Determining the apparent activation of the hydration of fresh and recycled cement by isothermal microcalorimetry and model-free kinetics

Eduarda BAPTISTA[1], Jorn VAN DE SANDE[1,2], Susana GIL-SAYAS[3], Guy VAN ASSCHE[1], Hubert RAHIER[1]

[1] Physical Chemistry and Polymer Science, Department of Materials and Chemistry, Vrije Universiteit Brussel (VUB), Pleinlaan 2, 1050 Brussels, Belgium

[2] KU Leuven Department of Materials Engineering, Kasteelpark Arenberg 44, 3001 Leuven, Belgium

[3] Department of Chemical and Materials Engineering, Universidad Politécnica de Valencia, Camino de Vera, s/n, 46022, Valencia, Spain

e-mail: eduarda.baptista@vub.be

Introduction

Cement-based materials are the backbone of our modern built environment and are a large consumer of energy, materials and natural resources. As sustainable development is currently a pressing global subject, recycled construction waste cementitious material can be an efficient pathway for low-CO_2, low-cost eco-efficient solutions [1-3]. After being subjected to high temperature (300 – 1000 °C) hardened cement can regain its hydration capacity [4-5], so the production of reactivated cementitious materials based on a thermal process is an option for the recycling of hydrated cement [2-3]. In this work, cement paste with a w/c=0.40 was dehydrated at 500 °C during 2.5 h.

The hydration of the cement minerals is an exothermal chemical process and at early stages the generated heat can be monitored by isothermal calorimetry. Based on the heat flow pattern and the total heat released reaction models can be established. A model free kinetics [6] approach can be used for a first analysis before further processing of the data.

Experimental Methods and Results

Isothermal calorimetric measurements

The heat released was recorded with an isothermal calorimeter from Thermometrics. The measurements were carried out for 3 days. 10 g of paste were placed in glass vessel and then into the calorimeter.

Thermal Analysis

The thermal analysis was carried out using a Q 5000 under an inert atmosphere and was performed in alumina crucibles, up to a maximum temperature of 1000ºC, with heating and cooling speeds of 10ºC/min.

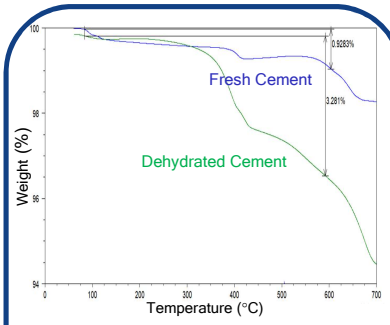

Figure 1 - Weight loss recorded by TGA for fresh cement and dehydrated cement.

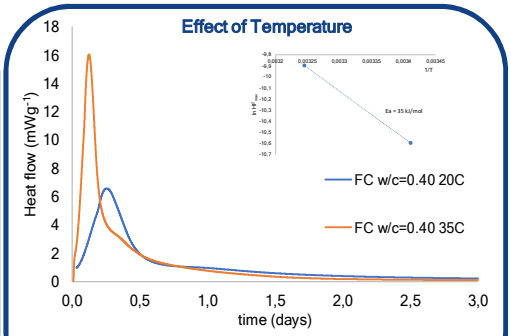

Figure 2 - Rate of heat evolution for: 20 °C and 35 °C. Apparent activation energy of fresh cement (w/c = 0.40).

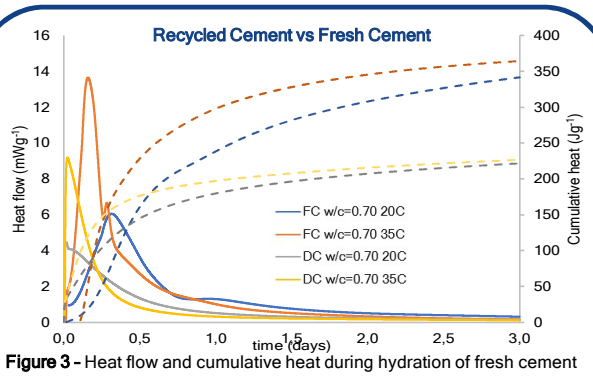

Figure 3 - Heat flow and cumulative heat during hydration of fresh cement (w/c=0.70) and recycled cement (w/c=0.70) at 20 °C and 35 °C.

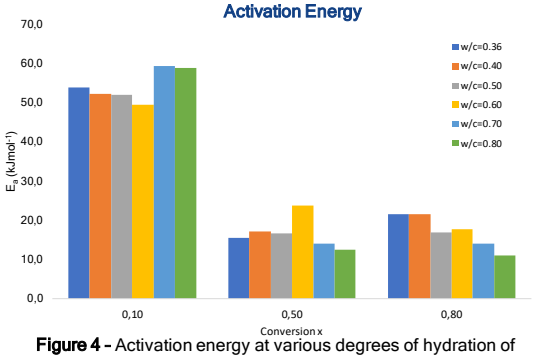

Figure 4 - Activation energy at various degrees of hydration of fresh cement with different w/c ratio.

Conclusions

- The dehydrated cement has a different hydration kinetics compared to fresh cement as observed using microcalorimetry.
- By model free kinetics the apparent activation energy of cement paste (w/c=0.40) prepared with fresh cement is 35 kJ/mol.
- Cement paste using recycled cements is not workable with a w/c below 0.70.
- The apparent activation energy strongly depends on conversion.
- The hydration rate increases with temperature for both fresh and dehydrated cement.

References

[1] K. L. Scrivener, V. M. John, and E. M. Gartner, "Eco-efficient cements: Potential, economically viable solutions for a low-CO2, cement-based materials industry," p. 50, 2016.
[2] R. Serpell and M. Lopez, "Properties of mortars produced with reactivated cementitious materials," *Cem. Concr. Compos.*, vol. 64, pp. 16–26, 2015.
[3] R. Yu and Z. Shui, "Efficient reuse of the recycled construction waste cementitious materials," *J. Clean. Prod.*, vol. 78, pp. 202–207, 2014.
[4] Z. Shui, D. Xuan, W. Chen, R. Yu, and R. Zhang, "Cementitious characteristics of hydrated cement paste subjected to various dehydration temperatures," *Constr. Build. Mater.*, vol. 23, no. 1, pp. 531–537, 2009.
[5] M. Castellote, C. Alonso, C. Andrade, X. Turrillas, and J. Campo, "Composition and microstructural changes of cement pastes upon heating, as studied by neutron diffraction," *Cem. Concr. Res.*, vol. 34, no. 9, pp. 1633–1644, 2004.
[6] S. Vyazovkin, "Model-free kinetics," *J. Therm. Anal. Calorim.*, vol. 83, no. 1, pp. 45–51, 2006.

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