Preliminary study of the mechanical and hygrothermal performance of concrete reinforced with nanofibrillated cellulose

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Natural fibres in cementitious composites

Natural fibres can be used as eco-friendly additives to reduce the environmental impact of the production of cement [1-2].

An innovative «green concrete»

Samples of a cementitious composite reinforced with micro and/or nanofibrillated cellulose were casted using Portland cement and Natural hydraulic lime and varying the ratio among the constituents (Figure 1 and Table1).

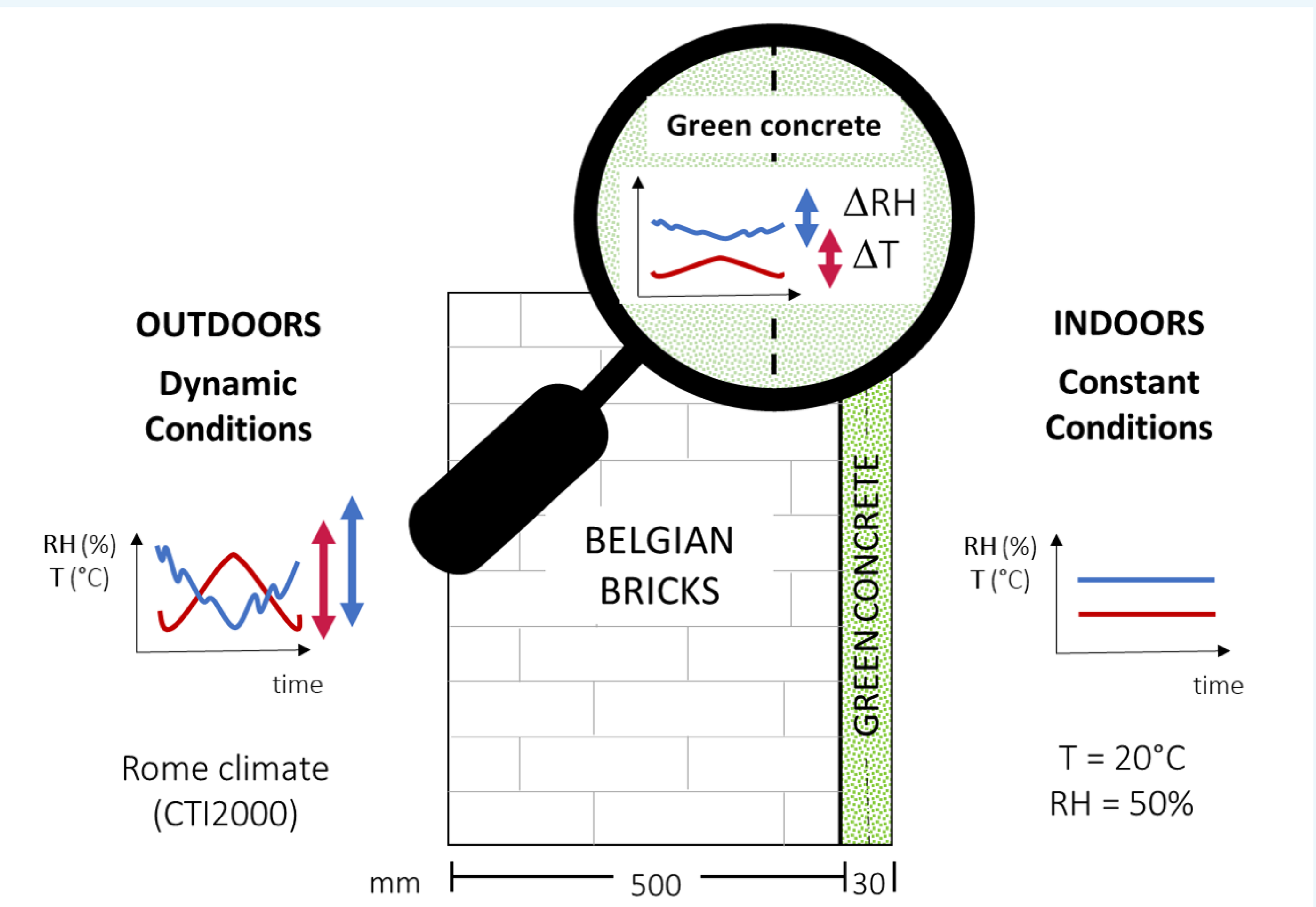
Figure 1 – Five samples of the innovative «green concrete».

Table 1 – Samples series of the «green concrete»: two different binders and two different commercial fibre products were tested (type 1, type 2).

Series	binder (b)	fibre (f)
P0	CEM II/B-LL 32.5R	-
P1	CEM II/B-LL 32.5R	type 1
P2	CEM II/B-LL 32.5R	type 2
N0	NHL 3.5	-
N1	NHL 3.5	type 1
N2	NHL 3.5	type 2

Materials and methods

1. Viscosity and setting time to study the effect of the fibres on the rheology and the hardening process;
2. Mechanical tests to assess the influence of the fibres on the flexural strength of the final composite;
3. Sensitivity analysis (SA) to investigate the the physical parameters influencing more the dynamic simulation of the maximum annual gradients of temperature (ΔT) and relative humidity (ΔRH), as schematized in Figure 2.



Sensitivity analysis inputs	Range
Density (ρ)	400–900 kg/m³
Specific heat capacity (C_p)	850–1500 J/(kg·K)
Dry thermal conductivity (λ_0)	0.06–0.20 W/(m·K)
Thermal conductivity supplement (σ)	1.0–5.0
Free water saturation moisture content (w_f)	65–430 kg/m³
Equilibrium moisture content at RH = 80% (w_{80})	20–60 kg/m³
Dry vapour diffusion resistance factor (μ)	6–25

Figure 2 – Scheme of the configuration of the wall model used for the sensitivity analysis of the maximum annual gradients of temperature (ΔT) and (ΔRH) over a year (top) and ranges of the selected hygrothermal properties tested (bottom) based on a literature survey [3-4].

Preliminary results

1. Fibre content influence the workability (Figure 3a) and the setting time (Figure 3b) of the fresh pastes;

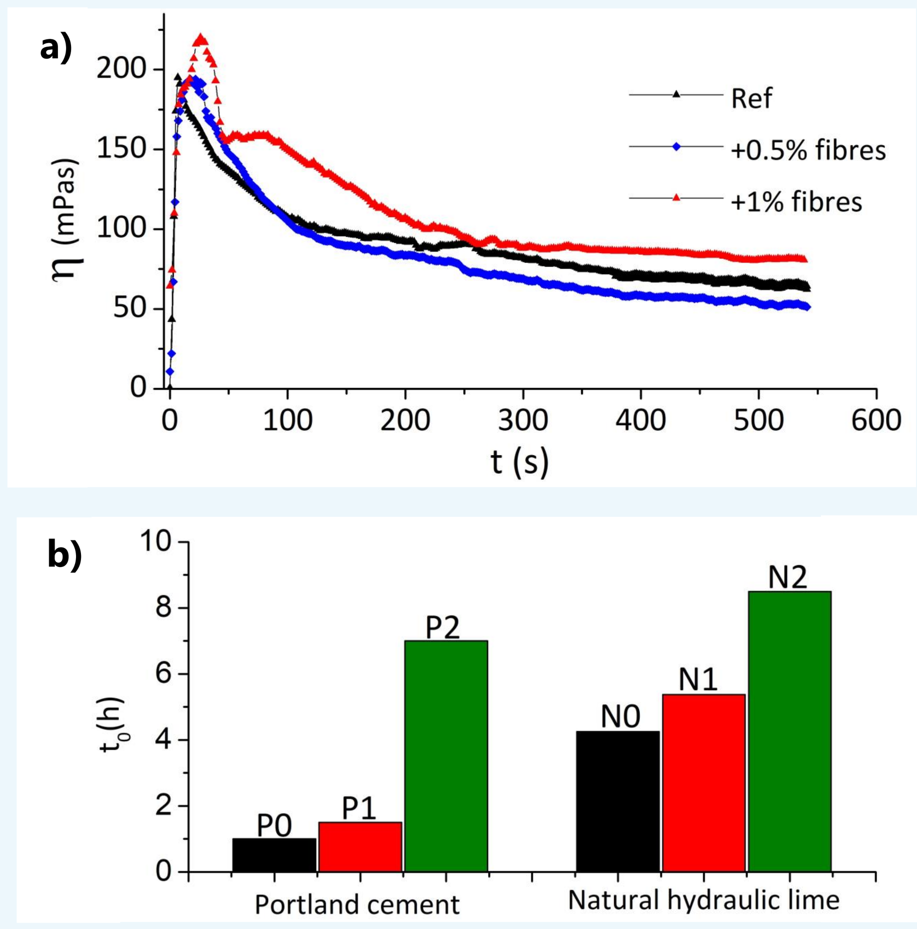


Figure 3 – (a) Apparent viscosity (η) *vs* time (t): the apparent viscosity and the shear point increases at higher fibres content;

(b) Vicat analysis to determine the setting time (t0) for samples with 1% of fibres: type 2 fibres highly delay t0.

2. At higher percentages, fibres can negatively affect the flexural strength of the «green concrete» (Table 2);

Table 2 – Flexural strength on samples additivated with 1% of fibres: the increasing amount of water (water/b ratio) determines a drop in the flexural strength (Fct).

Series	water/b	Fct mean	Fct std	Fct drop
P0	0.60	6.81	0.10	-
P1	0.90	5.19	0.17	-24%
P2	0.90	4.49	0.30	-34%
N0	0.65	0.88	0.18	-
N1	1.10	0.71	0.07	-19%
N2	0.96	0.65	0.05	-26%

3. SA highlighted that the tested parameters do not significantly affect the simulation of ΔT; μ, w_{80} and w_f have a between linear-monotonic influence on the ΔRH simulation (Figure 4).

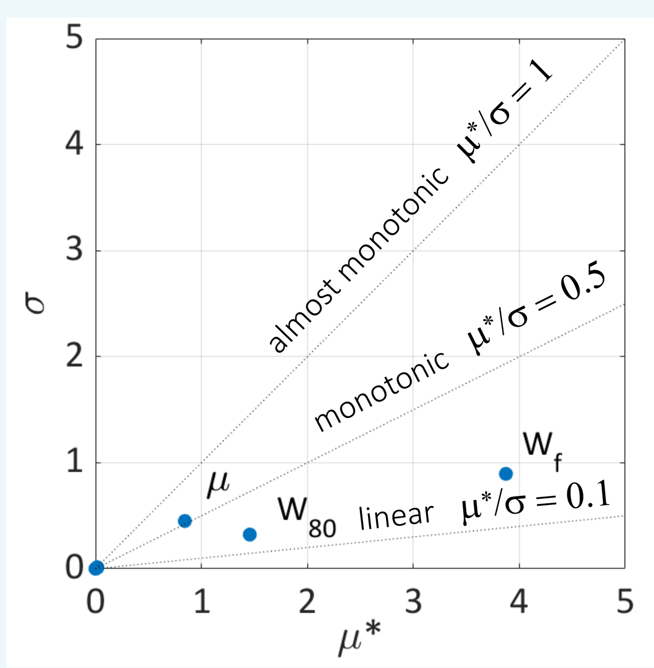


Figure 4 – Sensitivity analysis results in terms of the mean (μ*) and the standard deviation (σ) of the Elementary Effects calculated on ΔRH.

Conclusions

This investigation has led to the identification of the most promising samples. The N-series samples appear to be an interesting option as sustainable lime-based mortars. Further studies have already been planned to measure the thermo-physical and hygric properties of the innovative «green concrete». Dynamic hygrothermal simulations will be performed to investigate retrofit solutions based on the employment of the green concrete.

References

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