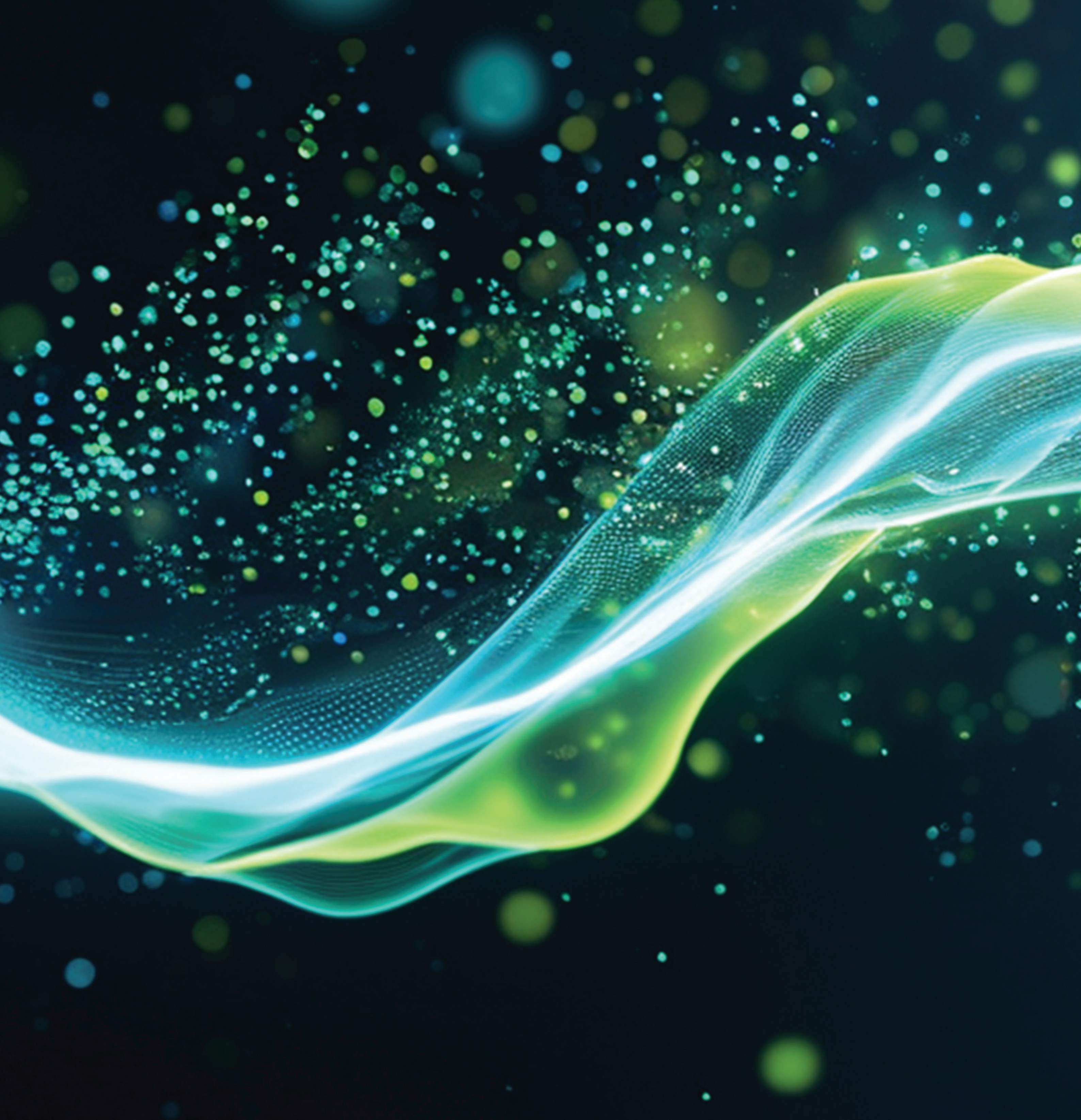
Stronger Blends, Greener Ends



Mike Stanzel & Oliver Sohn, Chryso North America, present a multilayered approach to maximising blended cement performance for use in concrete.

The landscape of cement manufacturing is evolving, driven by the need for more sustainable and lower embodied carbon construction materials. The introduction of blended cements, incorporating supplementary cementitious materials (SCMs), including finely ground limestone, has presented challenges for many cement producers. These challenges include reduced strength, leading to increased Blaine specific surface area (BSSA) and lower production rates, and subsequent field performance issues, such as higher water demand, reduced bleeding rates, plastic shrinkage cracking, and changes in set-times. These factors have led to some reluctance in certain markets to fully adopt these new materials.

While advanced grinding additives have helped regain some of the lost performance and production capacity, a more comprehensive approach is necessary to fully recover the desired performance and production levels of traditional ordinary portland cement (OPC). One must address the four critical levers essential for optimising blended cements to match traditional OPC expectations: proper clinker formation, mill optimisation, effective additive selection, and optimising quality targets (Figure 1).

By addressing all four key areas, cement producers can overcome the challenges associated with blended cements and achieve the performance and sustainability goals required in today's construction environment. Only by satisfying all four levers can the desired performance be achieved and sustained, ensuring that blended cements can meet modern needs without compromising on quality or efficiency.

Clinker formation

Clinker is the primary intermediate product in cement manufacturing, and its quality directly impacts the potential performance on the

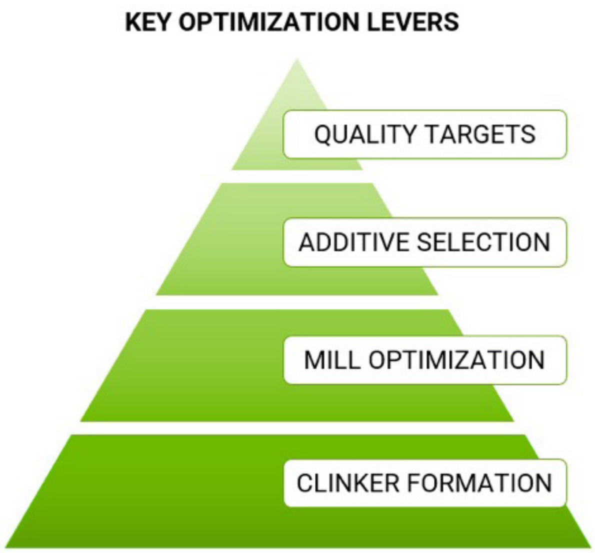


Figure 1. The four layers of cement optimisation necessary for achieving sustainable production.

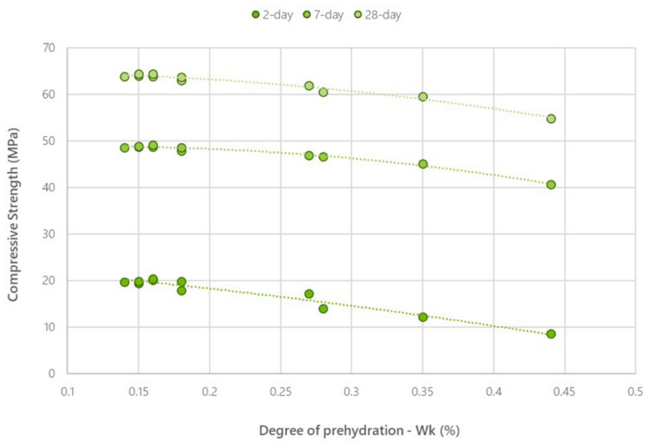


Figure 2. The impact of prehydration on EN-196 cement mortar strengths, where prehydration levels over 0.2% can lead to significant loss in performance.

final cement. Producing high-quality clinker consistently is a significant step to reducing emissions through supplementary material use, while meeting construction demands in the field. This involves careful control of:

- Chemical composition: particularly alite content, aluminate content, liquid phase to ensure good combinability, and a proper alkali-sulfur balance to avoid inhibiting C3S formation and cycling of the system.[1]
- Raw milling parameters: particularly kiln feed uniformity and sufficient target fineness to avoid free-lime and belite clustering.
- Burning and cooling conditions: ensuring oxidising conditions, proper burner alignment, rapid heating and cooling, and proper clinker density.

All of this not only impacts cement performance, but also clinker grindability, which is key to optimising combined particle size distributions of inter-ground blended cements.

While grinding additives can help address quality and process issues, they are most effective when the clinker quality is high to begin with. Quite simply, the better the clinker, the better the synergy with additives, the better the cement, and the happier the contractor out in the field.

Mill optimisation

Mill maintenance and optimisation is a critical area that often does not receive enough attention and budget allotment. Over the past two years, Chryso has conducted in excess of 350 mill audits globally, and identified several recurring issues. While chemical additives have proven to work even when a process is sub-optimal, minor operational adjustments and proper maintenance can result in significant improvements to both cement quality and mill output.

Air sweep and moisture optimisation

One of the more common deficiencies found in ball mill circuits is in achieving the designed airflow of 1 – 1.5 m/s over the charge, dependent on the mill geometry. Sufficient airflow is necessary both for ensuring adequate material transport through the mill and removal of fines, and for providing sufficient cooling. Although airflow measurements taken near the fan may often appear adequate, they do not always account for false air, which can be as high as 40% in sub-optimal systems.

This air flow loss may necessitate the use of higher volumes of cooling water, increasing the internal mill moisture. Combined with the moisture content of raw materials, this can increase the internal dew point, potentially leading to cement pre-hydration, which has negative effects on cement strength (Figure 2).

Elevated heat and moisture levels also increase the agglomeration tendency inside the mill, further reducing efficiency and often leading to increased usage of grinding aids to counteract the effects.

Ball charge optimisation

The mill ball charge is another critical factor in achieving an optimal grind. Many mills still use the same media design that was used for grinding OPC. However, the design needs to be adapted to optimise the circulating load for both the desired product performance and the mill circuit. This involves evaluation of both axial and circuit samples and often improves with finer charges and higher airflow to maintain proper filling degree and material transport. In many cases, a high degree of deformed scrap material was found within the charge and diaphragm slots, indicating that sorting frequencies needed to be increased and functional nib-traps installed.

Separator efficiency

Separator efficiency is key to ensuring a tight particle size distribution of the product and a low bypass of product back to the mill. Tromp curves should be run routinely to monitor performance and internal inspections conducted looking for signs of wear. In most cases, inefficiencies arise from low airflow, false air, or poor feed distribution, where the air-to-solids ratio is the primary driver of classification efficiency.

Measurable results

In one such case, a producer in North America was able to increase their production by nearly 5% by increasing their fan speed, replacing the mill outlet seal, and removing scrap material from the diaphragm. This resulted in over a 20% increase in mill airflow, which effectively reduced the cooling water usage by over 50% and the internal dewpoint from 67˚C to 58˚C, reducing the degree of prehydration to more tolerable levels (Table 1).

One final benefit from the inspection of the mill circuits by experienced external engineers that is often overlooked is the reassurance that can be obtained by being told the mill system is already well optimised. It is not uncommon that the plant staff are good at their jobs and confirmation of this by an external agency is always welcome.

Table 1. Process improvements made after a comprehensive mill audit in North America.

	Before	After
Total false air (%)	18	10
Fan speed (%)	68.0	90.0
Mill airflow (kg/h)	19 550	23 650
Water usage (%)	2.4	1.0
Dewpoint (C)	66.9	58.3
Feedrate (tph)	103	108
Returns (tph)	250	250

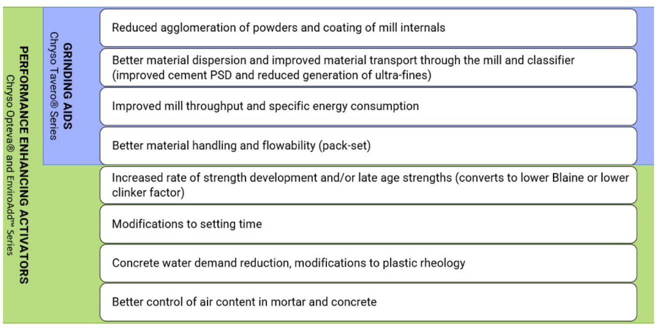


Figure 3. Traditional grinding aids reduce powder agglomeration tendencies and dispersion, improving mill throughput and specific energy consumption. Cement activators contain those same benefits but can be tailored to improve strength development or adjust other parameters important to field performance.

Additive selection

Once the producer has optimised the clinker and milling conditions, a high-performance additive can be much more effective at improving cement and mill performance. While traditional grinding aids improve powder dispersion and milling efficiency, activators can be tailored to a specific cement to augment various performance parameters (Figure 3), which can then be leveraged into further value for the cement producer.

Depending on the desired performance characteristics, a cement additive may contain several chemical components, including tertiary alkanolamines, retarders, or accelerators, which dissolve into the mix water during concrete production, altering the hydration process.[2] They can increase the degree of hydration, improve the morphology of hydration products, and enhance pore size distribution, leading to higher strength.

In summary, optimising clinker and milling conditions, combined with the appropriate use of cement additives, can significantly enhance cement performance, production efficiency, and overall quality. In addition to offering innovative products, it is also important for suppliers to offer localised technical support and a robust supply chain to ensure consistent and reliable performance in diverse market conditions.

Quality target optimisation

The capstone lever in cement optimisation is selection of appropriate quality targets. This goes beyond simply setting fineness targets and determining optimal sulfate addition, leveraging the value created through the whole optimisation chain to enhance cement quality, reduce energy consumption, and minimise CO_2 emissions.

Enhanced cement performance

Cement performance can be tailored to market demands, increasing strengths to reduce concrete cement contents, accelerate project timelines, or adjust setting times and workability. This flexibility allows for optimised concrete mixes with lower CO_2 footprints and faster completion times.

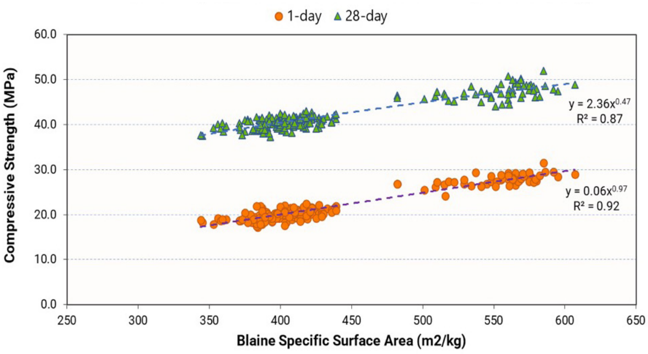


Figure 4. The impact of cement fineness (BSSA) and 1-day and 28-day compressive strengths. Data represents Type I and Type II cements, filtered for similar chemistry.

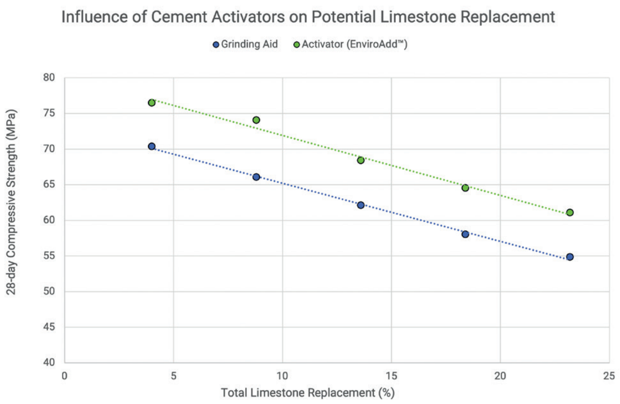


Figure 5. The impact of blending ground limestone (BSSA = 600 m²/g) into an industrial cement (BSSA = 450 m²/g) produced with a non-performance enhancing grinding aid (blue) and into the same cement with an admixed activator (orange).

Coarser grinding

Cement fineness affects strength, setting characteristics, and water demand. Coarser cements reduce temperature rise, capillary stresses, plastic shrinkage tendency, and micro-cracking in concrete.[3] Consequently, more reactive clinkers achieving the same strength at lower fineness are of particular interest to the industry. For a typical cement, a 1 MPA strength change corresponds to a change in BSSA of approximately 20 – 25 m²/kg (Figure 4), which further translates to an approximate change of 7% in energy consumption.[4] As such, full system optimisation enables reduced fineness, increasing mill productivity and lowering CO_2 emissions.

Clinker factor

Portland-limestone and blended cements are one of the key CO_2 emission reduction levers identified in the Global Cement and Concrete Association's 2050 Net Zero Roadmap.[5] Each 1% clinker substitution reduces CO_2 output by nearly the same amount, but impacts strengths at higher levels (Figure 5), necessitating finer grinding and leading to potential plastic performance changes in the field. As such, full system optimisation is necessary to maintain performance with decreasing clinker contents. Further CO_2 reductions can be achieved with SCMs like slag, fly-ash, and pozzolans, which can enhance strength and durability.

Clinker reformulation and kiln optimisation

Optimising clinker formulation and kiln operation can help balance plant capacities with some reduction in CO_2 emissions. Adjusting the kiln feed lime saturation factor can improve fuel efficiency and kiln output, though it may reduce strengths. Optimisation of the milling process and additive selection can help offset the strength losses, facilitating the use of alternative fuels and raw materials when warranted, enabling higher recycling rates.

Additional benefits

A full systems approach to cement optimisation can also help free up mill capacity, reduce mill run-hours, facilitate preventative maintenance, and enable clinker import and grinding to adapt to changing market demands. Benefits vary by plant and cement type, but can all contribute to a sustainable strategy.

Conclusion

A holistic approach to cement optimisation involves addressing all aspects of the process to ensure that the full potential is realised at each stage. This not only improves production efficiency and cement quality, but also contributes directly to the overall sustainability of the cement manufacturing process. Cement producers who effectively address all four levers – proper clinker formation, mill optimisation, effective additive selection, and optimising quality targets – are succeeding in achieving their vision of blended cements to meet modern needs and are paving the way for a more sustainable future in construction. ■

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