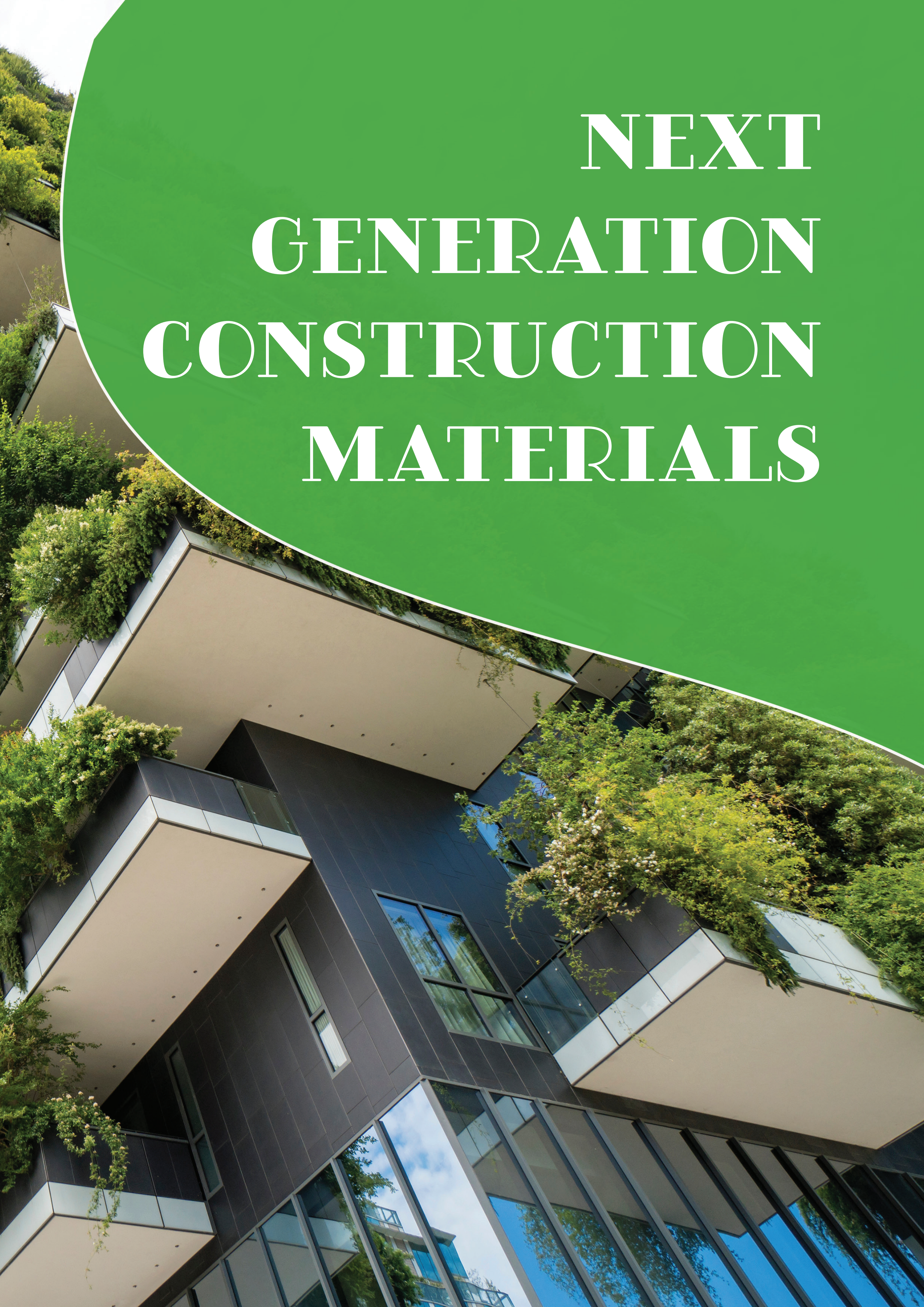
Martin Paterson, C2CA, predicts the next best SCMs in the race beyond slag and fly ash.

With an expected increase in cement production from 4.2 to 5.0 Gt/year by 2050, driven by population growth and urbanisation, there is an urgent need to reduce clinker content and increase supplementary cementitious material (SCM) usage to lower concrete's carbon footprint.

Reducing clinker content aligns with the available clinker production capacity, currently at a 70% utilisation rate, and the trend towards lower clinker and higher SCM use in cement. Laboratory tests have shown that cement blends with only 25% clinker can match the quality of existing solutions. However, accommodating these new blends requires evolving from prescriptive cement standards to performance-based specifications, as exemplified by the EU standards [EN197] specifying 34 unique cement types, many utilising SCMs.

NEXT GENERATION CONSTRUCTION MATERIALS



The availability of traditional SCMs such as fly ash and slag is increasingly becoming a concern due to their scarcity in many regions. The main reasons for this are the increased demand for sustainable construction materials, shifts in energy production, regulatory changes, economic factors, and geographical constraints. This scarcity poses a challenge for sustainable construction practices, as these materials are essential for reducing the environmental impact of concrete and cement production. In light of this scarcity, the need for alternative SCMs has become paramount.

Beside calcined clays, slags other than GGBFS and various mine tailings, waste concrete emerges as a viable and abundant solution to this challenge. Unlike most of the other mentioned alternatives, waste concrete is widely available and often found in proximity to construction sites where it is needed the most. This readily available source not only addresses the scarcity issue but also minimises transportation-related environmental impacts, making it a pragmatic and sustainable choice for SCMs in concrete and cement production. By harnessing the potential of waste concrete as an SCM, not only are the demands of the construction industry met but a contribution to the circular economy also takes place via the repurposing of materials that would otherwise end up as waste in landfills.

The global concrete waste market

The global concrete recycling landscape is characterised by both environmental challenges and significant economic potential. Each year at least 3 billion t of new concrete waste is generated worldwide, underscoring the magnitude of the issue and this does not even take into account the huge amount of waste that has been landfilled over the decade. However, this challenge is also an opportunity, as it paves the way for innovative and sustainable solutions. Size estimates for the major global concrete waste markets are shown in Figure 1.

While most of the currently available solutions focus either on landfilling or downcycling the waste to a road base aggregate, C2CA being a Dutch tech startup, has developed an innovative process (Figure 2) to transform this concrete waste into a highly reactive SCM, to either replace clinker in cement or cement in concrete.

"The process is unique and combines a series of technologies to ensure a clear separation between the different fractions, a smooth liberation and the highest possible yield of fines and an activation step which transforms the fines into a reactive binder", states Thomas Petithuguenin, CEO of C2CA.

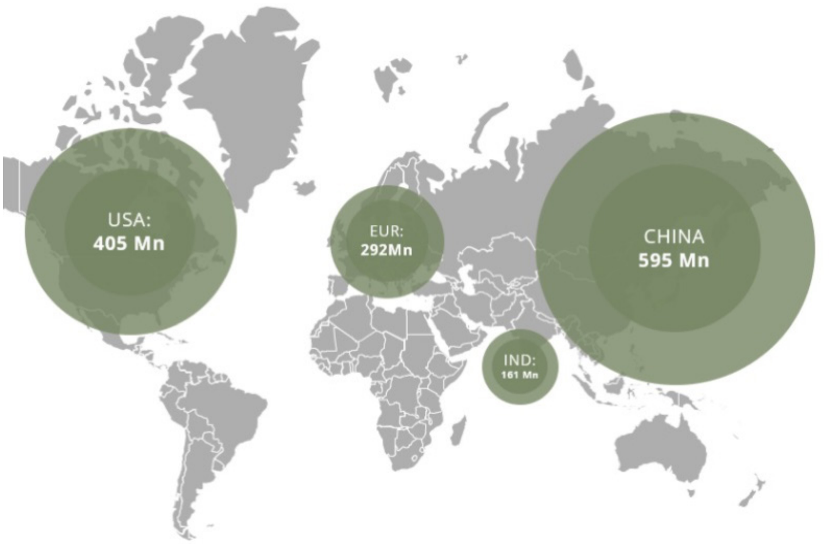


Figure 1. Annual concrete waste in tons.

Concrete waste showing an enormous potential

Considering the potential to harvest 15 – 30% of SCM from the concrete waste, the processing and upcycling could replace 450 – 900 million tpy of cement, which is equivalent to 25% of the global annual production and accordingly would allow for a reduction of 2% of global CO_2 emissions.

"To unleash the full potential of our technology

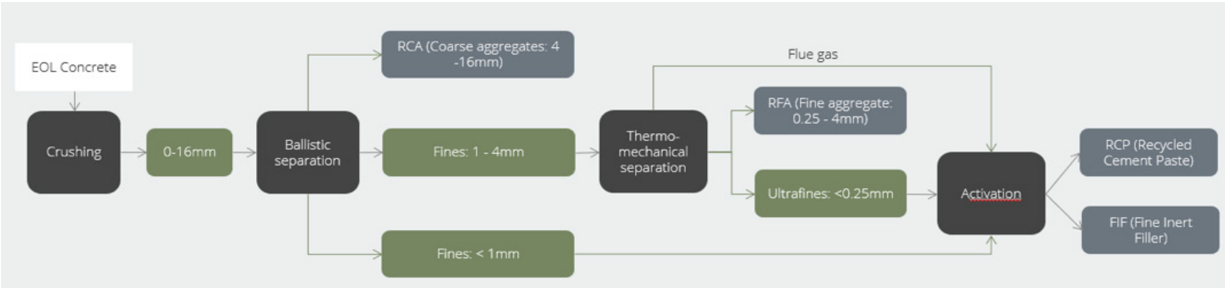


Figure 2. Core C2CA process.

it will need several thousand decentralised plants operating with the C2CA process but in the long term, we believe we will find enough global partners to create a significant impact on the reduction of greenhouse gas emissions", states Martin Paterson, CCO and Head of Products.

Martin further highlights that the processing of concrete waste not only has enormous environmental potential but also is very interesting from a commercial perspective:

"While traditional downcycling – this is mainly crushing down the concrete waste to road-based aggregates – can be sold to the market at a price of max. €2 – 5/t, the upcycling and selling of the gravel, sand and fines as an SCM can result in a total value of €30/t of upcycled concrete waste."

Production start next year

The C2CA process, along with its associated machinery and resulting products, has undergone an extensive development in various industrial-scale projects involving collaborations with both industrial and academic partners over the past four years.

Priya Perumal, C2CA Chief Science Officer explains: "In 2023, we successfully processed 1000 t of waste concrete, allowing us to fine-tune our process for enhanced reliability and quality. Our various output products went through rigorous testing for concrete mixes, encompassing evaluations of compressive and splitting strength, frost/thaw resistance, and shrinkage. Additionally, our involvement in six distinct sustainability projects within the Dutch

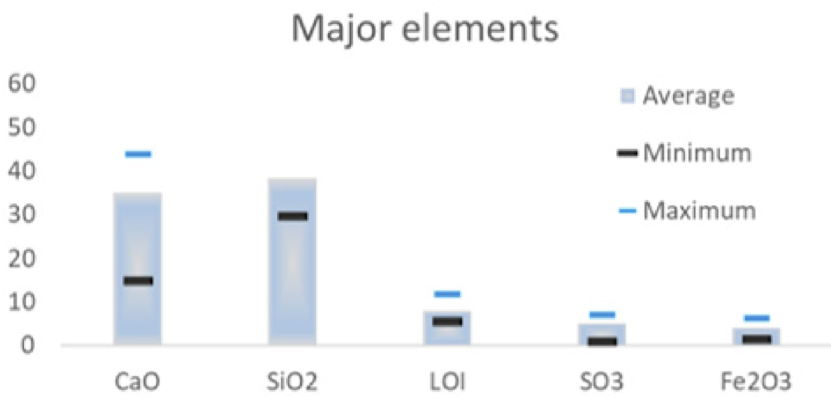


Figure 3. Chemical properties of Recycled Cement Fines (RCF).

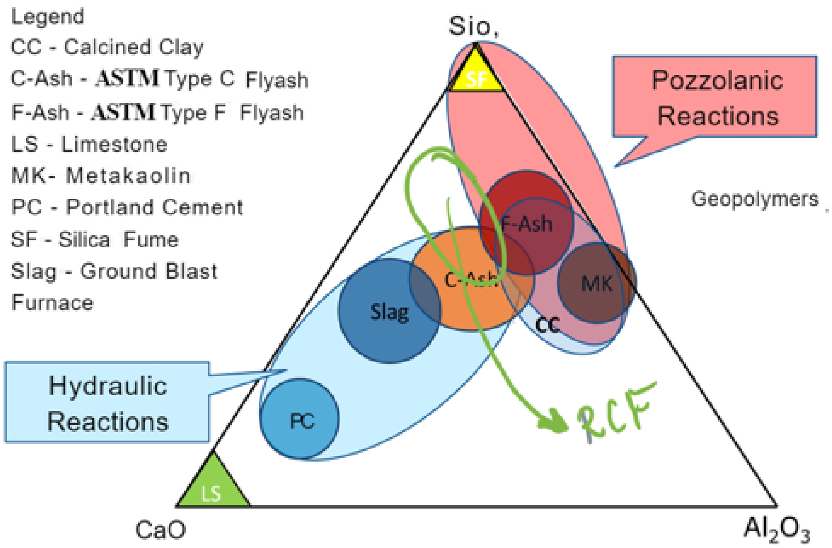


Figure 4. RCF in the Ternary Phase Diagram.

Process details.

The C2CA process allows for adjustments to maintain a certain high-level uniformity. Advanced screening methods increase the input material quality, the crushing and separation steps can be adjusted to control the chemical composition of the fines and if required, local side stream materials can be added. The variations in chemical properties are shown in Figure 3.

The main fractions, being CaO and SiO_2 which are expected to take part in the hydration reactions, are responsible for the binding properties of the RCF. However, SiO_2 is either crystalline quartz or exists as hydrated products of the parent material and CaO exists as $CaCO_3$ or in hydrated products. These main elements of RCF can be activated to enhance the reactivity with additional mechanical, carbonation and thermal treatment, which is taken care of by the C2CA process.

SCMs are expected to be lower in calcium compared to traditional Portland Cement (PC) and high in pozzolanic reactivity. From the ternary diagram of the existing SCMs (Figure 4), slag with relatively high calcium content goes close to PC. Silicafume (SF) lies close to the SiO_2 rich zone and metakaolin (MK) mid-way between SiO_2 and Al_2O_3 with great pozzolanic properties. RCF can be placed in a region between hydraulic and pozzolanic materials with the presence of both CaO and SiO_2. With enhanced treatment, the potential of this material can be tapped at higher replacement levels with PC.

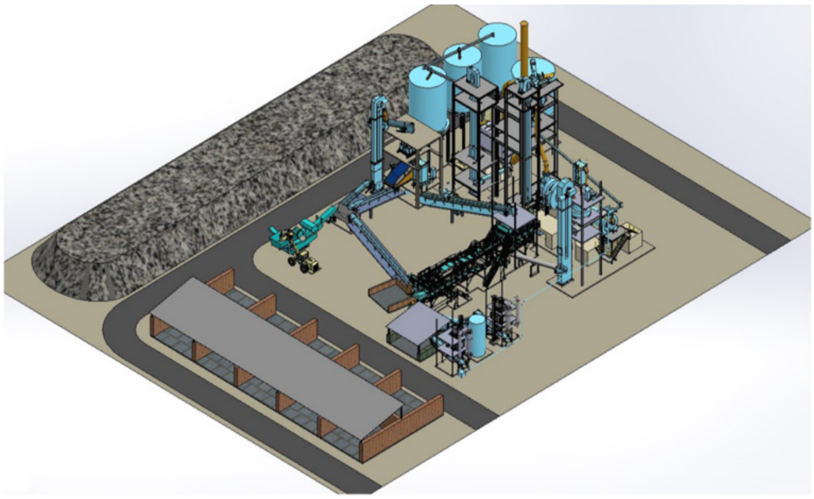


Figure 5. Plant layout C2CA flagship plant in NL.

government showcased the exceptional density and strength development of our materials. Importantly, these characteristics were identical to the reference structures produced with virgin raw materials."

The next milestone of the C2CA global rollout strategy, is the construction and operation of its first fully commercially scaled plant in the Netherlands. This flagship facility is set to commence production in Q2 2025, with the capacity to process approximately 150 000 tpy of waste concrete.

The project will be executed and operated through a joint venture with a local construction and recycling company. Their Circular Manager explains: "The Dutch construction sector is ready for upcycled construction materials and there is a strong push from the government and private sector to replace up to 50% of virgin raw materials by 2030. We have been searching for technology that is efficient, mobile, capable of operating in all weather conditions, and versatile in handling variable input quality and found everything in the C2CA process. The aim of committing to sustainability and keeping customer needs at the forefront, while guaranteeing high-quality output materials and robust economics made us believe in this long-term collaboration."

Combined forces to reach zero emissions

Answering the initial question on who will win the race of replacing slag and fly ash as traditional SCMs are not straightforward and will require a set of global and local solutions.

"There is no silver bullet and even though the CO_2 emissions for our recycled concrete fines (validated by a third-party Life Cycle Assessment), confirm a low carbon footprint of less than 20 kg CO_2/t of produced SCM, the industry needs to consider other solutions in addition. In many locations, calcined clays, geopolymers or activated mine tailings might be the right solution but the big advantage of concrete waste is that it is globally widely available and close to the construction areas", states Martin.

Thomas adds: "To make a significant short term reduction in the CO_2 emissions from our sector, all solutions must be explored. Our focus is to produce a SCM from locally available raw materials, upcycled locally and delivered to local concrete producers. Joining forces is key to achieving this vision: by working together, sharing ideas, exploiting synergies, we can build a low carbon future with a much more diverse cement and concrete composition."

While collaborative efforts are key, a pivotal aspect involves advocating for legislative and standards changes to accommodate new, sustainable construction materials.

By fostering an environment that encourages and aligns with green practices, the way for a future is paved where industry growth and environmental responsibility go hand in hand. ■

About the author

With over two decades of experience in Project Management, International Sales, and Business Development, Martin Paterson is recognised as a leader in sustainable technology for the cement, concrete, and mining industry. His impressive career is anchored by an M.Sc. in Civil & Environmental Engineering. Martin's entrepreneurial spirit is evident in his ability to identify opportunities, lead bids, negotiate contracts, and cultivate customer relationships.

His leadership is not only marked by strategic vision but also by the ability to efficiently lead teams and navigate the intricacies of company operations. Martin's strategic versatility was showcased in various key roles at Christian Pfeiffer, FLSmidth A/S, and IBAU HAMBURG.