# RHEOLOGY OF FRESH CEMENT PASTE AS AFFECTED BY CELLULOSE NANOFIBRES AND SUPERPLASTICIZER

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## ABSTRACT

Cellulose nanofibres (CNFs) have high water-retention capacity, which can potentially affect the rheology of fresh cement paste. This study examines the effect of 0-1.2 vol.% fraction of dry CNFs, prepared with high-carboxyl content, upon the rheology of two series of cement pastes. One series was without any superplasticizer and the other was cast with a polycarboxylate-based superplasticizer, that was adjusted in dosage to keep the workability equal to that of the reference paste. Controlled shear-rate experiments were performed using a rotational rheometer with vane spindles, to obtain the flow data that was used to calculate the yield stress and viscosity. In addition, the direct method provided the static yield stress. The results reveal that adding CNFs greatly increased the yield stress and to a lesser extent, also the viscosity. As expected, the superplasticizer reversed this action.

## BACKGROUND

Satisfactory workability in oil-well cementing is vital to its transport, placement, consolidation and finishing. It also ensures both strength and durability in the hardened composite. Fresh cement-based systems behave as per the Bingham model[1], whereby, once the shear stress exceeds a yield value, it increases linearly with the growth of the shear rate. However, other fluid models have been proposed including, the Herschel-Bulkley model, the Casson model and the Power Law model[2,3]. In all cases, two flow parameters are defined namely, (i) the yield stress and (ii) the plastic viscosity. In cement-based systems, the flow is governed by inter-particle contact, flocculation of fine particles, hydration kinetics of cement, the aqueous phase content, and the particle sedimentation, geometry, and size distribution. High range water-reducing admixtures, also called superplasticizers (SP) are often used to aid the flow of fresh cementitious composites. Cellulose nanofibres (CNFs) are a novel, renewable and bio-based fibrous derivatives of cellulose[4]. In comparison with other nanofibres, they are inexpensive and abundant in nature[5]. CNF is obtained as an aqueous suspension from chemically-assisted nanofibrillation after the biomass undergoes mechanical grinding[6]. One of the more common chemical agents is TEMPO (2,2,6,6-tetramethylpiperidine-1-oxyl radical)-mediated oxidation[7]. TEMPO breaks the hydrogen bonds of cellulose fibres and introduces several anionic carboxyl and hydroxyl groups on the nanofibrils' surface[8]. The surface-active groups render the cellulose nanofibre with strong charges to repel the nanofibrils away from one another, and impart high chemical reactivity, colloidal stability, tunability and, above all, exceptional hydrophilicity[9]. The CNF suspensions mostly behave as shear thinning fluids, although they are reported also to demonstrate thixotropic behaviour. To the authors' knowledge, there is no information for cement paste containing the CNF alongwith a superplasticizer. Hence, the focus of this study is to examine the rheological parameters of plastic cement pastes loaded with CNFs and combinations of CNF and SPs. The rheological parameters of two distinct series of CNF-reinforced pastes were examined. The first series had an increasing amount of the CNF gel, while the other incorporated judicious dosages of a polycarboxylate SP in addition to the CNF, with a view to keeping the flow within the range of the plain reference paste.

## PRINCIPAL FINDINGS

The paste samples were examined first in accordance with the controlled-shear-rate protocol and later, with the direct-static-yield-stress method. The flow parameters were estimated based on curve fitting along the Herschel-Bulkley model, the Casson model and the Power Law model. The following conclusions may be drawn:

- Adding increments of CNF to the reference plain paste increases all the stress parameters and also the viscosity. The rise was more accentuated in the yield stress than in the viscosity. Consequently, the CNF decreases the workability of fresh cement paste.
- Adding the polycarboxylate-based SP to the CNF-reinforced cement paste universally lowers the viscosity and to a lesser extent, also the yield stress.
- All the mixtures that were reinforced with CNF demonstrate a shear thinning fluid behaviour. On the other hand, the mixtures having the largest dosage of both CNF and the superplasticizer behaved as a shear thickening fluid.
- The cellulose nanofibres bridge the cement particles and create a fibrous network. This uniformly raised the rheological parameters of CNF-reinforced cement paste. The polycarboxylate superplasticizer mitigates the above by lubricating the surface of the cement particles, facilitating ease of flow. This mechanism is illustrated in Figure 1.

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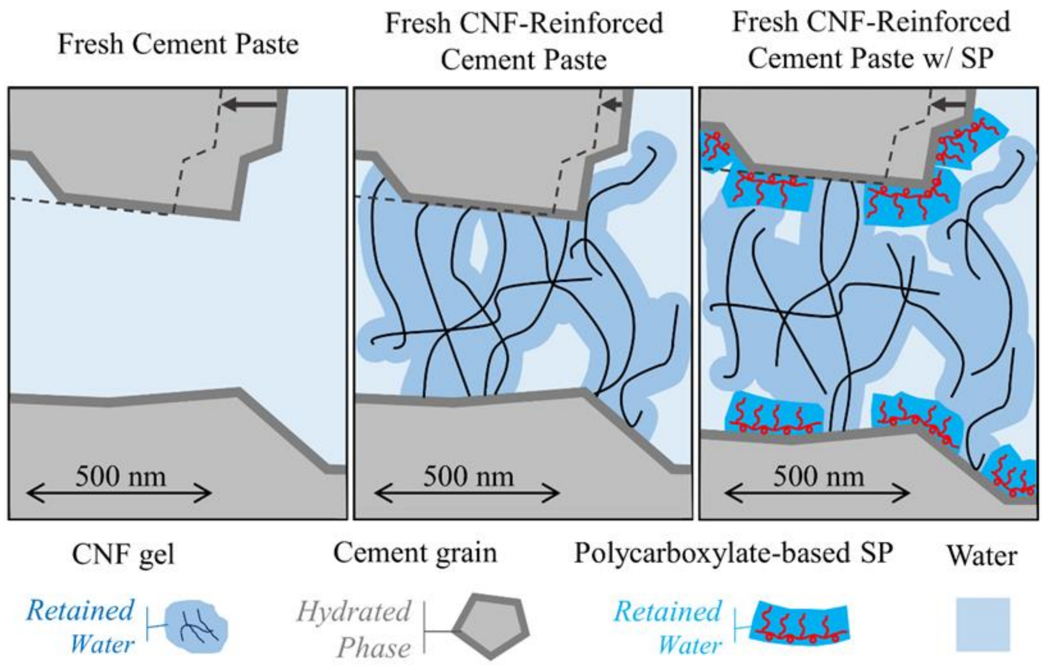


**Figure 1:** • CNFs restrain the solid particle displacement whereas SP mitigates this effect

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