Impact of lime pretreatment on reed concrete's hydration, thermal and mechanical properties

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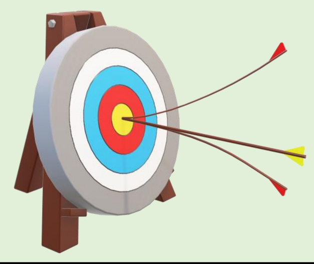
Context

Bio-based concretes, with their hygrothermal properties and renewable nature, are gaining increasing interest due to new thermal regulation to face the global warming issue. However, the mechanical properties of bio-based concretes remain relatively low of the order of a few MPa. Furthermore, it is widely recognized that the hydration of hydraulic binders in bio-sourced concrete is not optimal and still not fully understood. To address this hydration issue, various studies have explored different pretreatments of plant aggregates to improve their compatibility with the mineral binders.



Current challenge : Understanding of **reed concrete hydration mechanisms**.

Objective : Evaluate the correlation between hydration behavior, thermal conductivity and mechanical strength

Materials

Clinker	59
Blast furnace slag	30
Limestone	10
Secondary Constituents	1

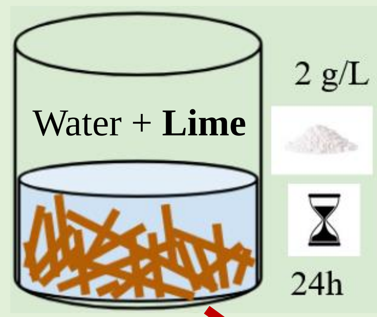
Table 1 : Main and secondary constituents of the cement used in this study (wt%).

Figure 1 : CEM II/ C-M (M for mix) from EQIOM used in the study.

Figure 2 : Reed aggregates as provided.

Methods

Reed pretreatment : drained and manually wrung out by squeezing them until their mass matched the amount of water they would absorb after 24 hours (135%).



CEM II/C-M	×	×		
CEM II/C-M + Reed	×	×	×	
CEM II/C-M + Reed-L	×	×		×

Table 2 : Studied formulations with a water-to-binder ratio fixed at 0.6 and a binder-to-reed ratio fixed at 5.4.

Calorimetry : Langavant Calorimeter following the NF EN 196-9.

Compressive strength : On 3 cylindrical specimens (11x22 cm) using a hydraulic press with a loading speed of 5 mm/min

Thermal conductivity : Hot Disk with the 5501-probe model.

Results

Hydration behavior

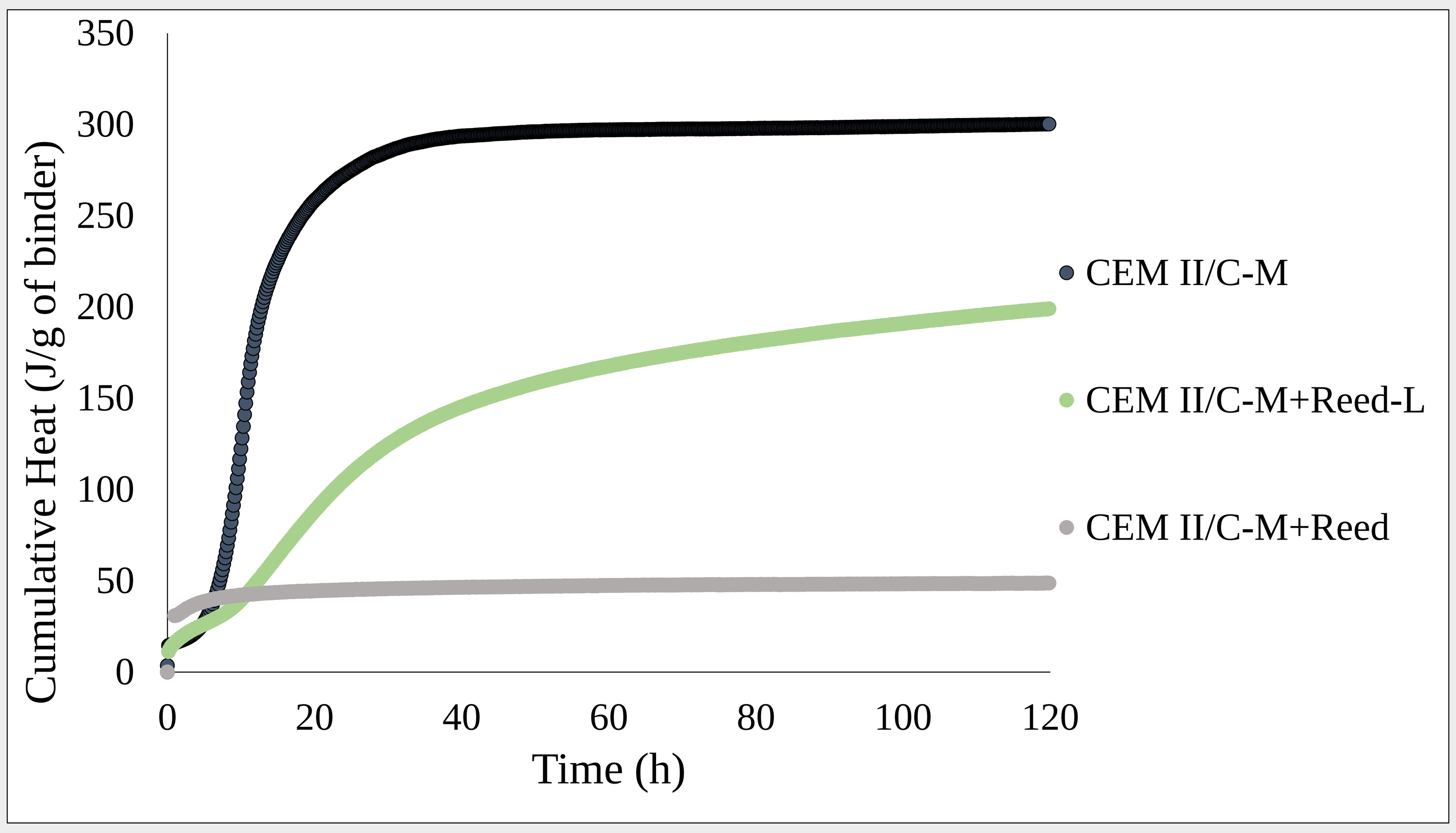


Figure 3 : Effect of adding reed particles (with and without pretreatment) on the cumulative heat

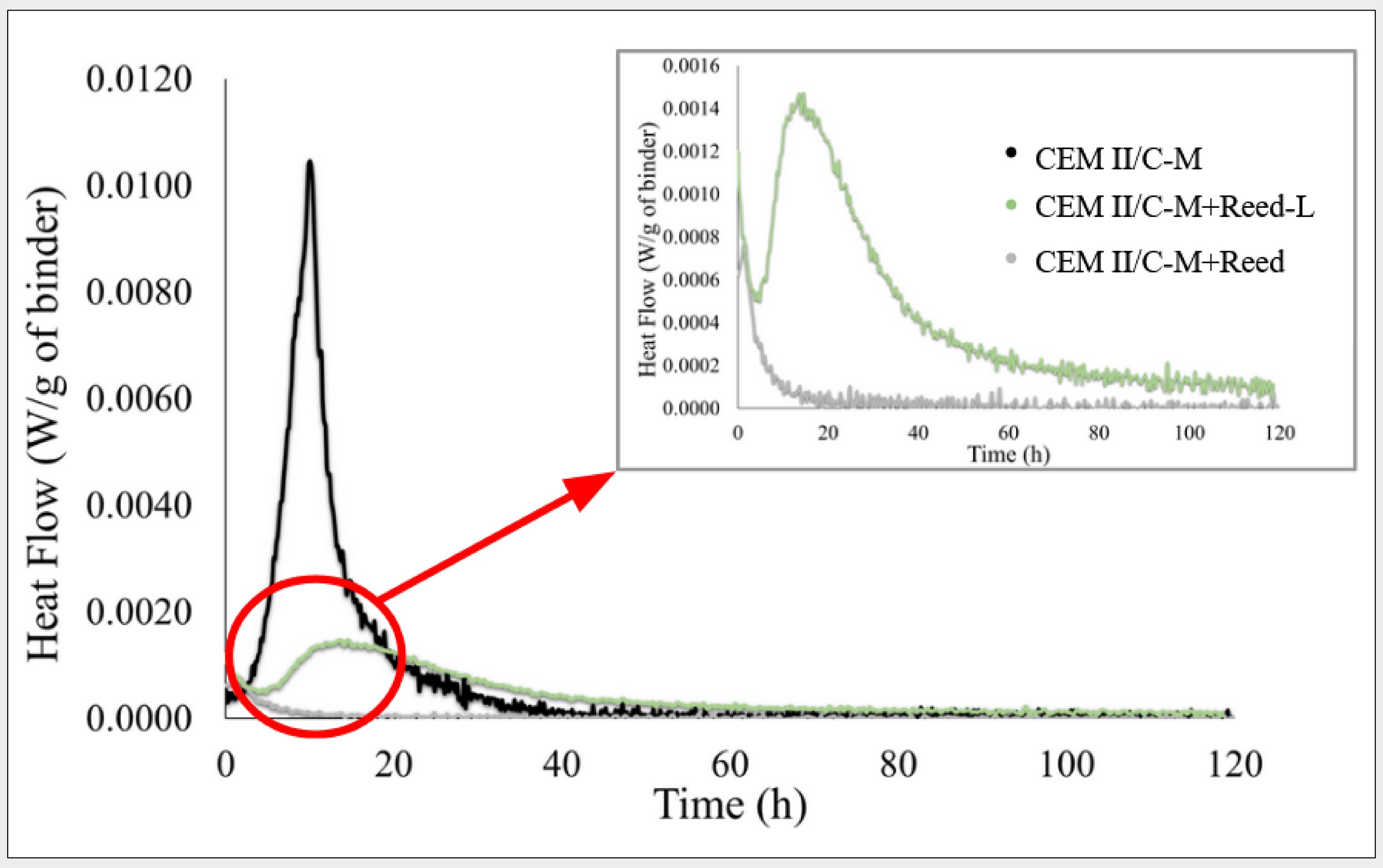


Figure 4 : Effect of adding reed particles (with and without pretreatment) on the heat flow.

→ The incorporation of **untreated reed particles significantly reduced the maximum cumulative heat** (from 300 to 48 J/g), whereas **pretreatment notably improved hydration**, raising it to approximately 200 J/g.

→ Complete **absence of heat flow** for the "CEM II/C-M + Reed" sample. In other studies, lower amounts of plant-based particles are used, allowing to observe this peak and the delay in hydration. A distinct peak appears for the sample with pretreated reed particles, in contrast to the sample containing untreated reed. Nevertheless, the maximum heat flow remains relatively low compared to the reference paste without aggregates.

Thermal and mechanical performances

	CEM II/C-M + Reed	CEM II/C-M + Reed – L
Compressive strength at 28 days (MPa)	0.85 ±0.29	2.67 ±0.11
Dry thermal conductivity (W/mK)	0.100 ±0.004	0.28 ±0.012
Dry density (oven-dried at 60°C) (kg/m³)	995 ±57	1091±8

Table 3 : Effect of adding reed particles (with and without pretreatment) on the thermal conductivity and compressive strength.

→ Lime pretreatment significantly improved the compressive strength, increasing it from 0.85 MPa to 2.67 MPa. Dry densities, after oven drying at 60°C were 995 ± 57 kg/m³ for CEM II/C-M + Reed and 1091 ± 8 kg/m³ for CEM II/C-M + Reed-L.

→ Regarding thermal properties, the CEM II/C-M + Reed-L sample demonstrated a thermal conductivity of 0.37 W/m·K at 28 days, in contrast to 0.18 W/m·K for the untreated CEM II/C-M + Reed sample. After drying, the thermal conductivity of the CEM II/C-M + Reed sample was 0.10 W/(m·K), whereas that of the CEM II/C-M + Reed–L sample was 0.28 W/(m·K).

→ **Increasing the maximum cumulative heat by slightly more than four times** (from about 50 to 200 J/g·mol) led to a considerable **increase in compressive strength and thermal conductivity by approximately three times.**

Take Home Message

→ Despite the presence of limestone in CEM II/C-M, which is typically regarded as compatible with plant-based aggregates, the addition of reed particles notably disrupted the cumulative heat profile.

→ The use of lime pretreatment led to an increase in cumulative heat, the emergence of a peak in the heat flux curve and enhanced the compressive strength, raising it from 0.85 MPa to 2.67 MPa. Additionally, lime pretreatment resulted in an increase in dry thermal conductivity, reaching 0.28 W/(m·K), compared to 0.10 W/(m·K) for the untreated sample.

Implications

While these results demonstrate the potential for improving hydration and mechanical properties, further analysis is required to investigate additional factors such as binder type, curing conditions, and alternative pretreatments in order to fully optimize the material's performance. A detailed microstructural analysis is also necessary to better understand and establish the link with hydrate formation.

References

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