Nanocellulose containing Concretes: Evaluation of NC properties affecting UHDC & Development of mixing protocols.

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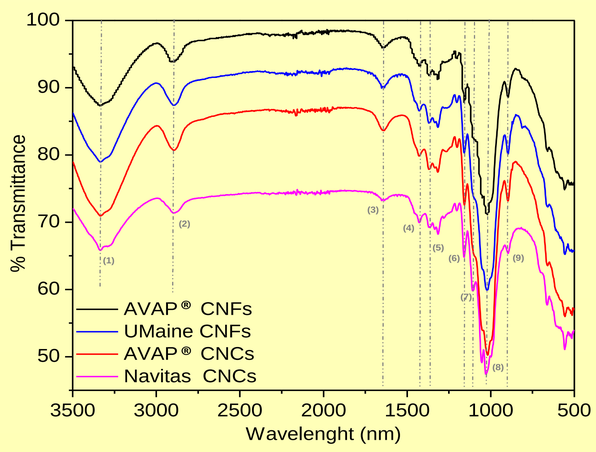
OBJECTIVES

Cement composites represent one of the most widely used construction materials, but their brittleness or low strength properties often limit their applications. In recent years, scientific interest turned to the utilization of cellulose nanostructures (NCs) as concrete reinforcing agents [1,2]. These novel materials considered to be promising candidates, capable of combining both the intrinsic cellulose properties and the unique features of nanomaterials [2]. Indeed, several research studies report a significant enhancement in both mechanical (flexural & mechanical strenght) and durability properties of concretes with the addition of a modest CNs amount [2,3]. This reinforcement capability has mainly been attributed to a combined effect of the final polymer loading and NC inherent properties that greatly affect hydration process reactions and composites cohesion (filling effect) [4,5]. Within this context API – Europe, has the objection of applying nanocellulose beneficial properties to Ultra High Durability Concretes (UHDC) technology. The main objective is to develop in-depth mixing protocols for the incorporation of cellulose nanoadditives into cementitous blends that will be finally tested in two European pilot plants. To this end, four different commercially available NC aqueous suspensions (two CNFs and two CNCs) were selected for the evaluation of the key aspects that potentially affect concretes final performance. Incorporation of NCs into cementous mixture will offer a side-by-side performance comparison between CNCs and CNFs leading to a better understanding of particle morphology impact on composite properties. To further investigate the relationship between NC elemental features and materials efficiency, a comprehensive analysis of both structural and physicochemical NC properties has also been accomplished through several characterization techniques. The as-obtained NC-enriched specimens will be tested and a correlation between strength and durability vs. nanocellulose properties will be obtained. In this way, proper selection of NC species along with fine tuning of additive content and fresh cement paste rheology will be feasible depending on manufacturer requirements.

RESULTS



Characteristic bands	Bonds
(1)	OH stretching
(2)	Aliphatic C-H stretching
(3)	OH bending (absorbed water)
(4)	C-H symmetric bending (CH_2)
(5)	C-H & C-O pyranose ring bending
(6)	C-O-C stretching
(7)	Out of phase bending
(8)	C-C, C-OH, C-H pyranose ring & side groups
(9)	C-O-C, C-C-O, C-C-H deformation & stretching

Fig. 1: FTIR spectrums (right) of NC fibrils (CNFs) & crystals (CNCs) and the corresponding band assignments (left).

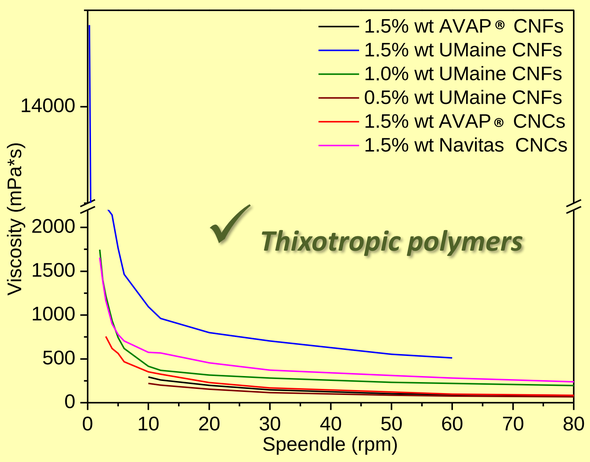


Fig. 2: Viscosity measurements of NC samples (RT).

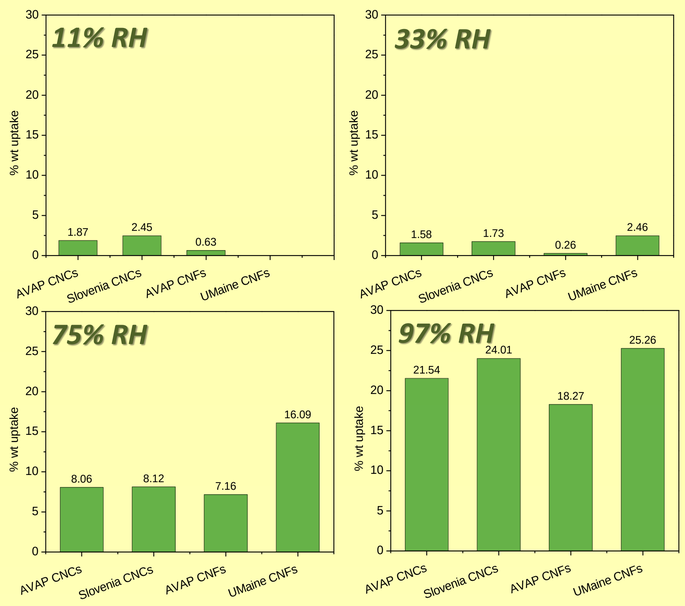


Fig. 3: Water absorption capacity of NCs at different relative humidity conditions (%RH) .

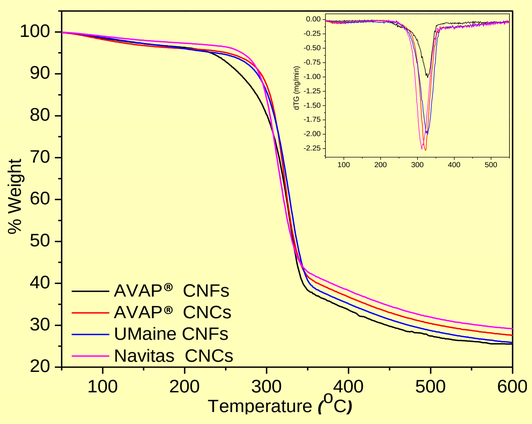


Fig. 4: TGA/dTG & DSC curves of NC materials (Ar flow, rate: 10°c/min, flow rate: 40ml/min)

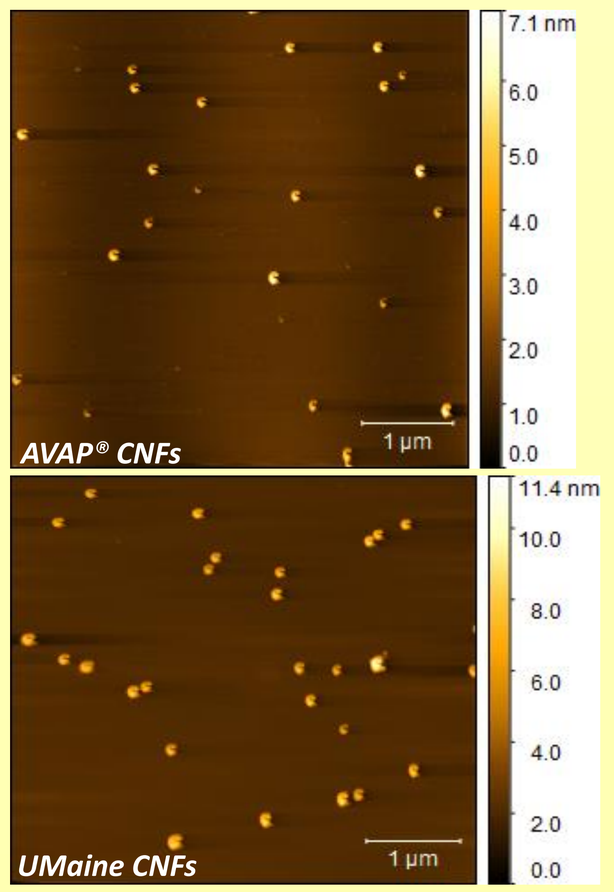


Fig. 5: AFM analysis of CNF samples featuring a uniform round-shaped particle morphology.

Table 1: Workability & strength properties of NC - enriched UHDC (under processing).

Sample	Workability	Flexural Strength (Mpa)	Compressive Strength (MPa)
AVAP® CNFs	n.a.	n.a.	n.a.
UMaine CNFs	n.a.	n.a.	n.a.
AVAP® CNCs	n.a.	n.a.	n.a.
Navitas CNCs	n.a.	n.a.	n.a.

CONCLUSIONS

- **FTIR analysis of NC materials indicate the presence of all characteristic a-cellulose peaks with similar bending-stretching bond vibrations & signal intensities.**
- **TGA/dTG analysis results, demonstrate materials with analogous degradation patterns. In DSC curves, the sharp and well-defined exothermic peak located at 325±5°C is assigned to crystal decomposition. In the endothermic area, peaks of different intensity can be distinguished related to different bounded water amounts amongst samples, which is further supported from water absorption capacity measurements at various %RH environments.**
- **Preliminary AFM results reveal the presence of particles 155nm±29.7 in length & 4.07nm±0.92 in height considering AVAP® CNF sample, whereas in the case of UMaine CNFs the corresponding values range between 203nm±18 & 5.78nm±0.77, respectively (n=50).**
- **Viscosity measurements verify a thixotropic behaviour in all samples. The higher viscosity values obtained in 1.5%wt UMaine CNF dilution could be attributed to high Mw and surface area values and/or to an enhanced degree of inter/intra entanglements in polymeric chain.**

REFERENCES

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