Rheological Behaviour of Render Mortars

A. Kaci [1], M. Chaouche [1]*, P.-A. Andréani [2] and H. Brossas [2]

[1] Laboratoire de Mécanique et Technologie – Cachan (ENS Cachan/CNRS UMR8535/UPMC/PRES UniverSud Paris), 61 av. du Président Wilson,-94230 Cachan, France
[2] Centre d'Innovation de ParexLanko, BP 5, 38 rue du Montmurier, ZI Parc des Chesnes, 38291 Saint Quentin Fallavier Lyon, France

* Email: chaouche@lmt.ens-cachan.fr
Fax: x33.1.47402240

Received: 10.6.2008, Final version: 3.9.2008

Abstract:
Steady state and transient rheological behaviours of a one-coat render mortar are considered experimentally using a shear rheometer equipped with the vane geometry. The flow curves performed at controlled shear-rates exhibit highly pronounced minima, which is attributed to shear localization and strong thixotropy. This latter property is further investigated separately by considering the temporal growth of the apparent stress at very low shear-rate, reflecting the material's microstructure rebuild up following shearing at different high shear rates. It is found that rebuilding characteristic time is roughly independent upon shear history, indicating that this is a material parameter. The influence of water dosage rate on the rheological behaviour is considered. As expected, apparent viscosity and yield stress decrease with increasing kneading water amount. The rebuilding up kinetics is found to be non sensitive to water dosage rate, suggesting that the material's processability would be preserved when changing this parameter, although significant creeping may be expected at high water dosage rates.

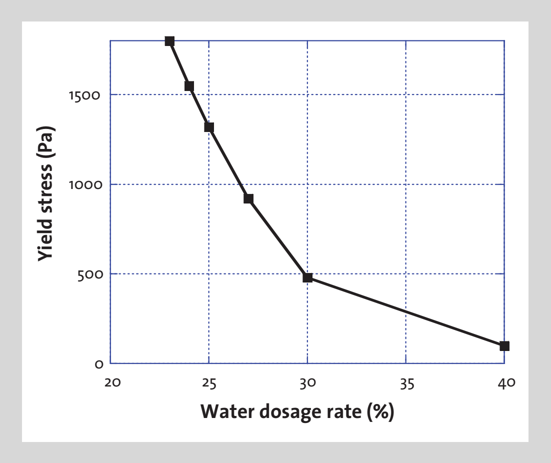
Zusammenfassung:
Das stationäre und transiente rheologische Verhalten eines einlagigen Putzmörtels wurde mit Hilfe eines Scherrheometers experimentell untersucht, das mit einer Schaufelgeometrie ausgestattet ist. Die Fließkurven, die bei kontrollierten Schergeschwindigkeiten aufgenommen worden sind, weisen ein ausgesprochenes Minimum auf, das einer Scherlokalisation und einem starken thixotropen Verhalten zugeschrieben wird. Dieses thixotrope Verhalten wurde weiterhin speziell untersucht durch Messungen des zeitlichen Spannungswachstums bei einer sehr niedrigen Schergeschwindigkeit, das den Wiederaufbau der Mikrostruktur des Materials nach einer Scherung bei unterschiedlich hohen Schergeschwindigkeiten wiedergibt. Es wird gezeigt, dass die charakteristische Zeit für die Wiederherstellung näherungsweise unabhängig von der Vorgeschichte der Scherung und damit ein Materialparameter ist. Des Weiteren wurde der Einfluss der Dosierungsrate für Wasser auf das rheologische Verhalten untersucht. Die scheinbare Viskosität und die Fließspannung nehmen erwartungsgemäß mit dem Wassergehalt ab. Die Kinetik des Wiederherstellungsprozesses hängt nicht von der Wasserdosierungsrate ab, so dass die Verarbeitbarkeit des Materials bei Dosierungsänderungen erhalten bleibt. Jedoch ist ein signifikantes Kriechen bei hohen Wasserdosierungsraten zu erwarten.

Résumé:
Le comportement rhéologique d'un enduit monocouche est considéré en utilisant un rhéomètre équipé d'une géométrie vane. Les courbes d'écoulement obtenues à taux de cisaillement imposé montrent l'existence d'un profond minimum qui peut être attribué à la localisation du cisaillement ainsi qu'à la thixotropie. Cette dernière propriété est étudiée séparément en considérant l'évolution temporelle de la contrainte apparente à de très faibles taux de cisaillement, ce qui correspond à la restructuration de la microstructure du matériau au repos, après un fort cisaillement. Les résultats montrent que le temps caractéristique de restructuration est indépendant de l'histoire de sollicitation ce qui suggère que cette propriété est un paramètre matériau. Par ailleurs, nous avons considéré également l'influence du dosage en eau sur le comportement rhéologique. Comme on pouvait s'y attendre, la viscosité apparente ainsi que la contrainte seuil diminuent en augmentant le dosage en eau. En revanche, la cinétique de restructuration est peu sensible aux taux de dosage en eau, ce qui montre une certaine robustesse de la formulation.

Key words: flow curve with minimum, thixotropy, shear-localization, rendering mortar

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

Figure 11 : Equilibrium stress at a very low shear-rate (0.01 s^{-1}) or static yield stress versus water dosage rate.



$$\sigma(t)=\sigma_{\infty}+(\sigma_{o}-\sigma_{\infty})e^{-(t/\tau_r)^{\alpha}} \qquad (6)$$

where σ_∞ and σ_o are respectively the equilibrium and the initial stresses and τ_r the characteristic of structure rebuilding. α is a constant, which is order 1 in our case.

Figure 10 represents a typical fit of the rebuilding branch of the stress curve with a stretched exponential (Equation 6). The water dosage rate in this case is 24% and the material is presheared at 50 s^{-1}. The best fit leads to an average equilibrium stress σ_∞ = 1549 Pa, τ_r = 339 s and α = 1.

All the rebuilding branches were fitted with the functional form (Equation 6) and the characteristic time and the equilibrium stress (which is actually the static yield stress) were determined. It is found that the characteristic time is almost independent upon the shear history. This indicates that it is a material property. Moreover, unexpectedly, it is also roughly insensitive to the water dosage rate. It can be readily seen in Figure 9 that the stress reaches its steady state plateau during roughly the same period of time for all the rebuilding branches.

On the other hand, the average equilibrium stress decreases strongly with increasing kneading water content (Figure 11). Yet, even for a dosage rate of 40 % the material can withstand its weight for a layer thickness up to $h = \sigma_\infty/\rho g$ (ρ is the density of the material = 1400 kg/m^3) = 0.7 cm. In practise, h is between 1 and 1.5 cm. For a dosage rate of 30 % the maximum layer thickness is 3.5 cm. However the yield stress is reached only within the characteristic rebuilding time during which some sagging would occur. Then from practical point of view the main parameter should be the required time period for the stress to exceed $\rho g h$ = 210 Pa (taking h = 1.5 cm). For water dosage rate of 24 %, this time period is about 15 s. For 30 %, the material can withstand its weight after about 200 s during which the material creeps.

4 CONCLUSIONS

The rheological behaviour, including equilibrium flow curves and thixotropy, of a rendering mortar was investigated. It was found that the equilibrium flow curve loops obtained by increasing-decreasing shear-rate displayed a particularly complex shape. Depending upon shear-rate interval the material showed both thixotropy and rheopexy. Moreover, the flow curves exhibited deep minima. This has been interpreted physically by invoking shear-localization and thixotropy. At this point, one can wonder if the presence of minimum in flow curves may have practical implication regarding optimization of pumping energy.

Thixotropy was investigated separately by considering stress temporal growth (related to structure rebuilding) following shearing at different rates. It was showed that the stress growth curve could be well fitted using a stretched exponential. This allowed determining a rebuilding characteristic time that was found to be roughly independent upon shear history. This parameter can be then considered to be a material parameter.

ACKNOWLEDGEMENTS

We are indebted to the company PAREXLANKO SA for financial support.

REFERENCES

[1] American Society for Testing and Materials, ASTM C780-96. Standard test method for preconstruction and construction evaluation of mortars for plain and reinforced unit masonry, Philadelphia, 1996.

[2] American Society for Testing and Materials, ASTM C1437-01. Standard test method for flow of hydraulic cement mortar, Philadelphia, 2001.

[3] 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 Concrete Res. 36 (2006) 1257–1262.

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

[5] Elton B, de Sousa GG, Guimarães AE, Silva FGS: Study of the laboratory Vane test on mortars. Building and Environment 42 (2007) 86–92.

[6] Ait-Kadi A, Marchal Ph, Chrissemant AH, Bousmina M, Choplin L: Quantitative analysis of mixer-type rheometers using Couette analogy. Canadian J. Chem. Eng. 80 (2002) 1166–1174.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

[7] Dullaert K, Mewis J: Thixotropy: Build-up and breakdown curves during flow. J. Rheol. 49 (2005) 1213–1230.
[8] Galindo-Rosales FJ, Rubio-Hernández FJ: Structural breakdown and build-up in bentonite dispersions. Applied Clay Science 3 (2006) 109–115.
[9] Barnes HA: Thixotropy – a review. J. Non-Newtonian Fluid Mech. 70 (1997) 1–33.
[10] Pignon F, Magnin A, Piau JM: Thixotropic colloidal suspensions and flow curves with minimum: Identification of flow regimes and rheometric consequences. J. Rheol. 40 (1996) 573–587.
[11] Coussot P, Leonov AI, Piau JM: Rheology of concentrated dispersed systems in a low molecular weight matrix, J. Non-Newtonian Fluid Mech. 46 (1993) 179–217.
[12] Picard G, Ajdari A., Bocquet L, Lequeux F: A simple model for heterogeneous flows of yield stress fluids. arXiv:cond-mat/0206260v2
[13] Coussot P, Raynaud JS, Bertrand F, Moucheront P, Guilbaud JP, Huynh HT, Jarny S, Lesueur D: Coexistence of liquid and solid phases in flowing soft-glassy materials. Phys. Rev. Lett. 88 (2002) 218301
[14] Huang N, Ovarlez G, Bertrand F, Rodts S, Coussot P, Bonn D: Flow of wet granular materials. Phys. Rev. Lett. 94 (2005) 028301.
[15] Roussel N, Leroy R, Coussot P: Thixotropy modeling at local and macroscopic scale. J. Non-Newtonian Fluid Mech. 117 (2004) 85–95.
[16] Dullaert K: Constitutive equations for thixotropic dispersions. PhD thesis, Katholieke Universiteit Leuven (2005).
[17] Mewis J.: Thixotropy - a general review. J. of Non-Newtonian Fluid Mech. 6 (1979) 1–20.
[18] Jarny S, Roussel N, Le Roy R, Coussot P: Thixotropic behavior of fresh cement pastes from inclined plane flow measurements. Appl. Rheol. 18 (2008) 14251–14259.
[19] Moore F: The rheology of ceramic slip and bodies. Trans. Br. Ceramic Soc. 58 (1959) 470–494.
[20] Dullaert K, Mewis J: A structural kinetics model for thixotropy. J. of Non-Newtonian Fluid Mech. 139 (2006) 21–30.
[21] Bouras R, Chaouche M, Kaci S: Influence of viscosity-modifying admixtures on the thixotropic behaviour of cement pastes. Appl. Rheol. 18 (2008), 45604.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org