Reducing embodied carbon in concrete

Research into low-carbon concrete is ongoing and the use of new sources of supplementary cementitious materials is a promising pathway. Moreover, the incorporation of construction waste into new concrete mixes leads to a more circular and sustainable construction industry. This article explores the latest developments in low-carbon concrete.

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In today's rapidly evolving world, the pursuit of sustainability has taken centre stage. Climate change, driven largely by greenhouse gas emissions, has become an urgent global concern. The construction industry, a significant contributor to these emissions, is undergoing a transformative shift towards decarbonisation. In the GCCA's Roadmap to Net Zero cement additives and concrete admixtures play a significant role in CO_2 emission reduction levers such as efficiency in design and construction and efficiency in concrete production, savings in cement and binders and savings in clinker production. One of the key strategies in this journey is the development of low-carbon concrete. This article explores the latest developments in low-carbon concrete, including strength enhancers, cement additives, circular economy solutions, and tailored admixture packages.

Convert C is an additive for the treatment of returned plastic concrete to convert it into a dry, hardened, granular state

New developments in low-carbon concrete with strength enhancers

Traditional concrete has long been a major contributor to carbon emissions due to the energy-intensive production of cement. To mitigate this, researchers have been exploring innovative ways to develop low-carbon concrete without compromising its structural integrity. One significant advancement in this area is the incorporation of strength enhancers.

Strength enhancers are admixtures designed to improve the early and ultimate strength of concrete, allowing for reduced cement content, while maintaining the desired performance. Chryso & GCP (Saint-Gobain Construction Chemicals) has been at the forefront of researching and developing these enhancers. For example, the company's EnviroMix® SE is an inventive strength enhancer for concrete that reduces the cement factor by approximately 10 per cent, with early and late age strength gains anywhere from an average of 350-600psi up to as high as 1000psi. At a low dose, the strength enhancer in addition to a moderate dosage of a water reducer maintains premium concrete quality and performance. By using less cement, a major source of CO_2 emissions, the environmental footprint of concrete can be significantly reduced.

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These strength enhancers refine morphology and reduce porosity by improving the pozzolanic reaction. This enhances the binding properties of the cementitious materials in concrete, thus increasing and accelerating hydration.

Development of new cement additives to enhance low-carbon concrete

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The CHRYSO & GCP application lab technicians work in partnership with customers to customise concrete mixes in response to ever-changing material such as manufactured sands, cements and SCMs

Portland limestone cement (PLC) and new blended cements using pozzolanic materials (fly ash, natural pozzolan and calcined clay (CC)), as well as ternary binders based on several supplementary cementitious materials (SCMs), are promising alternatives to conventional Portland cement. PLC incorporates limestone, which naturally produces less carbon. Other natural SCMs, even if transformed through calcination, like calcined clay, or by-products from other industries, also offer a lower carbon footprint. Both options hold great potential for reducing the carbon footprint of concrete.

GCP has been developing new generations of cement strength enhancers that enhance the viability and performance of PLC and blended cements in North America. These additives help overcome some of the challenges associated with these alternative cements, such as increased water demand, reduced strengths, and packset issues.

This new portfolio of patent-pending solutions is a very robust response to SCM content maximisation, while mitigating SCM mix and quality variations. These innovations pave the way to lower carbon cement production and provide cement and concrete producers with robust quality and performance binders to meet the construction industry requirements.

As proven in several projects, these non-chloride new strength enhancing technologies with limited, if not any staining propensity, provide impressive strength gains, while controlling water demand and cement packset. With PLC specifically, strength improvements can reach up to 20-25 per cent at one day and 15-20 per cent at 28 days. This creates room for process and quality optimisation and further clinker reduction.

These new technologies combined with the GCP team's technical expertise allows the company to design optimal solutions for its customers. By addressing these issues, the adoption of low-carbon concrete becomes more feasible in the region.

The use of PLC and blended cements not only reduces CO_2 emissions but also conserves natural resources by reducing the demand for clinker, a primary component of traditional cement production. These innovations represent significant progress in the pursuit of sustainable concrete solutions.

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Increasing adoption of circular economy solutions

In addition to advancements in low-carbon concrete production, the adoption of circular economy solutions is vital in the construction industry. Three notable

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examples are Chryso®Quad, Convert C, and the Recover system from Chryso & GCP.

The Chryso Quad system is designed to enhance the use of complex aggregates such as harsh manufactured sands. Using lower-quality, more complex sands, and aggregates, which are locally sourced, without compromising the concrete quality significantly contributes to reducing supply lead time, costs, and improving the concrete CO_2 footprint through reduction in transportation impacts. Chryso & GCP's analysis has shown that the use of locally-available materials contributes anywhere between 0.4-9 per cent reduction in CO_2 or for every 100 miles by truck, rail or ship the CO_2eq would be 15.2kg (33.6lb), 3.1kg (6.93lb) and 2.6kg (5.78lb) respectively.

Convert C is an additive for the treatment of returned plastic concrete to convert it into a dry, hardened, granular state. The product is packaged in small 500g water soluble bags which makes additions directly into the mixer drum fast, easy and efficient. After the appropriate drum rotations, the discharge of the granular material, a standard wash-out procedure can be used to clean the drum. The output is excellent as a road base, fill materials, or landscape base with good granular distribution and compaction.

The Recover system is another innovative solution that enhances sustainability in concrete construction. According to the NRMCA, 2-10 per cent (average of five per cent) of the estimated 455myd^3 of ready-mixed concrete produced in the USA is returned to the concrete plant. Recover enables the recovery of fresh concrete that would otherwise be discarded, allowing it to be reused in subsequent batches. One customer case study shows 275yd/month of concrete that is salvaged (331t CO_2 eq/year of avoided emissions from cement alone which is equivalent to emissions from 40,263,716 smartphones charged). As a system, Recover is also used to make truck wash-out more efficient, which reduces material, water waste, and minimises the environmental impact associated with concrete production.

The adoption of circular economy solutions aligns with the broader sustainability goals of reducing waste and conserving resources. It also opens new opportunities for innovation and collaboration within the construction sector.

Optimisation and tailored admixture packages

While these developments are promising, it is crucial to recognise that sustainable solutions often involve trade-offs. The construction industry must carefully balance various factors, including performance, cost, readily-available materials and environmental impact – mix optimisation is a key approach to achieving these goals.

Mix optimisation involves tailoring concrete mix designs to specific project requirements and environmental objectives. Rather than relying on a single "silver bullet" admixture, this approach considers the complete admixture package that best suits the situation. It allows for a customised blend of additives, including strength enhancers, cementitious materials and other performance-enhancing compounds. The development of Chryso & GCP's HRWRs for high SCM replacement and strength enhancers allow the company to be creative with admix combinations. To address multiple low-carbon issues, it can tailor an admix package, for example, the Quad system mentioned earlier, combined with the EnviroMix® SE strength enhancer, tackles low-quality aggregates alongside cement replacement and cement reduction to drive optimal CO_2 reduction.

This approach recognises that there is no one-size-fits-all solution for carbon reduction challenges in concrete production. Factors such as regional differences, project specifications, and environmental regulations all play a role in determining the optimal mix design. By prioritising mix optimisation, sustainability goals can be met while meeting the performance requirements of each project.

Ongoing research and future prospects

The journey towards low-carbon concrete is an ongoing process, marked by continuous research and development. The industry must remain committed to driving innovation in the field of sustainable construction. This commitment extends to ongoing research efforts aimed at expanding the use of industrial by-products and construction waste streams in concrete production.

One promising avenue of research involves further exploring new sources of SCMs, such as natural and glass pozzolans and blended cements. These materials have the potential to further reduce the carbon footprint of concrete and offer additional benefits, such as improved durability and reduced permeability.

Additionally, ongoing studies are examining how to effectively incorporate construction waste streams, such as demolished concrete and masonry, into new concrete mixes. By diverting waste from landfills and reusing it in construction, these efforts contribute to a more circular and sustainable construction industry.

Conclusion

It is crucial to recognise that sustainability in construction is about making informed choices. There is no single solution to carbon reduction challenges. Instead, it is important to customise concrete recipes to meet specific project requirements and environmental objectives.

The urgency of reducing carbon emissions in the construction industry cannot be overstated. It is vital that industry leaders such as Chryso & GCP remain dedicated to the pursuit of low carbon concrete solutions, to continue to make significant strides in various aspects of sustainable construction. From the development of strength enhancers and cement additives to the promotion of circular economy solutions and tailored admixture packages, these innovations, and future breakthroughs are paving the way for a more sustainable and decarbonised construction industry. By collaborating and embracing these innovations, the construction sector can play a pivotal role in mitigating climate change and building a more sustainable future. ■