CEMENT ADDITIVES CONCEPTS FOR ‚GREEN' CEMENT

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SIKA ADDS VALUE TO YOUR CEMENT

Cement is vital for today's construction industry. The cost optimized production of quality cement which meets customer demands and standards as well as sustainability issues challenges every cement plant individually. Sika offers innovative cement additive concepts combined with a specialized technical support, targeting improved production rates, enhanced strength development and adjusted workability. The reduced utilization of energy and clinker contributes to the profitability of your business.

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Concepts for 'green' cement

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Cement is a major part of today's construction industry which demands solutions that consider both economical and ecological aspects. Cement manufacturers are continuously striving to achieve more efficient and environmentally-friendly production methods. Sika offers cost-effective concepts for a more ecologically-friendly production of so-called 'green' cement.

Cement is a major part of construction solutions that consider both economical and ecological aspects

Green materials can be considered as materials that use less natural resources and energy and generate less CO_2[1]. Despite using optimised and sophisticated processes, green cements still emit large amounts of CO_2. To improve the ecological balance of cement, every possible initiative to make cement 'greener' needs to be considered.

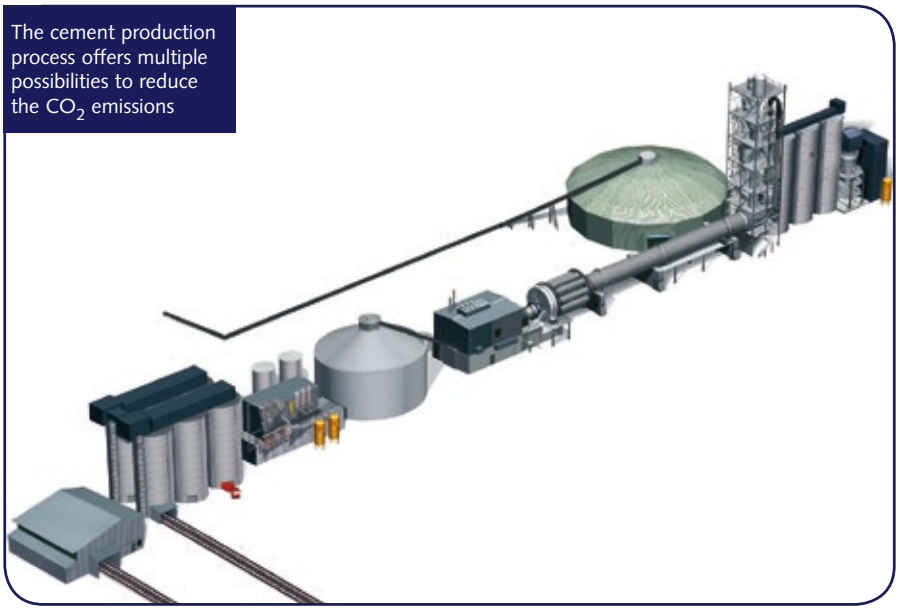
Reducing CO_2 emissions during clinker production

Cement accounts for approximately five per cent of the world's carbon dioxide emissions. The estimated average carbon footprint is 0.83t CO_2/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)[2]. 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. CO_2 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 CO_2 emissions derived from electric energy

Cement production consumes a high amount of electric energy, typically in the range of 90-130kWh/t of cement,



The cement production process offers multiple possibilities to reduce the CO_2 emissions

equivalent to 90,000-130,000t CO_2 per 1Mt of cement if the electricity is coal-generated. Indeed, the related CO_2 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[3]. Significant production increase versus blank grinding at constant fineness is achievable (Figure 1). As a consequence, CO_2 emissions can be reduced by up to 10,000t CO_2 per 1Mt of cement.

Reduced CO_2 emissions with cement formulation

The fact that clinker causes the main CO_2 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 pozzolanes, fly ash and slag. Each percentage of reduced clinker content lowers the carbon dioxide emission by 8300t CO_2 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[4].

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[5]. 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[6]. 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 CO_2 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.

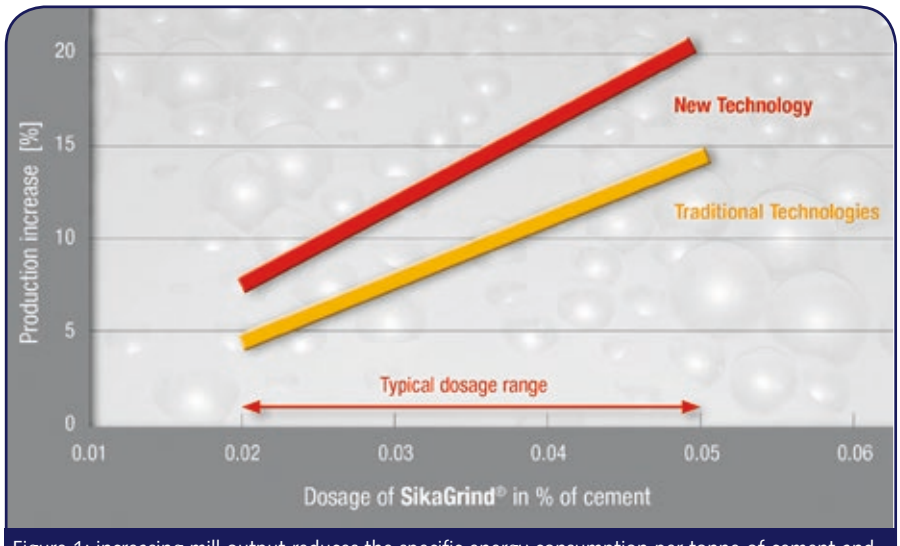


Figure 1: increasing mill output reduces the specific energy consumption per tonne of cement and hence the CO_2 emission

Figure 2: enhanced strength development with SikaGrind products can be used to minimise CO_2 emission of cement

Research in interactions of chemical processing additive and possible cementitious materials

the carbon footprint is diminished in the range of 33,000-83,000t CO_2 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.

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 CO_2 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 highest 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: CO_2 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 CO_2 emissions which are related to the specific energy consumption by 4.3 per cent. In this example, the annual CO_2 emission derived from electrical energy used for the cement grinding process accounts to 8.8 per cent of the total CO_2 emission. Therefore, the effect of the reduced electric energy consumption on total CO_2 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 CO_2 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 CO_2 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 CO_2 emissions.

In the presented case, the maximum annual CO_2 saving of 47,400t CO_2 (-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 CO_2 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 life[7].

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 CO_2 emissions demands increasing amounts of clinker replacements in cement formulations, resulting in a loss of strength and production capacity.

Sika supplies chemical additives 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.

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

CEM III/A 32.5 N		Glycol based grinding aid	SikaGrind-800 Series Grinding Aid	SikaGrind-800 Series Strength enhancer
Production [tph]		109	114	114
Dosage [%]		0.025	0.025	0.025
Clinker factor		0.46	0.46	0.46
Blaine [cm²/g]	Target 3450 cm²/g	3535	3565	3550
	Variation	+/- 200	+/- 200	+/- 200
Sieve residue 32 µm [%]		14.5	13.4	14.1
Inclination n in RRSB diagram		1.02	1.03	1.02
Position parameter x' in RRSB diagram [µm]		21.6	20.82	21.1
Water demand [%]		28	28.2	27.7
Compressive Strength 2 days [N/mm²]		8.0	8.8	10.2
Compressive Strength 7 days [N/mm²]		21.9	22.9	25.6
Compressive Strength 28 days [N/mm²]		41.1	41.0	48.7
CO_2 emission derived from raw material [tonne CO_2/year]		314300	314300	314300
CO_2 emission derived from electric energy of plant [tonne CO_2 /year]				
a) finished grinding process		35100	33600	33600
b) other electric energy of plant		49600		
Carbon dioxide emission [tonne CO_2/year]	**spend**	**399000**	**397500**	**397500**
	save		**1500**	**1500**

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

CEM III/A 32.5 N		Reference Glycol based grinding aid	Option 1 Use Grinding Aid to increase fineness and reduce clinker	Option 2 Use Strength enhancer to reduce clinker	Option 3 (1+2) Use Strength enhancer and fineness increase to reduce clinker	Option 4 Use Strength enhancer like Option 3 plus more stable production
Production [tph]		109	109	114	109	109
Dosage [%]		0.025	0.025	0.025	0.025	0.025
Clinker factor		0.46	0.44	0.42	0.40	0.38
Blaine [cm²/g]		3535	~ 3650	~ 3550	~ 3650	~ 3650
		+/- 200	+/- 200	+/- 200	+/- 200	+/- 100
Compressive Strength 2 days [N/mm²]		8.0	~ 9	~ 8	~ 8	~ 7
Compressive Strength 28 days [N/mm²]		41.1	~ 41	~ 43	~ 43	~ 42
CO_2 emission derived from raw material [tonne CO_2/year]		314300	302500	290600	278700	266900
CO_2 emission derived from electric energy of plant [tonne CO_2/year]						
a) finished grinding process		35100	35100	33600	35100	35100
b) other electric energy of plant		49600				
Carbon dioxide emission	**spend**	**399000**	**387200**	**373800**	**363400**	**351600**
[tonne CO_2/year]	**save**		**11800**	**25200**	**35600**	**47400**

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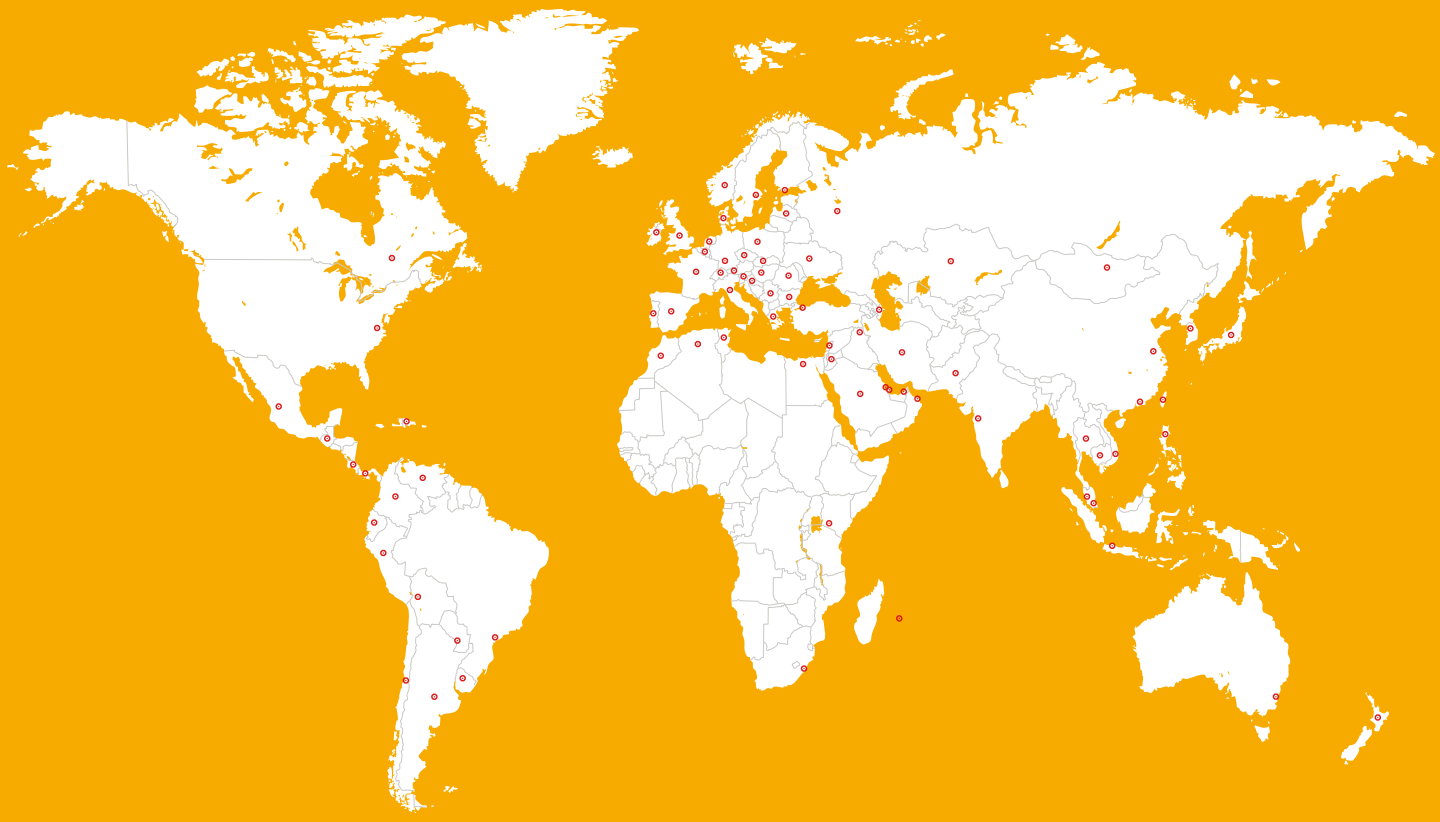

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