Temperture Influence on the Rheological Behaviour of Cementitous Pastes Prepared with Air-entraining Admixtures

Roberto Cesar de Oliveira Romano*, Rafael Giuliano Pileggi

Department of Civil Construction, University of São Paulo, São Paulo 61 548, Brazil

* Corresponding author: rcorjau@gmail.com
Fax: x55.11.3091.5544

Received: 14.7.2011, Final version: 8.12.2011

Abstract:
Cementitious pastes prepared with air-entraining admixtures (AEA) are very sensitive to mix procedures and environmental conditions. Some of the effects of AEA on the properties of cementitious material are discussed in literature, although for the most part, only in the hardened state. However, the impact temperature has on air-incorporation during the early age stages and on consolidation has been little investigated and as such, is the objective of this work. Thus, pastes formulated with Portland cement and air-entraining admixtures are evaluated in this work with a focus on the role temperature plays in the early age behavior. The results show that air-incorporation was affected by environmental conditions which caused changes in the kinematic viscosity and rate of consolidation.

Zusammenfassung:
Die Eigenschaften von zementartigen Pasten, die mit Hilfe von Luftporenbildnern (AEA) hergestellt wurden, hängen sehr stark vom Mischverfahren und den Umgebungsbedingungen ab. Der Einfluss von AEA auf die Eigenschaften zementartiger Materialien wurde teilweise in der Literatur diskutiert, jedoch größtenteils nur im verfestigten Zustand. Dagegen wurde der Einfluss der Belastungstemperatur auf die Bildung von Luftporen im Anfangsstadium und während der Verfestigung nur zu einem geringen Teil untersucht und ist daher Schwerpunkt dieser Arbeit. In dieser Arbeit wurden Pastenformulierungen mit Portland-Zement und Luftporenbildnern im Hinblick auf den Einfluss der Temperatur im Anfangsstadium evaluiert. Die Ergebnisse verdeutlichen, dass die Bildung von Luftporen von den Umgebungsbedingungen beeinflusst wird und dadurch zu Änderungen in der kinematischen Viskosität und der Verfestigungsrate führt.

Résumé:
Les pâtes de ciment préparées par mélanges aérés (AEA) sont très sensibles aux conditions de mélange et environnementales. Certains des effets du AEA sur les propriétés des matériaux cimentés sont discutés dans la littérature, bien que dans la plupart des cas, pour l'état solidifié. En revanche, l'impact de la température sur l'incorporation de l'air dès le début et sur la consolidation a été très peu étudié et par conséquent est l'objectif du présent travail. Ainsi, les pâtes formulées avec du ciment de Portland et les mélanges aérés ont été évalué ici en mettant l'accent sur le rôle joué par la température dans le comportement aux temps initiaux. Les résultats montrent que l'incorporation de l'air est affectée par les conditions environnementales qui causent des changements dans la viscosité cinématique et la vitesse de consolidation.

Key words: rheology, cementitious paste, air-incorporation, temperature, consolidation

1 INTRODUCTION

Many technical, practical, economical and environmental benefits can be obtained from rendering mortars with air-incorporation such as a reduction in density, which help to build a building using less materials, and eco-efficiency gains. The most common form of generating air-bubbles is through the addition of air-entraining admixtures (AEA). As the air-bubble are generated in the fine portion of the mortars, named in this work by paste (cement + water + AEA), the evaluation of this portion may to be important stage to understand what happens in the mortar. Although much research is readily found concerning the performance of cementitious pastes, most of the literature presents results about the performances of hardened air-void materials, with porosity, adhesion, modulus of elasticity and mechanical strength among the properties most frequently evaluated [1–12]. Conversely,

© Appl. Rheol. 22 (2012) 24333 DOI: 10.3933/ApplRheol-22-24333

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

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

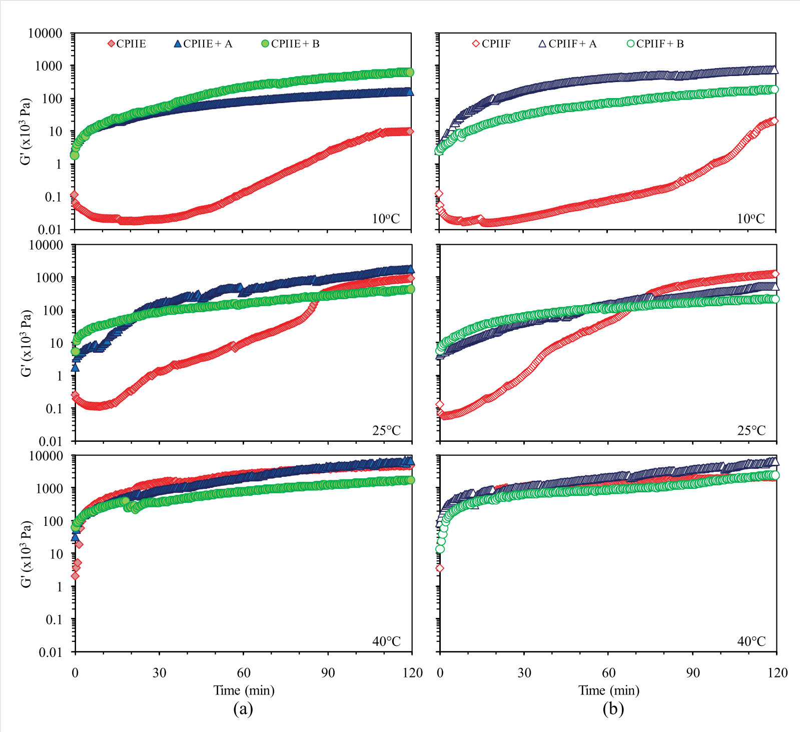

Figure 7:
The effect of temperature on the consolidation of (a) CPIIE and (b) CPIIF. The results of the tests are presented from top to bottom at 10, 25, and 40°C.

the presence of the additive. The highest increase in the 'early' yield stress of CPIIE suspensions is related to the highest addition of air-incorporation. Thus a relationship between the yield stress and the air content is coherent, showing that the air improves the cohesion of the suspensions, a fact frequently reported in literature for materials with air-entraining admixtures [9–11]. Maybe, because of this, the cohesion of the pastes with AEA was more intense than of the pastes without AEA, mainly those formulated with CPIIE.

Conversely, all systems had reduced and similar values of 'late' yield stress. The shear behavior was able to modify the structures of the agglomerates, which before, was responsible for different and higher initial cohesion. Now, systems with lower and similar levels of cohesion were observed. Considering the differences in suspension air-volume, an accurate interpretation of the factors which may affect late yield stress is quite complex, and involves phenomena such as particle de-agglomeration and changes in the air-bubble structure.

3.2.2 Oscillatory Test

In this part the rate of consolidation was evaluated using an oscillatory rheometry test. During the test, constant frequency and strain were applied to guarantee that the agglomerated structure was not broken. Suspension viscoelasticity was evaluated through the quantification of the viscous dissipative losses *G*" and the storage elastic of modulus *G*'. The results are presented, just in function of *G*', in Figure 7: pastes with CPIIE (a) and with CPIIF (b). From top to bottom, the results of the tests are shown at 10, 25, and 40°C. Cement consolidation occurs in function of time and is due to two different, yet, complementary phenomena: cement hydration reaction (which gives a chemical contribution) and coagulation/flocculation (which gives a physical contribution). So, the raise of *G*' during consolidation is expected for cementitious materials. The forces of coagulation/flocculation are intensified as the hydration reaction develops, due to this producing an increment of ionic forces and the formation of hydrated products. These phenomena are directly related to the temperature, because the dissolution of hydrated compounds, the Brownian motion, the rate of particle collision and the reaction rate, are all increased.

Therefore, the consolidation patterns of pastes without AEA were similar, temperature dependent and independent of the type of cement; both cements proved sensitive to the thermal conditions. Although not totally unexpected, the storage modulus of foamed suspensions was higher than of those without AEA, and less dependent of the temperature. This result upholds the view frequently found in literature that, air-bubbles strengthen the cohesion of cement materials. On the other hand, the type of cement had little or no effect on consolidation. The air-bubble effect on cohesion was more intense at the beginning of tests, where a higher difference of *G*' can be seen between the pastes with and without AEA. At the end of testing (120 minutes), consolidation was being activated by the reaction from cement hydration.

4 CONCLUSION

The air-incorporation was affected by the temperature, type of cement and type of airentraining admixture. The air-incorporation in pastes without AEA was inversely proportional to the temperature and unaffected by the type of cement. The larger airvolume in pastes with AEA was similar for both evaluated admixtures, which was expected because both air-entraining admixtures are very similar.The air-incorporation in the AEA suspensions with CPIIE was different from the airincorporation observed in the suspensions with CPIIF. Raising the temperature from 25 to 40°C increased the volume of air in the slag cement suspension.

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

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

The results pointed to a relationship between the air-volume and the yield stress, showing that the air may be affecting the suspension cohesion level. Although the temperature affected the kinematic viscosity, the effect of the air-entraining admixture was negligible and almost all tested pastes showed positive thixotropy. The paste consolidation rate was affected by the temperature and by the use of airentraining admixtures: In the pastes without AEA consolidation was proportional to the temperature; in the pastes with AEA cohesion was clearly intensified because the *G*' values were always higher than those of the reference pastes, regardless of the temperature.

ACKNOWLEDGMENTS

The authors are thankful to Capes for the financial support.

REFERENCES

[1] Romano RCO., Schreurs H, Silva FB, Cardoso FA, Barros MMSB, John VM, Pileggi RG: Impacto do tipo de misturador e do tempo de mistura nas propriedades de argamassas industrializadas, Ambiente Construído, Porto Alegre, 9(2009) 109 – 118.

[2] Munson BR, Young DF, Okiishi TH: Fundamentos da mecânica dos fluidos, Tradução da 4ª Edição Americana. Euryale de Jesus Zerbini. Edgard Blücher (2004).

[3] Santos NAA, Pinho FMCT, Oliveira MSNF: Estudo da Reologia de Fluidos Análogos ao Sangue, Universidade do Porto. Faculdade de Engenharia (2009).

[4] Roussel N, Lemaître A, Flatt R, Coussot P: Steady state flow of cement suspensions: A micromechanical state of the art, Cement and Concrete Research 40 (2010) 77 – 84.

[5] Otsubo Y, Miyai S, Umeya K: Time-dependant flow of cement pastes, Cement and Concrete Research 10 (1980) 631 – 638.

[6] Banfill PFG, Saunders DC: On the viscosimetric examination of cement pastes, Cement and Concrete Research 11 (1981) 363 – 370.

[7] Shaughnessy III R, Clark PE: The rheological behavior of fresh cement paste, Cement and Concrete Research 18 (1988) 327 – 341.

[8] Ramachandran VM: Concrete admixtures handbook, Noyes Publications, New York (1984).

[9] Rixon R, Mailvaganan M: Chemical admixtures for concrete, E & FN Spon, London (1999).

[10] Whiting DA, Nagi MA: Manual on control of air content in concrete. Portland Cement Association (1998).

[11] Antunes RPN: Influência da reologia e da energia de impacto na resistência de aderência de revestimentos de argamassa, Universidade de São Paulo, São Paulo (2006).

[12] Senff F, Hotza D, Labrincha JA: Effect of lightweight aggregates addition on the rheological properties and the hardened state of mortars, Appl. Rheol. 21 (2011) 13668.

[13] Alves NJD: Avaliação dos Aditivos Incorporadores de Ar em Argamassas de Revestimento, Escola de Engenharia, Universidade de Brasília, Brasília (2002).

[14] Malkin A, Foudazi R, Masalova I: The rheology of binary mixtures of highly concentrated emulsions, Appl. Rheol. 21 (2011) 25326.

[15] Metin C, Bonnecaze R, Nguyen Q: Shear Rheology of Silica Nanoparticle Dispersions, Appl. Rheol. 21 (2011) 13146.

[16] Romano RCO, Schreurs H, John VM, Pileggi RG: Influência da técnica de dispersão nas propriedades de sílica ativa, Cerâmica 54 (2008) 456 – 461.

[17] Salager JL: Surfactantes em solucion acuosa, Cuaderno FIRP S201A, Modulo de Enseñanza em Fenomenos Interfaciales, Universidad de los Andes, Merida, Venezuela (1993).

[18] Fortes MA, Corghlan S: Simple model of foam drainage, J. Applied Physics 76 (1994) 4029-4035.

[19] John VM: Cimento de escória ativada com silicatos de sódio, Escola Politécnica da Universidade de São Paulo, Departamento de Engenharia de Construção Civil, São Paulo (1995).

[20] Krivenko P: Alkaline cements, concretes and structures: 50 years of theory and practice, in International Conference Alkali Activated Materials – Research, Production and Utilization. Praga (2007) 313 – 331.

[21] Oliveira IR, Studart AR, Pileggi RG, Pandolfelli VC: Dispersão e empacotamento de partículas: Princípios e aplicações em processamento cerâmico, Fazendo Arte Editorial (2000).

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

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