Influence of Viscosity-Modifying Admixtures on the Thixotropic Behaviour of Cement Pastes

R. Bouras[1], M. Chaouche*[2] b and S. Kaci[1]

[1] Laboratoire de Modélisation expérimentale et numérique des Matériaux et structures en génie civil Université Mouloud Mammeri de Tizi-Ouzou-Algérie

[2] LMT-Cachan, Ecole Normale Supérieure de Cachan/CNRS/ PRES UniverSud Paris 61, Av. du Président Wilson, 94235 Cachan Cedex, France

* Email: chaouche@lmt.ens-cachan.fr

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Abstract:
Water soluble polymers such as cellulosic or starch ethers are often included in the mix-design of Self Compacting Concretes (SCCs) in order to improve their stability and robustness. The stability, including resistance to liquid-solid separation and sedimentation, may be attributed to the increase of the viscosity of the liquid phase due to the thickening effect of the polymer. The later is then referred to as a Viscosity-Modifying Admixture (VMA). In the present study, we consider the influence of VMAs on the rheological properties of the material at cement scale level. In particular, the change in the thixotropic properties of the cement paste due to the inclusion of VMA is investigated. It is found that addition of VMA significantly enhances rebuild-up kinetics at rest following shearing at high shear rate. The influence of VMA on the steady state rheological properties is also considered. As reported in the literature, the yield stress is found to monotonically increase with VMA content, while the consistency presents a minimum indicating the existence of an optimum value of the VMA for which the workability of the cement paste is maximum.

Zusammenfassung:
Wasserlösliche Polymere wie Zellulose- oder Stärkeether werden häufig in die Herstellung von Mischungen mit selbstverfestigendem Beton miteinbezogen, um deren Stabilität und Robustheit zu verbessern. Die Stabilität, einschließlich des Widerstandes zur Flüssigphasen-Feststoffphasentrennung und zur Sedimentation, kann der Viskositätserhöhung der flüssigen Phase aufgrund des Verhärtungseffektes des Polymers zugeschrieben werden. Dieser Zusatz für den Verhärtungseffekt wird als viskositätsmodifizierende Beimischung (VMA) bezeichnet. In dieser Arbeit wird der Einfluss von VMAs auf die rheologischen Eigenschaften des Materials im Zementzustand betrachtet. Insbesondere wird die Änderung der thixotropen Eigenschaften des Zements aufgrund der VMA-Inklusionen untersucht. Die Zugabe von VMA erhöht wesentlich die Wiederherstellungskinetik im Ruhezustand nach einer Scherung mit einer hohen Schergeschwindigkeit. Der Einfluss von VMA auf die stationären Eigenschaften wird ebenfalls untersucht. Im Einklang mit Literaturangaben nimmt die Fließspannung monoton mit dem VMA-Inhalt zu. Die Konsistenz nimmt dabei ein Minimum an, was die Existenz eines optimalen VMA-Wertes für die optimale Verwendung der Zementpaste andeutet.

Résumé:
Les polymères solubles dans l'eau tels que les éthers cellulosiques, sont souvent utilisés dans la formulation des bétons autoplaçants (BAP) afin d'améliorer leur stabilité et leur robustesse. La stabilité, la résistance à sédimentation et la résistance à la séparation de phase (liquide solide) peut être attribuée à l'augmentation de la viscosité de la phase liquide qui est due à l'effet viscosifiant du polymère. Ce dernier est alors considéré comme un agent de Viscosité ou viscosifiant (A.V.). Dans la présente étude, nous considérons l'influence des ajouts de l'agent de viscosité sur les propriétés rhéologiques des pâtes de ciment. En particulier, le changement des propriétés thixotropiques de la pâte de ciment, due à l'ajout de l'agent de viscosité (AV). Il a été constaté que l'AV améliore de façon très significative la reprise de thixotropie après un cisaillement à un taux élevé. L'influence de l'AV sur les propriétés rhéologiques est également pris en compte. Comme cela a été déjà rapporté dans la littérature, le seuil d'écoulement est proportionnel avec l'AV, tandis que la consistance présente un minimum indiquant l'existence d'une valeur optimale de l'AV pour laquelle l'ouvrabilité de la pâte de ciment est maximale.

Key words: cement paste, self-compacting concretes, thixotropy, viscosity-modifying admixture

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tropy) and steady state behaviours were investigated. Without VMA the pastes exhibited complex steady-state flow-curves, including a shear-thinning branch at low shear rate and a shear-thickening one at high shear rates. It was found that the shear-thinning branch was absent for pastes with VMA. The evolution of the steady state rheological parameters was found to found to be complex: the dynamic yield stress monotonically increases with VMA content, while the consistency and the fluidity index present an extremum value around the reference dosage of VMA (the one used to mix-design self-levelling concretes).

The influence of the VMA on thixotropic behaviour was investigated by considering breakdown kinetics under high rates and rebuild up at rest or very low shear rate. It was found that the breakdown kinetics was governed by two main characteristic times (the relaxation curves could be fitted with the sum of two exponentials) which differ by an order of magnitude. This was attributed to the two different constituents of paste, namely the VMA polymer and the granular phase, whose relaxation dynamics would take place at quite different timescales. On the other hand, the rebuild up kinetics was found to follow a stretched exponential-like process. This was attributed to the fact that, at rest or very low shear rate, a large set of relaxation times, including those corresponding to the polymer and the grains may be mobilized.

REFERENCES

[1] Ghio VA, Monteiro PJM, Demsetz LA: The rheology of fresh cement pastecontaining polysaccharide gums, Cement and Concrete Research 24 (1994) 243-249.

[2] Sonebi M: Rheological properties of grouts with viscosity modifying agents as diutangum and welan gum incorporating pulverised fly ash, Cement and Concrete Research 36 (2006) 1609-1618.

[3] Saric-Coric M, Khayat KH, Tagnit-Hamou A: Performance characteristics of cement grouts made with various combinations of high-range water reducer and cellulosebased viscosity modifier, Cement and Concrete Research 33 (2003) 1999-2008.

[4] D'Aloia Schwartzentruber L, Le Roy R, Cordin J: Rheological behaviour of fresh cement pastes formulated from a Self Compacting Concrete (SCC), Cement and Concrete Research 36 (2006) 1203-1213.

[5] Khayat KH: Viscosity-enhancing admixtures for cement-based materials An overview, Cement and Concrete Composites 20 (1998) 171-188.

[6] Ambroise J, Péra J: Private communication.

[7] Phan TH, Chaouche M, Moranville M: Influence of organic admixtures on the rheological behaviour of cement pastes, Cement & Concrete Research 36 (2006) 1807-1813.

[8] Wallevik JE: Thixotropic investigation on cement paste: Experimental and numerical approach, J. Non Newt. Fluid Mech. 132 (2005) 86-99.

[9] Roussel N: Steady and transient flow behaviour of fresh cement pastes, Cement and Concrete Research 34 (2005) 1656-1664.

[10] Jarny S, Roussel N, Le Roy R, Coussot P: Thixotropic behavior of fresh cement pastes from inclined plane flow measurements, Appl. Rheol. 18 (2008) 14251.

[11] Papo A: The thixotropic behavior of white Portland cement pastes, Cement and Concrete Research 18 (1988) 595-603.

[12] Lapasin R, Longo V, Rajgelj S: Thixotropic behaviour of cement pastes, Cement and Concrete Research 9 (1979) 309-318.

[13] Feys D, Verhoeven R, DeSchutter G: Evaluation of time independent rheological models applicable to fresh Self-Compacting Concrete, Appl. Rheol. 17 (2007) 56244.

[14] Hu C, de Larrard F: The rheology of fresh high-performance concrete, Cement and Concrete Research 26 (1996) 283-294.

[15] Assaad J, Khayat KH: Assessment of Thixotropy of Self-Consolidating Concrete and Concrete-Equivalent-Mortar-Effect of Binder Composition and Content, ACI Materials Journal 101 (2004) 400-408.

[16] Tchamba JC, Amziane S, Ovarlez G, Roussel N: Lateral stress exerted by fresh cement paste on formwork: Laboratory experiments, Cement and Concrete Research 38 (2008) 459-466.

[17] Roussel N, Le Roy R, Coussot P: Thixotropy modeling at local and macroscopic scale, J. Non Newt. Fluid Mech. 117 (2004) 85-95.

[18] Barnes HA: Thixotropy - a review, J. Non Newt. Fluid Mech. 70 (1997) 1-33.

[19] Stokes JR, Telford JH: Measuring the yield behaviour of structured fluids, J.Non Newt. Fluid Mech. 124 (2004) 137-146.

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[20] Bauer E, de Sousa JGG, Guimarães EA, Silva FGS: Study of the laboratory Vane test on mortars, Building and Environment 42 (2007) 86-92.
[22] Galindo-Rosales FJ, Rubio-Hermàdes F.J: Structural breakdown and build-up in bentonite dispersion, Applied Clay Science 33 (2006) 109-115.
[23] Mujundar A, Beris AN, Metzner AB: Transient phenomena in thixotropic systems, J. Non Newt. fluid Mech. 102 (2002) 157-178.
[25] Tiu C, Boger DV: Complete rheological characterization of time dependent food products, J. Texture Stud. 5 (1974) 328-338.
[26] De Kee D, Code RK, Turcotte C: Flow propreties of time depenent Foodstufs, J. Rheol. 27 (1983) 581-604.
[27] Alessandrini A, Cautin B, Lapasin R, Papo A: Phenomenological description of the thixotropic behavior of gypsium plaster pastes, Rheol. Acta 24 (1985) 617-622.
[28] Barnes HA: Shear-Thickening ("Dilatancy") in Suspensions of Non aggregating Solid Particles Dispersed in Newtonian Liquids, J. Rheology 33 (1989) 329-366.
[29] Cyr M, Legrand C, Mouret M: Study of the shear thickening effect of superplasticizers on the rheological behaviour of cement pastes containing or not mineral additives, Cement and Concrete Research 30 (2000) 1477-1483.
[30] Holmberg K, Jönsson B, Kronberg B, Lindman B: Surfactants and Polymers in Aqueous Solution, John Wiley & Sons (2003).
[31] Hatzikiriakos SG, Vlassopoulos D: Brownian dynamics simulations of shearthickening in dilute polymer solutions, Rheol. Acta 35 (1996) 274-287.
[32] Indei T: Necessary conditions for shear thickening in associating polymer networks, Journal of Non-Newt. Fluid Mech. 141 (2007) 18-42.
[33] Paiva H, Silva LM, Ferreira VM, Labrincha JA: Effects of a water retaining agent on the rheological behaviour of a single-coat render mortar, Cement and Concrete Research 36 (2006) 1257-1262.
[34] Lombois H, Lootens D, Halary JL, Hébraud P, Colombet P, Lécolier E, van Damme H: Sur le rôle ambigu de la lubrification dans la rhéologie des pâtes granulaires, Rhéologie 7 (2005) 11-21.

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