Effect of Lightweight Aggregates Addition on the Rheological Properties and the Hardened State of Mortars

L. Senff*[1], D. Hotza[2], J. A. Labrincha[1]

[1] Department of Ceramics and Glass Engineering/Centre for Research in Ceramics and Composite Materials (CICECO), University of Aveiro, 3810-193 Aveiro, Portugal

[2] Department of Chemical Engineering (EQA), Federal University of Santa Catarina (UFSC), 88040-900 Florianópolis, SC, Brazil

* Corresponding author: lsenff@gmail.com
Fax: x55.48.37219687

Received: 8.7.2010, Final version: 26.11.2010

Abstract:
This paper evaluates the use of lightweight aggregates (LWA), namely perlite (PER) and vermiculite (VER) in cement mortars. The workability of mortars was defined in rheometer and flow table tests. Three distinct LWA levels were added (0–3, 4.5–7, and 9–10.5 wt%) requiring the use of distinct water/solids (W/S) ratios (0.18, 0.265 and 0.35, respectively). In order to evaluate the performance of such formulations in the hardened state, the flexural and compressive strength after 28 days curing was also measured. In general, LWA caused a high variation on the yield stress and spread on table, being the yield stress the best rheological parameter to be related with the flow table. PER exerts a strong impact on initial yield stress, while the effect of VER is stronger for longer rheology testing periods. The compressive strength ranged from 12.3 MPa (0 % LWA) to 2.77 MPa (PER) and 2.39 MPa (VER).

Zusammenfassung:
In diesem Artikel wird der Einsatz von Leichtgewichtsaggregaten (LWA), Perlit (PRE) und Vermiculit (VER), in Zementmörtel evaluiert. Der Anwendungsbereich des Mörtels wurde durch rheologische Messungen und sogenannten Fließtisch-Tests ermittelt. Drei verschiedene LWA-Konzentrationen (0–3, 4.5–7 und 9–10.5 Gew.-%) wurden hinzugefügt, die unterschiedliche Wasser/Feststoff (W/S)-Verhältnisse erfordern (0.18, 0.265 bzw. 0.35). Um den Einsatz dieser Formulierungen im verfestigten Zustand zu evaluieren, wurde die Biege- und die Druckfestigkeit nach einer Aushärtungszeit von 28 Tagen ebenfalls gemessen. Die Zugabe von LWA verursachte i. Allg. eine hohe Variation der Fließspannung und der Ausbreitung bei den Fließtisch-Experimenten. Die Fließspannung war der geeigneteste Parameter, um mit den Resultaten der Fließtisch-Experimente in Beziehung gesetzt zu werden. PER beeinflusst wesentlich die Fließspannung, wohingegen VER sich bei längeren rheologischen Versuchen als stärker erwies. Die Druckfestigkeit variierte zwischen 12.3 MPa (0% LWA) bis 2.77 MPa (PER) und 2.39 MPa (VER).

Résumé:
Cet article évalue l'utilité des agrégats légers (LWA), c-à-d la perlite (PER) et la vermiculite (VER), pour les mortiers de ciment. La facilité de mise en œuvre des mortiers a été définie à l'aide de tests rhéomètriques et de tables d'écoulement. Trois niveaux différents de LWA ont été additionnés (0–3, 4.5–7, et 9–10.5% en poids) ce qui a requis l'emploi de ratios eau/solide distincts (0.18, 0.265 et 0.35, respectivement). Afin d'évaluer les performances de telles formulations à l'état dur, la résistance en flexion et compression après 28 jours de stockage ont également été mesurées. De manière générale, les LWA causent une grande variation de la contrainte seuil et de l'étalage sur table, la contrainte seuil étant le meilleur paramètre rhéologique ayant une relation avec la table d'écoulement. La PER exerce un impact fort sur la contrainte seuil initiale, tandis que l'effet de la VER est plus fort pour les périodes de tests rhéologiques plus longs. La résistance à la compression varie de 12.3 MPa (pour 0 % de LWA) jusqu'à 2.77 MPa (pour la PER) et 2.39 MPa (pour la VER).

Key words: Lightweight aggregates, perlite, vermiculite, mortar, rheology, flow table test

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

workability as determined in flow table and rheology tests. After defining the compositions the performance of such formulations were evaluated through flexural and mechanical strength at 28 days.

LWA caused a noticeable change in the rheological properties in relation to the REF mortar. The rheological behavior between PER and VER also differed being the yield stress the more affected rheological parameter. PER showed the highest absolute values of initial yield stress, while VER tended to act for longer periods. However, such changes depended on the dosage of water and LWA added. For the initial plastic viscosity PER exhibited the highest values but the difference between LWAs was not noticeable up to the end of the test. LWAs decreased the spread values on table and exhibited a better relationship with the initial yield stress if compared to plastic viscosity. Mortars with 3, 7, and 10.5 % PER exhibited similar values of spread on table, but at the end of rheology test they exhibited distinct results.

As expected the use of LWA degraded the mechanical resistance of mortars. However, changes on flexural and compressive strength were small with LWA additions when the W/S ratio was kept constant. On one hand, PER may contribute to fill the intergranular space of mixtures, on the other hand, the irregular shape of VER particles may influence developing stronger bonds within the matrix. The lowest value of compressive strength obtained were 2.77 (9.75 wt% PER) and 2.39 MPa (10.5 wt% VER), repectively. The lowest flexural strength was approximately 1 MPa for the same mortars.

ACKNOWLEDGMENTS

The authors acknowledge the support of CAPES, Brazil. The authors also thank Weber Portugal, Elken (microssilica) and Basf (superplasticizer) for providing raw materials for this work.

REFERENCES

[1] Soroka I: Concrete in hot environments. Taylor & Francis, London (1993).
[2] Clarke JL: Structural lightweight aggregate concrete. Taylor & Francis, London (1993).
[3] Chandra S and Berntsson L: Lightweight aggregate concrete: science, technology, and applications. Noyes Publications William Andrew, Norwich (2002).
[4] Mehta PK and Monteiro PJM: Concrete – microstructure, properties, and materials. McGraw-Hill,New York (1993).
[5] Klieger P and Lamond FL: Significance of tests and properties of concrete and concrete-making materials. ASTM International (1994).
[6] Delatte NJ: Concrete Pavement Design, Construction, and Performance. Taylor & Francis, New York (2007).
[7] Abeles PW and Bardhan-Roy BK: Prestressed concrete designer's handbook. Taylor & Francis, New York (1981).
[8] Nawy EG: Fundamentals of high-performance concrete. John Wiley and Sons, New York (2001).
[9] Popovic S: Concrete materials: properties, specifications, and testing. William Andrew, New Jersey (1992).
[10] Older I: Lea's chemistry of cement and concrete. Arnold, London (1998).
[11] Hedda V: Rheology and reactivity of cementitious binders with plasticizers. Ph.D. thesis, University of Science and Technology, Trondheim (2005).
[12] Senff L, Barbetta PA, Repette WL, Hotza D, Paiva H, Ferreira VM and Labrincha JA: Mortar composition defined according to rheometer and flow table tests using factorial designed experiments, Constr. Build Mater. 23 (2009) 3107 – 3111.
[13] Ramachandran VS and Beaudoin JJ: Handbook of analytical techniques in concrete science and technology. Noyes/ William Andrew, New York (2001).
[14] Demirboga R and Gül R: Thermal conductivity and compressive strength of expanded perlite aggregate concrete with mineral admixtures, Energy and Build. 35 (2003) 1155 – 1159.
[15] Vessalas K, Ray AS, Thomas PS, Sri Ravindrarajah R, Joyce P and Haggman DJ: Pitchstone Fines Pozzolanic Activity Assessment as Partial Portland Cement (PC) Replacements, J. Aust. Ceram. Soc. 44 (2008) 7 – 12.
[16] Demirboga R, Orung I and Gu R: Effects of expanded perlite aggregate and mineral admixtures on the compressive strength of low-density concretes, Cem. Conc. Res. 31 (2001) 1627 – 1632.
[17] Demirboga R and Gu R: The effects of expanded perlite aggregate, silica fume and fly ash on the thermal conductivity of lightweight concrete, Cem. Concr. Res. 33 (2003) 723 – 727.
[18] Erdem TK, Meral C, Tokyay M and Erdogna TY: Use of perlite as a pozzolanic addition in producing blended cements, Cem. Concr. Compos. 29 (2007) 13 – 21.
[19] Turkmen I and Kantarc A: Effects of expanded perlite aggregate and different curing conditions on the physical and mechanical properties of self-compacting concrete, Build Environm. 42 (2007) 2378 – 2383.
[20] Topçu IB and Isikdag B: Effect of expanded perlite

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

aggregate on the properties of lightweight concrete, J. Mater. Proces. Tech. 204 (2008) 34–38.
[21] Yu LH, Ou H and Lee LL: Investigation on pozzolanic effect of perlite powder in concrete, Cem. Concr. Res. 33 (2003) 73–76.
[22] Silva LM, Ribeiro RA, Labrincha JA and Ferreira VM: Role of lightweight fillers on the properties of a mixed-binder mortar, Cem. Concr. Compos. 32 (2010) 19–24.
[23] Mladenovic A, Suput JS, Ducman V and Skapin AS: Alkali–silica reactivity of some frequently used lightweight aggregates, Cem. Concr. Res. 34 (2004) 1809–1816.
[24] Min BH, Erwin L and Jennings HM: Rheological behaviour of fresh cement paste as measured by squeeze flow, J. Mater. Sci. 29 (1994) 1374–1381.
[25] Wong GS, Alexander AM, Haskins R, Poole TS, Malone PG and Wakeley L: Portland-Cement Concrete Rheology and Workability: Final Report. Publication nº FHWA-RD-00-025. Structures Laboratory USAE Research and Development Center (ERDC) (2001).
[26] Okamura H and Ouchi M: Self-Compacting Concrete, J .Adv. Concr. Technol. 1 (2003) 5–15.
[27] Phan TH and Chaouche M: Rheology and stability of self-compacting concrete cement pastes, Appl. Rheol. 15 (2005) 336–343.
[28] Hendrickx R, Rezeau M, Van Balen K, Van Gemert D: Mortar and paste rheology: concentration, polydispersity and air entrapment at high solid fraction, Appl. Rheol. 19 (2009) 52550.
[29] Cardoso FA, John VM and Pileggi RG: Rheological behavior of mortars under different squeezing rates, Cem. Concr. Res. 39 (2009) 748–753.
[30] Roel Hendrickx. The adequate measurement of the workability of masonry mortar. Ph.D. Thesis, Katholieke Universiteit Leuven, Belgium (2009).
[31] De Larrard F: Concrete Mixture Proportioning: A Scientific Approach. Taylor & Francis (New York) 1999.
[32] Banfill PFG: The rheology of fresh cement and concrete? A review. In Proc. 11th International Cement Chemistry Congress, Durban (2003) 161–171.
[33] EN 197-1:2004. Cement: composition, specifications and conformity criteria for common cements.
[34] Banfill PFG: Use of the ViscoCorder to study the rheology mortar, Mag. Concr. Res. 42 (1990) 213–221.
[35] Banfill PFG: Rheological methods for assessing the flow properties of mortar and relates materials, Constr. Build. Mater. 8 (1994) 43–50.
[36] EN 1015-3:2007. Methods of test for mortar for masonry. Part 3: determination of consistency of fresh mortar (by flow table).
[37] EN 196-1:2005. Methods of testing cement: determination of strength.
[38] EN 1015-11:1999. Methods of test for mortar for masonry – Part 11: determination of flexural and compressive strength of hardened mortar.
[39] Funk JE and Dinger DR: Predictive process control of crowded particulate suspensions. Kluwer Academic Publishers, Boston (1993).
[40] Ovarlez G, Bertrand F and Rodts S: Local determination of the constitutive law of a dense suspension of noncolloidal particles through magnetic resonance imaging, J. Rheol. 50 (2006) 259–292.
[41] Mechtcherine V, Haist M, Staerk L and Mueller HS: Optimization of the rheological and fracture mechanical properties of lightweight aggregate concrete. In Report 24: Workability and Rheology of Fresh Concrete: Compendium of Tests – Report of RILEM Technical Committee TC 145-WSM (2002).
[42] Seng CK: Workability and stability of lightweight aggregate concrete from rheology perspective. Ph.D. Thesis, National University of Singapore, Singapore (2006).
[43] Roussel N: Correlation between yield stress and slump: Comparison between numerical simulations and concrete rheometers results, Mat. Struct. 39 (2006) 501–509.
[44] Ferraris CF and De Larrard F: Modified slump test to measure rheological parameters of fresh concrete, Cem. Conc. Aggreg. 20 (1998) 241–247.

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