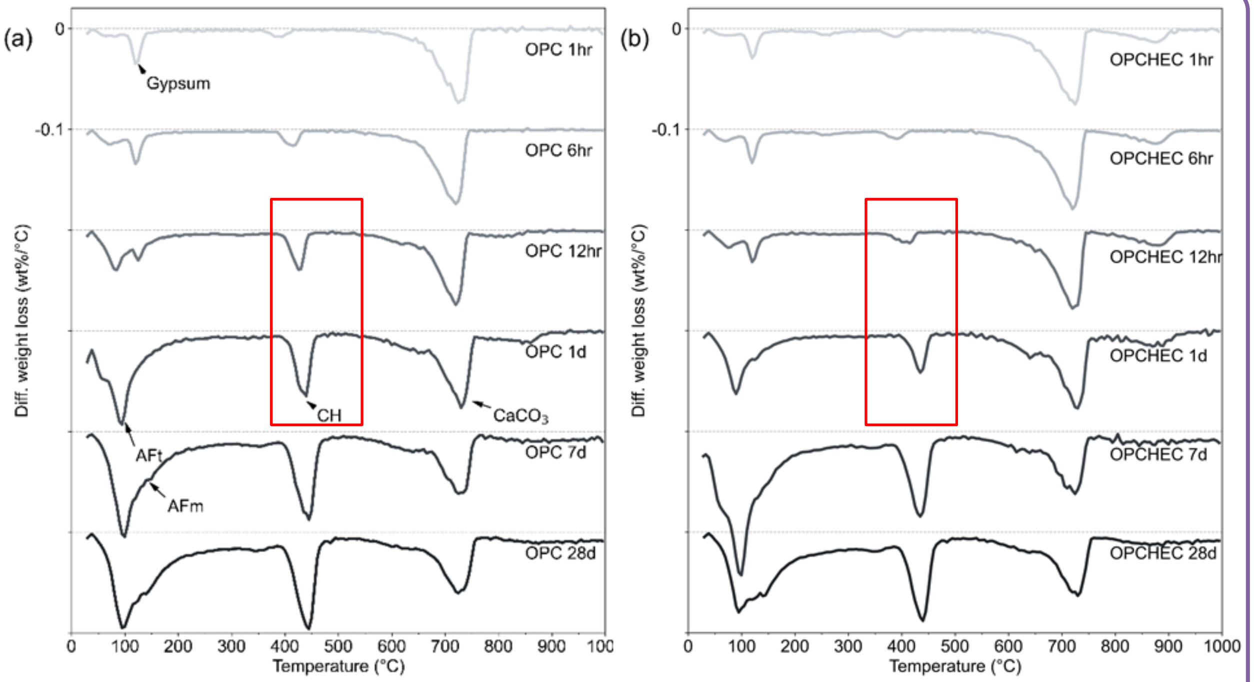
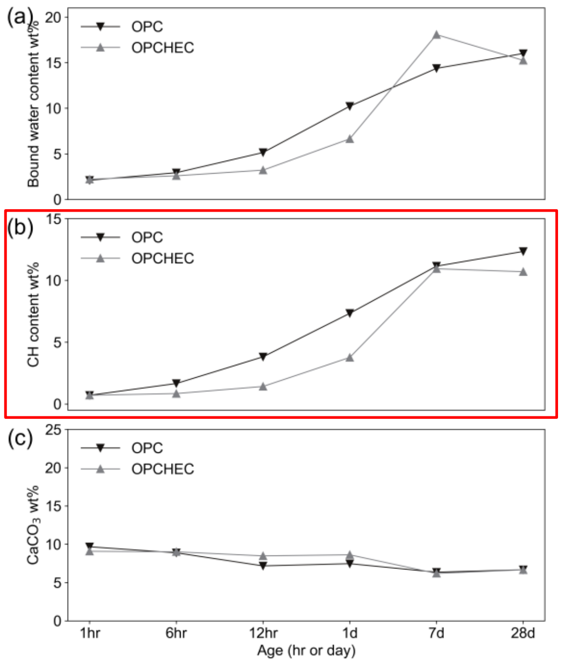
Results

Thermogravimetric analysis – OPC



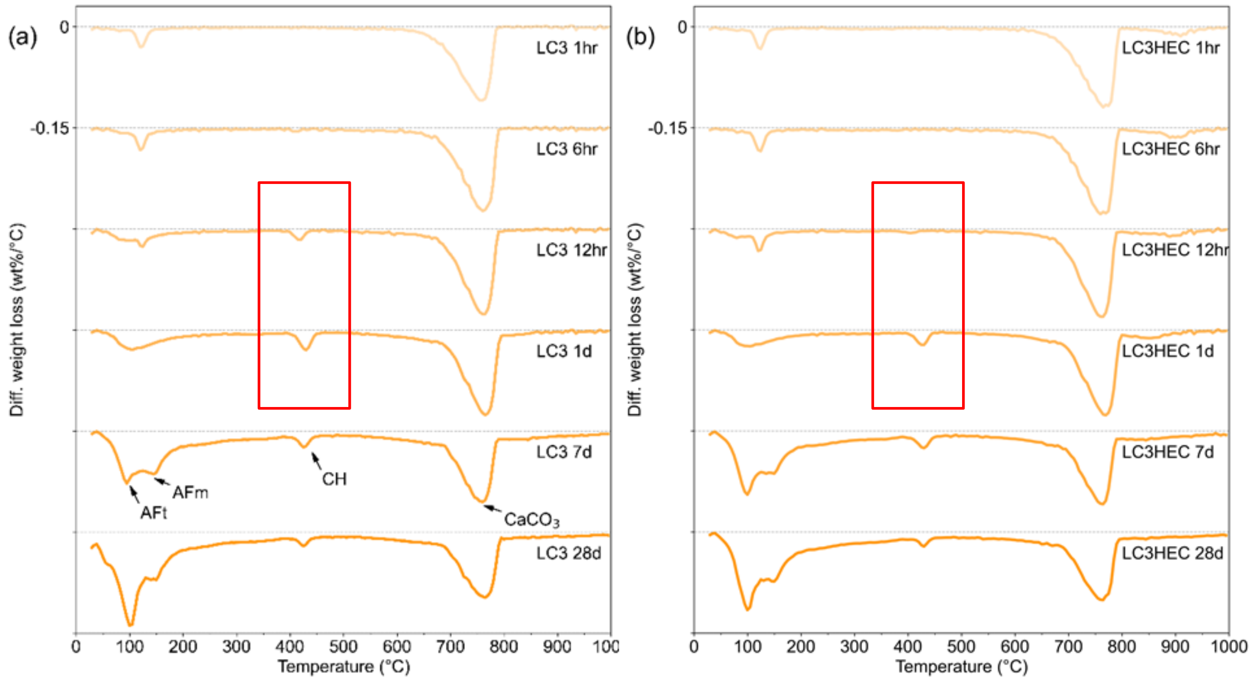
DTG results of (a) OPC and (b) OPCHEC samples during 28 days of hydration.



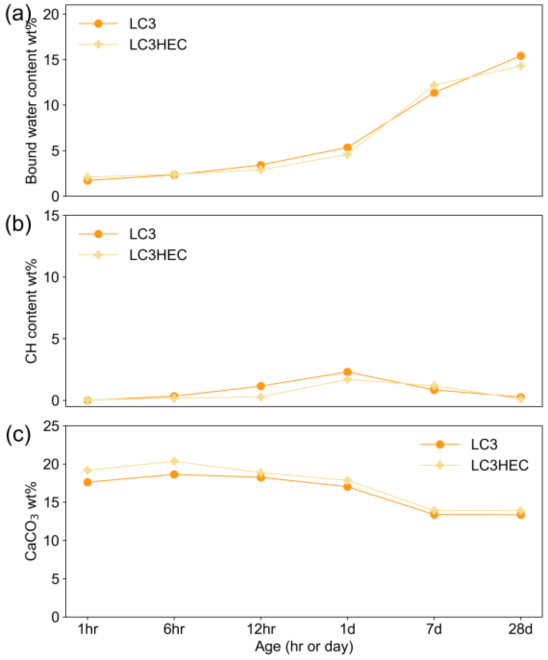
Weight loss from (a) bound water, (b) CH, and (c) $CaCO_3$ for OPC pastes with and without HEC

Results

Thermogravimetric analysis – LC^3



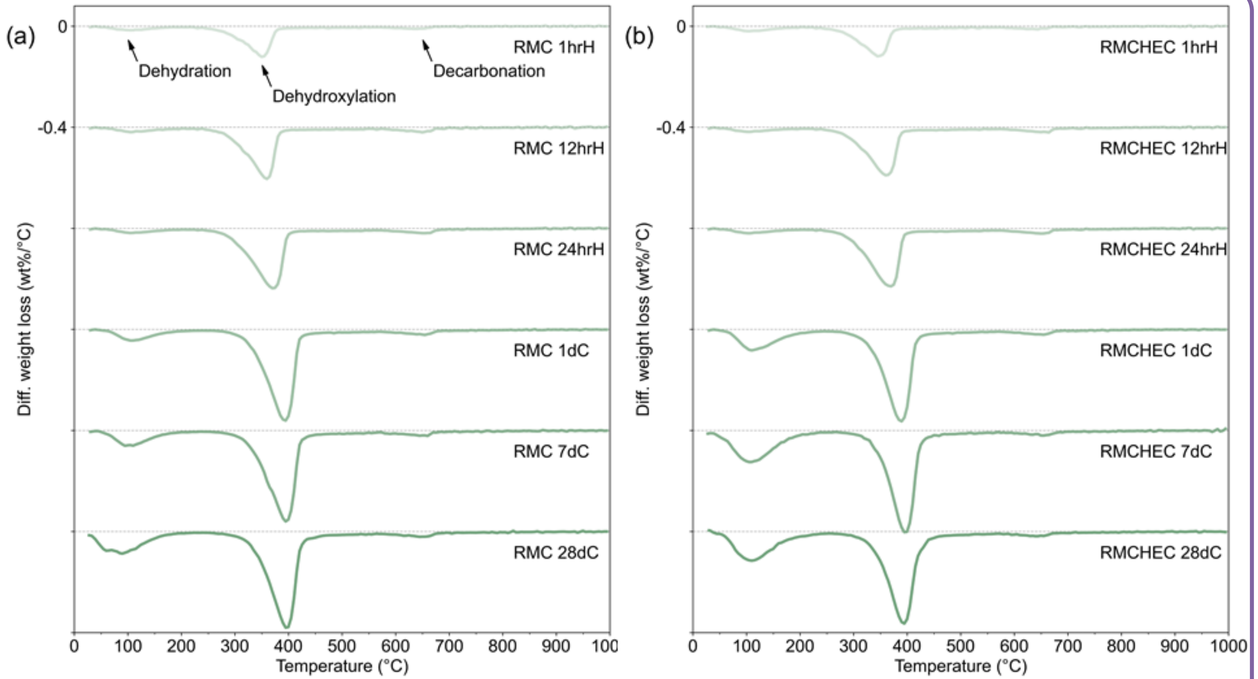
DTG results of (a) LC3 and (b) LC3HEC samples during 28 days of hydration.



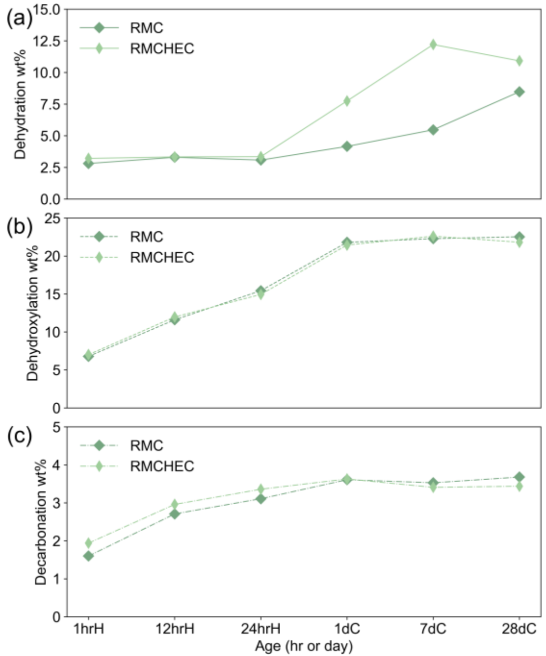
Weight loss from (a) bound water, (b) CH, and (c) $CaCO_3$ for LC^3 pastes with and without HEC

Results

Thermogravimetric analysis – RMC



DTG results of (a) RMC and (b) RMCHEC samples during first day of hydration and during 28 days of carbonation.



Weight loss from (a) dehydration, (b) dehydroxylation, and (c) decarbonation of RMC pastes with and without HEC

Conclusions

Summary

- HEC significantly delayed early hydration in OPC and LC^3 pastes, as seen in heat evolution, but had no such effect in RMC within the first two days—likely due to different surface adsorption behavior.
- HEC improved rheological properties across all binders, especially plastic viscosity. The RMC system showed the strongest response.
- Compressive strength dropped in all systems due to HEC, mainly from air entrainment. OPC was most affected (−52.2% at 28 days), while RMC showed minimal reduction (−1.7%).
- TGA confirmed early-age retardation in OPC and LC3, with suppressed CH formation at 12 and 24 hours. This effect faded over time. In RMC, HEC had little to no impact on hydration products.

Thank you !

Contact xw1742@nyu.edu for more questions