Adhesive and Rheological Properties of Mortar Joints

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

Laboratoire de Mécanique et Technologie – Cachan (ENS Cachan/CNRS UMR8535/UPMC/PRES UniverSud Paris) 61, av. du Président Wilson, 94230 Cachan,France

[1] 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: 31.1.2009, Final version:21.6.2009

Abstract:
Adhesive properties of fresh mortar joints containing different dosage rates of a water-soluble polymer (cellulose ether based) are investigated using the probe tack test. This test consists of measuring the evolution of the normal force required to separate at a given velocity two plates between which a thin layer of the sample is sandwiched. Three different adhesive components are inferred from the measured stretching force: cohesion, adhesion and adherence. The influence of the polymer dosage rate and the pulling velocity on the evolution of these adhesive properties is investigated. The adhesive components are then related the rheological properties of the mortars which are shown to behave as Herschel-Bulkley shear-thinning fluids.

Zusammenfassung:
Die adhäsiven Eigenschaften von frischen Mörtelverbindungen, die unterschiedliche Anteile eines wasserlöslichen Polymers (basierend auf einem Zellulose-Ether) enthalten, werden mit Hilfe des Klebtests untersucht. Dieser Test beinhaltet die Messung der Normalkraft, die notwendig ist, um bei einer bestimmten Geschwindigkeit die beiden Platten zu trennen, zwischen denen sich die dünne Probe befindet. Aus den Messungen der Normalkraft geht hervor, dass drei Komponenten wesentlich sind: Kohäsion, Adhäsion und Klebkraft. Der Einfluss der Polymerkonzentration und der Dehngeschwindigkeit auf die adhäsiven Eigenschaften werden untersucht. Die adhäsiven Komponenten werden mit den rheologischen Eigenschaften der Mörtel in Beziehung gesetzt, die sich wie scherverdünnende Herschel-Bulkley-Fluide verhalten.

Résumé:
Les propriétés adhésives des mortiers joints contenant différents taux de dosage en polymère hydrosoluble (à base d'éther de cellulose) sont étudiées en utilisant un test d'arrachement. Ce dernier consiste à mesurer l'évolution de la force normale nécessaire pour séparer, à une vitesse donnée, deux plateaux parallèles entre lesquels se trouve une couche mince d'un échantillon pré-comprimé. Trois différentes composantes caractérisant les paramètres adhésives du matériau sont déterminées à partir de la force d'arrachement mesurée : la cohésion, l'adhésion et l'adhérence. L'influence du taux de dosage en polymère et de la vitesse d'arrachement sur l'évolution de ces paramètres est étudiée. Les paramètres adhésifs sont reliés aux propriétés rhéologiques. Ces dernières sont déterminées en montrant que les mortiers sont bien modélisés par un fluide d'Herschel-Bulkley rhéofluidifiant.

Key words: mortar joints, adhesive properties, tack test, rheological properties.

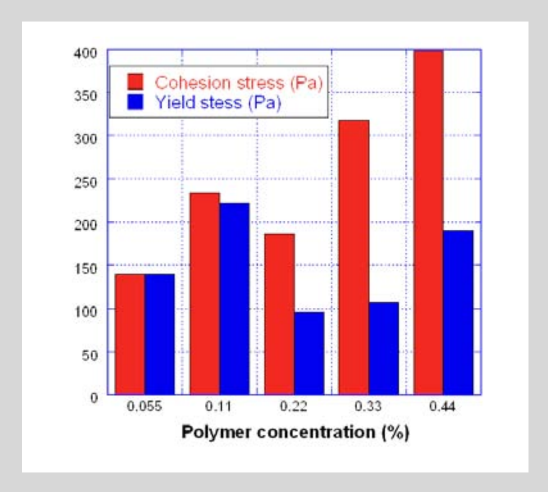
1 INTRODUCTION

The probe tack test is widely used to characterize debonding properties of different types of soft materials. This includes for instance pressure-sensitive adhesives (PSA) [1 – 5]. It has been shown that the tackiness of these copolymer-based materials arise form a complex combination of cavitation and visco-elastic dissipation. In order to be effective, an adhesive must posses both liquid properties, to wet the surface when the bond is formed and solid properties, to sustain a certain level of stress during the process of debonding [6, 7]. On the other extreme case, a large number of studies have been devoted to the problem of Saffman-Taylor instability arising when separating two plates between which a Newtonian or a Non-Newtonian fluid is confined [6 – 11].

DOI: 10.3933/ApplRheol-19-51970

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

Figure 16: Comparison between the cohesion stress and the yield stress for different polymer concentrations.



between the shear-thinning character of the polymer solution and the shear-thickening contribution of the granular phase. The fluidity index remains smaller that unity indicating that the mortars are shear-thinning in the shear-rate interval considered.

3.7 RELATIONSHIP BETWEEN THE ADHESIVE AND THE RHEOLGICAL PROPERTIES

The above experimental results showed that the rheological behaviour of the mortar joints can be well-described using the Herschel-Bulkley model. In addition, in our tack test experiments the instantaneous distance between the plates is remains small compared to the sample diameter at least up to gap corresponding to Fmax. Under these conditions, one can use a lubrication-type approach to calculate Fmax [22]:

$$F_{max} = \frac{2\pi R^3 \tau_0}{3h_m} + \frac{2\pi k}{n+3}\left(\frac{2n+1}{n}\right)^n \frac{R^3}{h_m}\left(\frac{RV}{h_m{}^2}\right)^n \tag{1}$$

In Equation 1 R is the sample radius, R_m the instantaneous distance between the plates corresponding to F_{max} and V the pulling velocity. From Equation 1 one can determine the cohesion force by setting $V = 0$. That is:

$$F_{coh} = \frac{2\pi R^3 \tau_0}{3h_m} \tag{2}$$

Figure 14 represents in diagrammatic plot a comparison between the cohesion stresses measured in the tack test experiments the yield stresses determined in shear-rheometry for different polymer contents. We use Equation 2 to calculate the cohesion stresses from the cohesion forces determined in the tack tests.

Figure 16 shows that for low polymer concentrations (0.055 and 0.11 %), the values of the cohesion stress are close to those of the yield stress. In this case the flows involved in the tack test and shear-rheometry are similar. Increasing the dosage rate of the polymer the cohesion stress becomes higher than the yield stress and the gap between the two quantities increases with polymer content. A possible explanation is the increase of the elongational contribution to the flow with polymer content in the tack tests.

4 CONCLUSION

Adhesive properties of mortar joints containing different dosage rates of a cellulosic ether based additive were investigated using the probe tack test. From the measured tack force curves 3 different adhesive quantities were determined, including adhesion, cohesion and adherence. It was found that the evolution of these properties versus polymer concentration was in general non monotonous. Such behaviour was attributed to the competition between different opposing effects of the polymer, including air-entraining, lubrication of granular contacts, increase of viscous drag, etc. More investigation of these different effects of the polymer additive is needed in order to achieve quantitative interpretation of the tack test results.

Finally, a tentative comparison between adhesive and rheological properties was presented. In particular the cohesion stresses that were determined from the tack tests were compared to the yield stresses. It was found that the cohesion stress was comparable to the yield stress at low polymer content. At higher polymer concentrations the cohesion stress became larger than the yield stress and the gap between the two increases with polymer content. This was attributed to an eventual increase of the elongational contribution to the flow in the tack tests due to the polymer.

ACKNOWLEDGMENTS

This investigation has been sponsored by the company ParexLanko-France.

REFERENCES

[1] Lakrout H, Sergot P and CretonC: Direct observation of cavitation and fibrillation in a probe tack experiment on model acrylic pressure-sensitive adhesives, J. Adhesion 69 (1999) 307-359.

[2] Derks D, Lindner A, Creton C, Bonn D: Cohesive failure of thin layers of soft model adhesives under tension, J. Appl. Phys. 93 (2003) 1557-1566.

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

[3] Mizumachi H: Theory of Tack of Pressure Sensitive Adhesive. I. Journal of Applied Polymer Science 30 (1985) 2675-2686.
[4] Hammond FH Jr.: Tack. Advances in Pressure Sensitive Adhesive Technology, Satas D ed., Satas & Associates, Warwick (1982) 32-49.
[5] Zosel A: Fracture Energy and Tack. in Advances in Pressure Sensitive Adhesive Technology - 1, Satas D ed., Satas & Associates, Warwick (1992) 92-127).
[6] Lindner A, Derks D, Shelly JM: Stretch flow of thin layers of Newtonian liquids: fingering patterns and lifting forces, Phys. Fluids 17 (2005) 072107.
[7] Zosel A: The Effect of Bond Formation on the Tack of Polymers. J. Adhesion Sci. Technology 11 (1997) 1447-1457.
[8] Ben AmarM, Bonn D: Fingering instabilities in adhesive failure, Physica D 209 (2005) 1-16.
[9] Shull KR, Flanigan CM, Crosby AJ: Fingering instability of confined layers in tension, Phys. Rev. Lett. 84 (2000) 3057-3060.
[10] Poivet S, Nallet F, Gay C, Teisseire J, Fabre P: Cavitation-induced force transtion in confined liquids under traction, Eur. Phys. J. E 15 (2004) 97-116.
[11] Teisseire J: Tack de matériaux modèles, Ph.D. Thesis, Université Bordeaux I (2006).
[12] Mohamed Abdelhaye YO, Chaouche M, Van Damme H: Tackiness of smectite muds: 1. The dilute regime, Appl. Clay Sci. 42 (2008) 2163-2167.
[13] Van Damme H, Mansoutre S, Colombet P, Lesaffre C, Picart D: Pastes: Lubricated and cohesive granular media, C. R. Physique 3 (2002) 229-238.
[14] Mohamed Abdelhaye YO: Tackiness of granular pastes, Phys. Rev. E (submitted).
[15] Bauer E, de Sousa JGG, Guimarães EA, SilvaFGS: Study of laboratory vane test on mortars, Buildi. Environ. 42 (2007) 86-92.
[16] Stokes JR, Telford JH: Measuring the yield stress of structured fluids, J. Non-Newton. Fluid Mech. 124 (2004) 137-146.
[17] Bousmina M, Ait-Kadi A, Faisant JB: Determination of shear rate annd viscosity from batch mixer data, J. Rheol. 43 (1999) 415-433.
[18] Paiva H, Silva LM, Labrincha JA, Ferreira VM: Effects of a water retaining agent on the rheological behaviour of a single-coat render mortar, Cem. Concrete Res. 36 (2006)1257-1262.
[19] Creton C, Leibler L: How Does Tack Depend on Time of Contact and Contact Pressure? J. Polymer Sci.: Part B: Polymer Phys. 34 (1996) 545-554.
[20] Zosel A: Adhesion and Tack of Polymers: Influence of Mechanical Properties and Surface Tensions. Colloid & Polymer Sci. 263 (1985) 541-553.
[21] Bouras R, Chaouche M, Kaci S: Influence of Viscosity-Modifying Admixtures on the Thixotropic Behaviour of Cement Pastes, Appl. Rheol. 18 (2008) 45604.
[22] Meeten GH: Constant-force squeeze flow of soft solids. Rheol. Acta 41 (2002) 557-566.

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