Additives and admixtures in action

The use of advanced additives and admixtures enables concrete producers to use calcined clay and other types of low-carbon cement, supporting the decarbonisation of concrete and construction projects. Research has shown that the use of additives and admixtures can significantly reduce the need for clinker, while maintaining strength development.

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While the high CO_2 impact of Portland cement has been widely acknowledged, the cement industry took early action towards measuring and reducing its CO_2 impact. Ongoing research is proving that concrete acts as a carbon sink throughout its lifecycle, further solidifying concrete as the material of choice with its durability, resilience, cost effectiveness and availability. To reach aggressive global decarbonisation goals there is still much work to be done, as the concrete sector seeks to use even lower cement content and ever-changing supplementary cementitious materials (SCMs).

The role of admixtures

SCMs such as fly ash, silica fume and slag have been used for years. However, with fly ash becoming less available due to coal power plant shutdowns, the industry has been seeking a variety of alternatives, such as ground glass pozzolans, natural pozzolans and calcined clays. Every SCM, whether used in blended cements or as a cement replacement in concrete mix design, has its own challenges: inconsistent supply, variable quality, transportation costs, storage and handling, increased water demand, setting time variability and strength development to name a few. Chemical admixtures have become critical in mitigating this wide range of issues.

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For example, solutions from Chryso, such as EnviroAdd™ for cement and EnviroMix®C-Clay for concrete, will become game changers in addressing these issues with added limestone in Type 1L cements and opening the use of calcined clays as "new" SCMs. Admixtures such as Chryso®Optima® and Chryso Quad® make it possible to use optimised amounts of natural pozzolans and utilise harsh materials such as aggregates lacking fines or having high fines content.

Ongoing research and testing seeks to unlock the potential of SCMs with advanced additives

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Unlocking the potential of SCMs with advanced additives

SCMs such as calcined clays, natural pozzolans, silica fume (Force 10,000 D), and slag are revolutionising concrete production by offering sustainable alternatives to traditional Portland cement. These materials, often derived from natural or industrial byproducts, replace a portion of cement in concrete mixtures, significantly reducing the carbon emissions associated with cement production, a major contributor to global CO_2 emissions. SCMs not only lower the carbon footprint but also enhance the performance and longevity of concrete.

Cement additives and concrete admixtures play distinct yet complementary roles in enhancing sustainability. EnviroAdd,

Figure 1: Using Chryso's proprietary Clear Test, the R&D team worked on the characterisation of over 30 calcined clays, originating from around the world

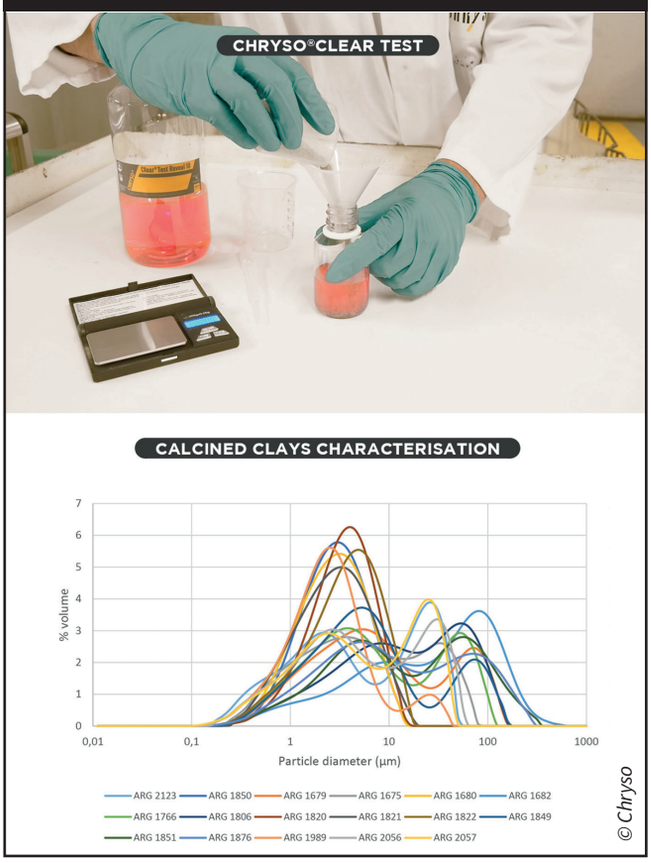
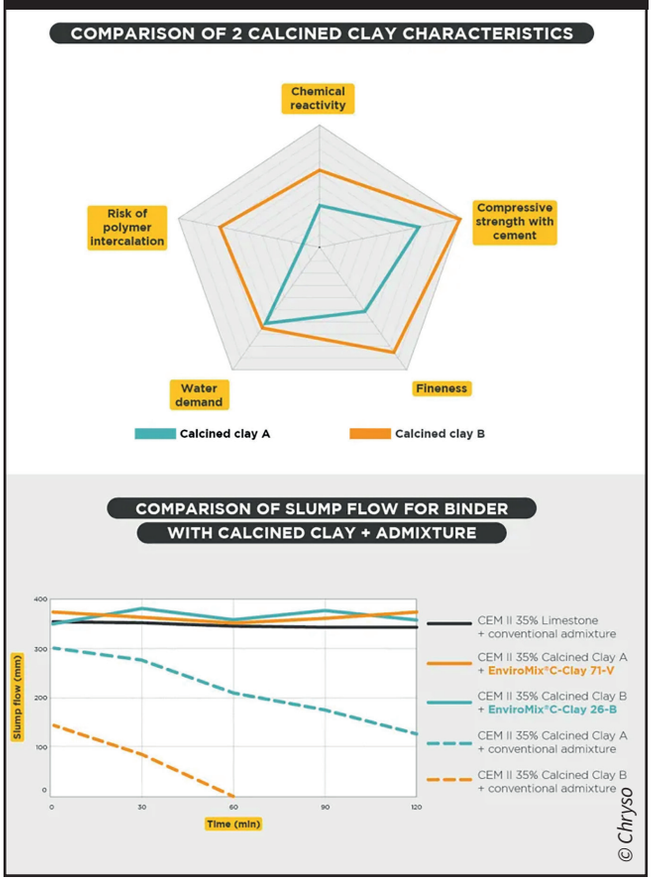


Figure 2: characterisation of over 30 calcined clays enables Chryso to create customised admixture solutions



as a cement additive, represents a range of tailor-made additive solutions to maximise the reduction of clinker in cement production. By enhancing cement reactivity and improving strength development, EnviroAdd improves cement performance when using slag or calcined clays in the cement manufacturing process, reducing the carbon-intensive clinker content, and costs of producing cement while maintaining superior cement performances.

Conversely, concrete admixtures, such as the EnviroMix C-Clay and Optima 1000 series, target the performance of SCMs within concrete mixtures. While Quad improves overall concrete performance in the face of optimising the use of local aggregates and sands, EnviroMix C-Clay improves the hydration and reactivity of calcined clays in concrete, ensuring their effective integration. Chryso Optima 1000 series enhances the dispersion and strength development of SCM-based mixes, while Quad ensures superior workability and finishability, even with harsh aggregates and sands, making concrete easier to place and finish, and addressing swelling clay mitigation to improve overall performance.

Together, these innovations enable substantial clinker reduction and maximise SCM utilisation, as well as locally available materials delivering lower-carbon, high-performance concrete that meets modern sustainability and engineering standards.

Applications and their results

Case study 1: key benefits

An independent study conducted with a German laboratory highlighted the transformative benefits of Chryso's next-generation activators, EnviroAdd, when used with CEM II/C-M(S-LL) cement containing 30 per cent slag and 20 per cent limestone. Key findings include:

- **exceptional strength gains** – EnviroAdd activators delivered compressive strength improvements of up to 17 per cent at 28 days and 84 per cent at one day, outperforming traditional grinding aids.
- **enhanced sustainability** – by enabling a seven per cent clinker substitution, the activators reduced CO_2 emissions and production costs, while maximising the efficiency and performance of SCMs.
- **low-carbon cement innovation** – EnviroAdd supports the development of low-CO_2 binders, including novel cement types such as CEM II/C-M(S-LL), achieving clinker content as low as 47 per cent.

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Case study 2: production of low-carbon cement

In an industrial trial with LC^3-50 cement (30 per cent calcined clay, 15 per cent limestone), EnviroAdd activators

demonstrated significant compressive strength improvements:

- with EnviroAdd "C": +5MPa (+38 per cent) at one day
- with EnviroAdd "B": +8MPa (+18 per cent) at 28 days .

Additionally, a customised additive, EnviroAdd "A", consistently met the cement plant's target performance across all ages, showcasing its versatility. The tailored combination of LC^3 and EnviroAdd solutions provides robust results, enabling the production of durable, low-carbon cement for the future of sustainable construction.

Case study 3: admixture for calcined clay applications

Chryso's R&D team worked extensively on the characterisation of over 30 calcined clays, originating from around the world, using in-house and patented methodologies, such as the CHRYSO® Clear test, to determine the optimum EnviroMix C-Clay formulation for each configuration (see Figure 1). This characterisation methodology enables R&D teams to determine, for each calcined clay studied, an "identity card" of the characteristics that have the most significant impact on its use in cement. These characteristics include fineness, water demand, chemical reactivity, compressive strength with cement and risk of polymer intercalation. This methodology empowers innovation teams to create customised solutions for the diverse calcined clays used in cement and concrete in the various markets where Chryso operates. Figure 2 highlights two different formulations of EnviroMix C-Clay favourable impact on slump retention over time. Both variations of CEM II including 35 per cent of different types of calcined clay using EnviroMix C-Clay significantly outperformed conventional admixtures in both initial slump flow and slump retention.

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Case study 4: CalPortland, USA

To lead the adoption of new SCMs and increase the use of its natural pozzolan, CalPortland's Phoenix operations in Arizona, USA, partnered with Chryso to identify admixtures to offset the higher water demand of the material. Using Chryso's expertise in polycarboxylate technology, the team tested solutions to balance performance and efficiency.

Quad and Chryso Optima 1000 series

Reference mix before EnviroMix®SE 30, no cement reduction (left) and reference after EnviroMix SE 30, minus 22.7kg (50lb) of cement (right)

emerged as optimal choices. Quad provided superior slump response, achieving better results when dosage was reduced by 30-60ml (1-2 fl oz). Chryso Optima 1000 series demonstrated high efficiency, with potential dosage reductions to 177ml (6 fl oz) while maintaining excellent performance. Both admixtures offered superior slump retention, enabling additional admixture reductions.

Quad also enhanced the mix's robustness, allowing higher incorporation of natural pozzolan, and offered opportunities to reduce the overall water content of their mixtures. Reducing water by 3.8-7.6l (1-2 US gallons) has the potential to improve strength and shrinkage performance, further enhancing durability and sustainability.

In North America, specifically the Southwest region, the Quad and Chryso Optima 1000 series together provided a cost-effective, efficient solution for SCM-rich concrete, supporting sustainability goals while maintaining high performance and durability.

Case study 5: Midwest, USA

The US Midwest, characterised by high volumes of residential construction, presents a significant opportunity to improve the sustainability of concrete without compromising its performance. Recent applications of EnviroMix® SE 30 in this region demonstrate its effectiveness in achieving cement reductions of 17.8-29.7kg/m³ (30-50lb/yd³), while maintaining or exceeding strength requirements.

Primarily used in single-family home construction, these adjustments have yielded measurable improvements. Concrete mixes incorporating EnviroMix SE 30 have shown superior workability and finishability, as noted in direct contractor feedback. Before-and-after comparisons further illustrate enhancements in surface quality, streamlining the placement and finishing process.

Beyond technical performance, the reduction in cement content contributes to a tangible decrease in CO_2 emissions, aligning with the industry's broader sustainability goals. This is particularly relevant in high-volume residential projects, where even incremental reductions can translate into significant environmental benefits over time. Additionally, the resulting cost savings provide an economic advantage to ready-mix producers, reinforcing the practicality of adopting strength enhancers in competitive markets.

These findings suggest that EnviroMix strength enhancers offer a viable pathway for balancing performance, cost efficiency and sustainability in residential concrete applications. Further study could explore its potential in other sectors or under varying regional conditions to extend its impact.

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Driving change in sustainable construction practices

The ability to integrate new SCMs into concrete and cement production is revolutionising the construction industry's approach to decarbonisation and sustainability. By incorporating materials such as natural pozzolans, calcined clays, or industrial byproducts, the carbon intensity of concrete can be significantly reduced without compromising performance. This shift directly impacts the built environment by lowering its overall carbon footprint, aligning with global climate goals.

Equally transformative are advancements in concrete admixtures and cement additives. Innovative products, such as strength enhancers, water reducers and advanced cement activators, enable higher concrete performance at lower cement content, further minimising CO_2 emissions. These solutions not only reduce the need for energy-intensive clinkers but also enhance durability, extending the lifespan of built structures and reducing lifecycle impacts of construction projects.

The widespread adoption of these technologies is poised to reshape industry standards. As these materials and admixtures prove their effectiveness, they are becoming integral to new building codes and green certifications, driving broader adoption. Furthermore, their scalability across global markets ensures their influence will be felt worldwide, from industrialised nations to regions seeking more sustainable construction solutions.

Through SCMs and admixtures, the concrete industry is leading a crucial shift, fostering a low-carbon future while maintaining resilience and innovation.

Advancing sustainability with innovative SCM solutions

Cutting-edge SCM-enhancing additives enable the effective use of alternative SCMs, such as calcined clays, dramatically reducing the carbon footprint of concrete, while maintaining or even enhancing its performance. Their integration delivers significant environmental benefits by curbing greenhouse gas emissions, and supports the industry's transition to low-carbon construction.

Beyond the environmental advantages, these additives provide significant economic and structural value. By optimising material efficiency and improving durability, they lower overall construction and maintenance costs. Their ability to enhance the performance of alternative SCMs also ensures that projects meet stringent industry standards without sacrificing quality, making sustainable solutions more accessible than ever.

To accelerate the decarbonisation of construction, a call to action is imperative. Widespread adoption of these technologies can drive sustainability at scale, offering immediate impacts, while paving the way for long-term industry reform. Ongoing trials with alternative SCMs, including diverse clay sources, and collaborations between industry stakeholders are essential to refine these innovations further. Through partnership and innovation, the concrete sector can lead global decarbonisation efforts, building a future where environmental responsibility and industrial growth coexist seamlessly. ■