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Advances in Cement Research

Editorial: Clinkering reactions

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Clinker is the key ingredient in conventional concrete, responsible for providing the favourable binding properties as well as the unfavourable carbon dioxide (CO_2) emissions associated with concrete production. These emissions amount to approximately 10% of anthropogenic CO_2 emissions that are changing our climate and endangering human life on Earth. They arise mainly from the clinkering process thermochemistry which involves the calcination of limestone ($CaCO_3 \rightarrow CaO + CO_2$) and currently relies on fossil fuels to supply red heat that enables the reactions leading to the formation of desired clinker minerals, emitting CO_2 in the process (fossil fuel + $O_2 \rightarrow$ Heat + H_2O + CO_2).

Clinker research has been relatively overlooked and underfunded for decades compared to other areas of cement and concrete research. One reason for this is the oligopoly of cement production that is centralised, with manufacturers preferring to support research that utilises their raw materials and main product and increases efficiency of their existing capital equipment, while maintaining manufacturing know-how internally. However, the dangers of climate change have brought about the eye-opening realisation that radical change in clinker production is necessary. It is now inevitable that the way we produce clinker is going to change dramatically and existing cement kiln configurations, or at least parts of them, will become redundant. We should experience the decentralisation of cement production in the near future and the number of projects and startups in this space is testament to this.

Furthermore, infrastructure produced after World War II is reaching end-of-life and this, along with ongoing disasters and conflicts, is accelerating the transformation of the cement industry since large amounts of concrete waste need to be recycled. Re-clinkering hardened cement paste diminishes the use of virgin limestone and fossil fuels, and is a genuine route to circular concrete production which also promotes local businesses and opens up new pools of alternative raw materials and fuels.

This *Advances in Cement Research* (ADCR) issue on "Clinkering reactions" presents four papers that highlight some of the major challenges concerning modern and future clinker production, including the effect of minor elements that can stem from both fuels and raw materials, process modelling, and variations/fluctuations in process conditions and materials chemistry across the cement factory. I am honoured to have been the Associate Editor handling these four works, which I now introduce, and am extremely grateful to all the reviewers and publisher staff who supported the process.

- In their paper "*Thermochemical behaviour of several common salts blended with cement raw material*", Sun *et al*. discuss the role and fate of chemical elements, in particular volatile chlorine and sulfur containing salts, involved in the clinkering process and assessing their influence on targeted clinker minerals.
- Vikström *et al*. discuss "*Volatilization of elements during clinker formation in a carbon dioxide atmosphere*". Their work assumes a CO_2 rich processing atmosphere that could form in clinkering systems where, for example, air is not used as an oxidant, and they study variations in composition of minor elements including those regulated in EU directive 2010/75.
- When clinker is produced, it is generally quenched to maintain, insofar as possible, the high temperature phase assemblage and preserve it at room temperature. For this, a grate cooler is generally used in the cement plant. In their work, Kao and Wang perform a "*Numerical investigation of heat transfer in the clinker cooling process of grate cooler*". The understanding and optimisation of the clinker cooling process is important to improve process efficiency and advance cement research.
- Belgacem and Galai focus on "*Formation of build-up in a cement kiln preheater: qualitative and quantitative mineral characterisation*". It is extremely important to understand the phase changes that occur across the clinkering process as buildup can be detrimental to the process efficiency and economics as well as to the equipment and health and safety of the plant.

There is now good momentum driving research on alternative cement manufacturing processes and the production of alternative clinkers, and ADCR is supporting this research. In June 23–25 2025, the 3rd International Workshop on Calcium Sulfoaluminate Cements will be held at the University of Leeds, where the entire first session focuses on clinkering and showcases novel production techniques and alternative and/or locally sourced raw materials for the production of clinker, including at semi-industrial/pilot scale. Selected papers from the event will be published in an ADCR special issue.