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# Hydraulicity Regeneration in Cement Pastes via Thermal Activation

**Abdellatif ABIDAR[1], Rabah HAMZAOUI[1], Othmane BOUCHENAFA[2], Sandrine MANSOUTRE[3], Céline FLORENCE[1], Laury BARNES DAVIN[4], Claire CAPRA[5], Bruno CLASSEN[6]**
[1]Université Paris-Est, Institut de Recherche, ESTP, 28 avenue du Président Wilson, 94234 Cachan, France
aabidar@estp.fr; rhamzaoui@estp.fr
[2]Concrete4change, Unit 4-5-7 - The Heathcoat Building, Nottingham Science & Technology Park, University Boulevard, Nottingham, NG7 2QJ, United Kingdom
o.bouchenafa@concrete4change.com
[3]Ecotoolbox, 44 Boulevard de Picpus 75012 Paris, France
[4]Vicat, 4 Rue Aristide Bergès, Les Trois Vallons 38080 L'Isle d'Abeau, France
[5]Lafarge France, 2 avenue du général de Gaulle 92148 Clamart Cedex, France
[6]Ciments Calcia – Heidelberg Cement, Pôle Route et Développement, BP01 Les Technodes 78930 Guerville, France

## Extended Abstract

Concrete is one of the world's most widely used construction materials. Its extensive use in infrastructure and buildings makes it a fundamental pillar of modern society. However, conventional concrete manufacturing generates an environmental footprint, with emissions of carbon dioxide ($CO_2$) and other pollutants, as well as intensive exploitation of natural resources.

Faced with these growing environmental challenges, concrete recycling is a promising solution. Concrete recycling involves recovering crushed concrete aggregates from demolition debris and using them as a substitute for natural materials in producing fresh concrete or granular pavement material, particularly in structural layers such as pavement bases and sub-bases.

Other alternatives involve utilizing the fine fraction of concrete waste as an alternative raw material for clinker manufacturing or as an addition to cement [1], [2]. In recent studies, researchers have been exploring the potential of thermal activation to regenerate the hydraulic properties of cementitious materials. This method is being investigated to develop an innovative and eco-friendly cementitious binder [3].

This recent document presents part of a research project [4] focused on concrete recycling from a circular economy perspective. It provides an in-depth study of the regeneration of cement paste hydraulicity. We propose a process based on the thermal treatment of powders obtained from crushing hydrated cement pastes for 28 days at various temperatures between 400°C and 800°C. Characterization techniques, including $^{29}$Si-NMR and XRD with the Rietveld method, were used to understand the mechanisms behind hydraulicity regeneration.

Starting from a thermal treatment of 600°C, the formation of two $C_2S$ polymorphs ($\alpha'_H$-$C_2S$ and $\beta$-$C_2S$) was identified by X-ray diffraction, as shown in previous experimental work[5]. This finding was further confirmed by $^{29}$Si-NMR spectroscopy, which also showed that C-S-H is completely decomposed at this temperature, leading to the formation of belite. Further research corroborated these results, highlighting the formation of both $C_2S$ polymorphs with a predominance of $\alpha'$-$C_2S$ [6], [7]. These studies provided further confirmation of our initial observation, underlining the consistency of the conclusions obtained.

Quantification using the Rietveld method revealed that the predominant polymorph is $\alpha'_H$-$C_2S$, and amorphous phases were also significant with a weight of 30%. In contrast, NMR spectroscopy showed the opposite based on the peak areas corresponding to the identified polymorphs. These results indicate that the $\beta$-$C_2S$ formed at these temperatures could be nanosized or poorly crystallized, making it undetectable by the diffractometer.

The hydration of binders obtained between 600 and 800°C required higher water quantities than traditional cement. They are also reactive, likely due to the high reactivity of lime produced during thermal treatments. Thus, all the belite formed was consumed after 28 days of hydration.

These results suggest that this process would allow the obtention of belitic cement at low temperatures, which can be considered a low-carbon cement. This demonstrates that producing cement from recycled concrete is feasible.

***Keywords*****:** Hydraulic regeneration; Structure; Heat treatment; recycling; XRD; NMR; Rietveld method.

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