Green materials can be considered as materials that use less natural resources and energy and generate less CO₂. Despite using optimised and sophisticated processes, green cements still emit large amounts of CO₂. To improve the ecological balance of cement, every possible initiative to make cement ‘greener’ needs to be considered.

Reducing CO₂ emissions during clinker production
Cement accounts for approximately five per cent of the world’s carbon dioxide emissions. The estimated average carbon footprint is 0.83t CO₂/t of traditional Portland cement clinker (ranging from 0.7 to 1.4t). About 60 per cent of this is released in unavoidable chemical reactions as the limestone decomposes (calcination process). The remaining 40 per cent is generated from the vast amounts of energy needed to heat the clinker to about 1450°C.

The main focus for the cement plants is the optimisation of clinker production. As a result, the share of alternative fuels is strongly increasing and the generated heat is used more efficiently. Today, most cement plants operate dry-process kiln systems with multi-stage cyclone preheaters and precalciners, consuming approximately 3000MJ thermal energy per tonne of clinker. However, a significant amount of cement plants still operate long wet-process kiln systems with a thermal energy consumption of up to 6000MJ/t of clinker. CO₂ is saved when the wet ground raw material slurry contains less water. Sika offers special wet-system grinding aids allowing moisture content reduction of the kiln feed while maintaining the viscosity of the slurry.

Reduced CO₂ emissions derived from electric energy
Cement production consumes a high amount of electric energy, typically in the range of 90-130kWh/t of cement.
Hard Fact No. 9
Creative Grinding Solutions for Cement

Your challenge: Production of high quality cement, while considering energy efficiency and cost optimization.
Our solution: Sika cement additives combine efficiency and performance with innovation.

For Information about the SikaGrind® and Sika® ViscoCrete® Technology or additional Hard Facts, please visit www.sika.com/hardfacts
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equivalent to 90,000-130,000t CO₂ per 1Mt of cement if the electricity is coal-generated. Indeed, the related CO₂ emission depends on the source of the electric energy. More than 50 per cent of the consumed electrical energy is related to the grinding of raw materials and the finish cement grinding process.

Chemical processing agents like grinding aids increase production rates and reduce specific energy consumption. Sika offers products based on traditional technologies for grinding aids but also a unique new grinding aid technology which uses polycarboxylate polymers to generate the highest mill output. Significant production increase versus blank grinding at constant fineness is achievable (Figure 1). As a consequence, CO₂ emissions can be reduced by up to 10,000t CO₂ per 1Mt of cement.

Reduced CO₂ emissions with cement formulation

The fact that clinker causes the main CO₂ emissions during cement production leads the industry to a stronger cement formulation optimisation. The focus of new cement developments is to increasingly replace clinker with secondary cementitious materials like limestone, natural pozzolanas, fly ash and slag. Each percentage of reduced clinker content lowers the carbon dioxide emission by 8300t CO₂ per 1Mt blended cement, but also adversely affects the strength development in the magnitude of -0.5N/mm². Chemical processing agents offer different opportunities to enhance the strength development of cement.

Improved cement fineness with adjusted separator settings and grinding aids

In cement technology, fineness, clinker content and strength are in close connection. Exact relations can be determined for different local conditions. As a first approximation, increasing specific surface according to Blaine by additional 100cm²/g leads to enhanced strength development in the scale of +1N/mm² after two days and +1.5N/mm² after 28 days respectively.

Significant enhancements can be achieved when targeting an optimised particle size distribution towards a greater proportion of the particle size fraction 3-32µm, which is the most important for strength development. At a constant specific surface, an additional five per cent content of particles 3-32µm result in approximately 1N/mm² more final strength.

Higher fineness also implicates a lower production rate. Each 100cm²/g more specific surface according to Blaine reduces the cement production rate by approximately 3-4 per cent. As already described, grinding aids can compensate a loss of production and thus contribute to achieving the desired fineness in the most economical way. A typical production increase of 10-12 per cent with a grinding aid versus blank grinding could in this way generate an approximately 300cm²/g higher specific surface at constant production rate.

Acceleration of cement hydration with quality improving additives

Chemical substances can accelerate the hydration of the clinker phases, leading to higher strength at different ages (see Figure 2). At constant fineness and depending on the local conditions like the amount of clinker and reactivity, strength after two days can be improved in the range of 2-5N/mm² while the final strength can be enhanced up to approximately 7N/mm² (standard mortar according to EN 196).

The indicated early strength development allows reducing clinker content by 4-10 per cent. Consequently, the carbon footprint is diminished in the range of 33,000-83,000t CO₂ per 1Mt of blended cement. Another opportunity to take advantage of the strength increase would be to partially use less reactive clinker, eg belite clinker.
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Combining the effects of chemical acceleration and fineness, strength improvements in the range of 5-8N/mm² after two days are possible. This advantage can be used to replace clinker by 10-16 per cent of the cement and in that way reduce 80,000-130,000t CO₂ per 1Mt of blended cement. Effects of an optimised particle size distribution could further boost this benefit.

Sika offers standard and tailormade quality improvers which include efficient grinding aid technologies to minimise the carbon footprint.

**Constant production with reduced variations**

Cement production is a continuous process subject to natural variations. Cement manufacturers invest a lot in homogenising equipment along the production chain, from raw material storage to different raw meal and clinker storages to finished cement silos. On all levels, constant quality control ensures that the variations are kept as low as possible. The smaller the variations, the smaller the necessary safety margins are and hence the needed clinker content is lower to ensure the cement properties.

During cement grinding, a more constant production with reduced variation leads to higher production rates and best strength results. Regular control of cement fineness with help of particle size analysis and the use of chemical processing agents like SikaGrind can help to ensure that cement plants achieve the required quality.

**Case study: CO₂ reduction potential**

The potential to reduce the carbon footprint can be demonstrated best in a case study. The chosen plant produces 770,000tpa of CEM III/A 32.5N with a clinker factor of 0.46. The target of the project was the ecological and economical optimisation of the cement formulation, bringing the slag content close to the maximum allowed for a CEM III/A. Table 1 shows plant results which compare a pure traditional grinding aid with two products of the SikaGrind-800 Series, a pure grinding aid and a strength enhancer with incorporated grinding aid. Without any changes of formulation, both SikaGrind products increase production by 4.6 per cent and consequently reduce the CO₂ emissions which are related to the specific energy consumption by 4.3 per cent. In this example, the annual CO₂ emission derived from electrical energy used for the cement grinding process accounts to 8.8 per cent of the total CO₂ emission. Therefore, the effect of the reduced electric energy consumption on total CO₂ emission is only very limited (0.4 per cent saving).

Converting the production increase into higher specific surface at a constant production rate (Option 1) would reduce the clinker factor to 0.44 and save three per cent of total CO₂ emissions, which is distinctly more than with the savings of electrical energy.

The strength-enhancing property of the SikaGrind Quality Improver allows the reduction in the clinker factor to 0.42 and increasing the slag content accordingly (Option 2). This reduces the annual CO₂ emissions by 6.3 per cent.

Options 1 and 2 can be combined (Option 3), resulting in a clinker factor of 0.40 which saves 8.9 per cent CO₂ emissions.
In the presented case, the maximum annual CO₂ saving of 47,400t CO₂ (-11.9 per cent) can be achieved when additionally targeting a more constant production with reduced variations and a minimised clinker factor of 0.38 (Option 4).

**Reducing CO₂ emissions in concrete**

Continuous research aims to understanding how chemical additives and admixtures react in dry-process and wet-process cement applications. Based on these findings, creative solutions for today’s challenging market can be developed for general targets as well as for individual conditions.

One topic which is linked to green cement as well as to the final cement application is the water demand of the cement which in the end has an influence on the concrete consistency. Finer ground blended cements tend to have a higher water demand and therefore are subject to a lower concrete workability combined with a faster slump loss. Polycarboxylate polymer based SikaGrind Quality improver cause cements with improved workability and extended slump life7.

Sika has 100 years of research and experience in cementitious construction materials that allows it to offer also concepts for ‘green’ concrete. Special concrete admixtures ensure the production of easy to handle and ecologically-friendly high performance concretes for the modern construction industry.

**Conclusions**

Cement manufacturers have been continuously optimising the clinker production process to achieve more efficient and environmentally-friendly production methods. The growing pressure to reduce CO₂ emissions demands increasing amounts of clinker replacements in cement formulations, resulting in a loss of strength and production capacity.

Sika supplies chemical admixtures which help to reduce the carbon footprint in different steps of the cement production as well as in the cement application. The main focus for SikaGrind technology in this regard is to reduce the clinker content as well as the specific energy consumption per tonne of cement. The new polycarboxylate polymer powered grinding aid technology of the SikaGrind-800 series achieves highest production increases and can be incorporated into quality improvers targeting chemical early and/or final strength enhancement.

SikaGrind enables cement manufacturers to decrease the carbon footprint and maximise their profitability.______

**References**


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**Table 1: comparison of two products from the SikaGrind-800 Series with a traditional glycol-based grinding aid in plant application**

<table>
<thead>
<tr>
<th>CEM III/A 32.5 N</th>
<th>Glycol based grinding aid</th>
<th>SikaGrind-800 Series Grinding Aid</th>
<th>SikaGrind-800 Series Strength enhancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production [tph]</td>
<td>109</td>
<td>114</td>
<td>114</td>
</tr>
<tr>
<td>Dosage [%]</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
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<tr>
<td>Clinker factor</td>
<td>0.46</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>Blaine [mm²/g]</td>
<td>target 3450</td>
<td>3655</td>
<td>3650</td>
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<tr>
<td>Variation +/- 200</td>
<td>14.5</td>
<td>13.4</td>
<td>14.1</td>
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<tr>
<td>Water demand [%]</td>
<td>28.2</td>
<td>28.2</td>
<td>27.7</td>
</tr>
<tr>
<td>Compressive Strength 2 days [N/mm²]</td>
<td>8.0</td>
<td>8.8</td>
<td>10.2</td>
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<tr>
<td>Compressive Strength 7 days [N/mm²]</td>
<td>21.9</td>
<td>22.9</td>
<td>25.6</td>
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<tr>
<td>CO₂ emission derived from raw material (tonne CO₂/year)</td>
<td>314300</td>
<td>314300</td>
<td>314300</td>
</tr>
<tr>
<td>a) finished grinding process</td>
<td>35100</td>
<td>33600</td>
<td>33600</td>
</tr>
<tr>
<td>b) other electric energy of plant</td>
<td>46900</td>
<td>46900</td>
<td>46900</td>
</tr>
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</table>

**Table 2: opportunities to save carbon dioxide emission due to optimised cement formulation and SikaGrind products**

<table>
<thead>
<tr>
<th>CEM III/A 32.5 N</th>
<th>Reference</th>
<th>Option 1: Use Grinding Aid to increase fineness and reduce clinker</th>
<th>Option 2: Use Strength enhancer</th>
<th>Option 2 (T=4) Use Strength enhancer and fineness increase to reduce binder</th>
<th>Option 3: Use more stable production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production [tph]</td>
<td>109</td>
<td>114</td>
<td>114</td>
<td>114</td>
<td>114</td>
</tr>
<tr>
<td>CO₂ emission derived from raw material (tonne CO₂/year)</td>
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<td>302500</td>
<td>290600</td>
<td>278700</td>
<td>266900</td>
</tr>
<tr>
<td>CO₂ emission derived from electric energy of plant [tonne CO₂/year]</td>
<td>49600</td>
<td>49600</td>
<td>49600</td>
<td>49600</td>
<td>49600</td>
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<tr>
<td>a) finished grinding process</td>
<td>35100</td>
<td>33600</td>
<td>33600</td>
<td>33600</td>
<td>33600</td>
</tr>
<tr>
<td>b) other electric energy of plant</td>
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<td>49600</td>
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<td>Carbon dioxide emission</td>
<td>save</td>
<td>399000</td>
<td>397500</td>
<td>397500</td>
<td>397500</td>
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<tr>
<td>CO₂ emission [tonne CO₂/year]</td>
<td>397500</td>
<td>397500</td>
<td>397500</td>
<td>397500</td>
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</tr>
</tbody>
</table>

- **References**
Creative Grinding Solutions
by Philippe Jost and Jorg M. Schrabback

Sika Services AG,
Tüffenwies 16, CH-8048 Zürich, Switzerland
Phone +41 44 436 4040, Fax +41 44 436 4150, www.sika.com

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Performance of polyurethane polymer-powered grinding aids. In this case, the innovative technology can produce a 8% production increase at a dosage of 0.03% (Figure 5). Moreover, these flexible technologies can become if the mill output can be economically correlated to the grinding aid dosage.

Case study of PCE powered glycol-based grinding aid technology

The third plant trial example demonstrates that efficiency is also possible in the above case, 0.025% of a traditional glycol-based grinding aid achieved a production increase of 9%, while the same dosage of the PCE/glycol formulation easily achieved a production increase of 16%.

Polycarboxylate polymers improve the performance of the traditional grinding aid technologies of amino alcohols and glycols and allow for a further increase in energy efficiency and more favorable PSD at constant production rate. The resulting enhanced quality allows plants to reduce their clinker content and hence to decrease their carbon footprints while increasing the cement manufacturer's stability.

Conclusions

Polycarboxylate polymers improve the performance of the traditional grinding aid technologies of amino alcohols and glycols and allow on the grinding and energy consumption. It can also be used to achieve strength enhancements with homogeneity and optimised particle size. The potential clinker reduction minimises the carbon footprint.

Sika's polycarboxylate polymer-powered grinding solutions for individual challenges and also maximises the stability.
Sika – a global Player in Specialty Chemicals for Construction and Industry

Sika is a leading Swiss company, globally active in specialty chemicals. Our local presence worldwide links us directly with customers and ensures the success of Sika and its partners. Every day highly motivated people strive to provide the best customer service.