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Alkali-activated cements - A clinker-free alternative to Portland cement

The Portland cement industry is facing a key challenge: how to dramatically reduce its CO_2 footprint while satisfying a growing global demand. In order to meet environmental targets, a range of new technologies, including low CO_2 cement(s), will need to be adopted over coming decades.

This enormous challenge has started a race within the scientific community to develop a new generation of environmentally-friendly cements. A number of materials have already been developed, although none of them alone is likely to change the industry on a global scale. Long term, there is likely to be more than one 'winner,' as sustainability can only be achieved by adopting an increasingly diverse range of cements that takes advantage of the chemistry and availability of local raw materials.

Alkali-activated cements (AACs), often called geopolymer cements, are recognised as one of the most viable alternatives to ordinary Portland cement (OPC) due to their low embodied CO_2 and cost. Since their discovery in the 1950s, AACs have been commercialised on a relatively small-scale and used mainly for non-structural applications. In general, they are competitive on cost and performance in comparison with OPC, and have environmental and technical benefits, including significant reduction in CO_2 emissions and increased fire and chemical resistance. In recent years, there has been an increase in the use of AACs due to their scientific and technological advancements. Lucideon has developed MIDAR, a range of geopolymers that deploy and exploit AACs on a commercial scale in general construction, nuclear waste immobilisation and other niche applications.

One of the main barriers to widespread adoption of AACs has been the lack of building standards for cement and concrete. Recently the BS PAS 8820 standard was developed in the UK to remove this obstacle and encourage the use of AACs in the construction sector. The new standard specifies the performance and durability requirements and acts as an important guide for producers. In the UK, it is a significant milestone for the technology, as it provides AACs with a stronger route to market. There is no indication as to whether or not EU standards will follow this approach in the near future.

In the current market, access to AAC technology is either through: **1.** A commercial producer (provided that the distance is not cost prohibitive), or; **2.** Locally-available materials to formulate AAC and optimise it for a given application.

There is no single geopolymer formula and different mineral precursors may require different levels of activation. Furthermore the producer-user needs to

Below: MIDAR terrazzo is GGBS concrete with decorative aggregate. Ground surface gives a terrazzo effect.

Right: GGBS MIDAR concrete paving slab.

precursors into silicate and alumina units, which then re-combine in void spaces to produce a rigid inorganic polymer that acts as a strong binder.

The mechanical strength and other properties of AACs arise from the chemical bonds between aluminium and silicon, instead of calcium and silicon in OPC. Depending upon the selection of mineral precursor and by controlling the amount and composition of the activator, the geopolymer can be specifically tailored. This allows a degree of performance control than is available with OPC. It is possible, for example, to achieve a combination of very high early and final strengths in the same application.

Geopolymers, such as Lucideon's MIDAR formulations, have the potential to replace a significant proportion of OPC currently used in general construction. AACs may also find a range of niche applications where their highly controllable properties allow them to go further than OPC. Initial routes to market for concrete products based on AACs could be via simple applications such as precast elements, grouts, rapid set sealing formations or ultra-low viscosity products to seal porosity.

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have an understanding of relevant performance tests and technical support. Using its MIDAR technology, Lucideon, an international materials technology company, provides support throughout the entire customised AAC product development process.

MIDAR formulations may utilise globally distributed virgin precursors, such as fired clays, as well as locally-available industrial wastes and by-products of different qualities. Suitable raw materials include ground granulated blast furnace slag, silico-manganese slag, fired kaolinitic clays, mineral processing tailings (e.g. coal gangue, red mud, mine tailings, etc.), catalyst residues, coal fly ash and incinerator bottom ash, rice husk ash, palm oil fuel ash, biomass ash, waste glass and ceramic, incineration sludges (e.g. paper sludge ash, sludges resulting from water treatment, etc.) and natural minerals (e.g. volcanic ashes). The most readily available aluminium and silicon containing raw materials are fly ash, slag and clays which, in general, require calcination at 750°C to become useful. The alumino-silicate rich material is mixed with a small amount of soluble alkali activator to make a paste that performs in a comparable way to OPC. The alkaline solution decomposes the mineral

Right: Aerated fly ash MIDAR concrete.