American Concrete Institute®
Advancing concrete knowledge

Innovations in Chemical Admixture Technology as Related to Sustainability, Part 2

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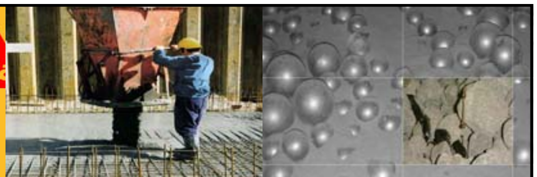

Influence of Polycarboxylate Ether Polymers (PCE) on Sustainability in Concrete Production

Presentation by –
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Objective

- This presentation examines how PCE polymers influence the environmental footprint of concrete at different stages of production process.
- Effects of PCE polymers in Concrete Production and Cement Grinding were analyzed.
- Life Cycle Assessment (LCA) techniques were used to assess impacts associated with the use of PCE polymers.

Contents

- Introduction
- Life Cycle Assessment (LCA)
- Influence of PCE's on Concrete Mix Design
- Influence of PCE's on Cement Grinding
- Conclusion

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Introduction –
Concrete Admixtures and Sustainability

Concrete is a building material with a remarkable product performance in case of Durability and Technical Solutions and Concrete Admixtures are part of this successful concept!

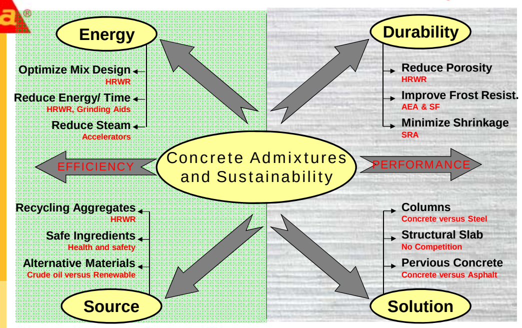
PERFORMANCE

Concrete Admixtures and Sustainability

Concrete Admixture are a relevant part to achieve a significant Energy reduction of the concreting Process. Source wise Admixtures play and have an important task in prospect of Sustainability

EFFICIENCY

Concrete Admixtures and Sustainability



The Cement and Concrete Industry

Cement production

Limestone calcination:

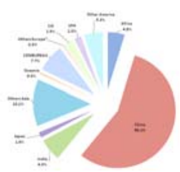
100 kg $CaCO_3$ → 56 kg CaO + 44 kg CO_2

→ 440 kg CO_2 / ton cement

+ emissions related to fuels

+ emissions related to electricity and other processes

= **850 kg CO_2 / ton cement**



3.3 billion tons (2010)

*Source: M. Calkins (2009). Materials for Sustainable Sites, Wiley & Sons, New Jersey

*Cembureau

Strategies for Environmental Improvement

- Energy efficiency in production processes
- Alternative fuel use for making clinker
- Clinker substitution by supplementary or complementary cementing materials
- Carbon capture and storage (CCS)
- Optimization of concrete mix design

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Life Cycle Assessment (LCA)

- LCA is a method to quantify and evaluate potential environmental impacts throughout a product's life cycle
- The main purpose of LCA is to improve the environmental impacts of products and activities by guiding the decision making process.
- LCA provides comprehensiveness in two respects:
  - Takes into account all relevant life cycle aspects of a product
  - Analyses different environmental impact categories

Life Cycle Assessment (LCA)

- In this study, in order to compare different options regarding environmental footprints, LCA techniques were used to assess the impacts associated with the use of PCE polymers.

LCA were run on:

1. Concrete Mix Design
2. Cement Grinding

Life Cycle Assessment (LCA)

- Concrete mixes were modeled in the software, GaBi
- Datasets for modeling were retrieved from commercial data bases (European Reference Life Cycle Database, PE International and ecoinvent)
- Impact assessment on inventory data was calculated following CML 2001 and Eco-indicator 99 methods.
- LCA was performed by our Corporate Product Sustainability Group

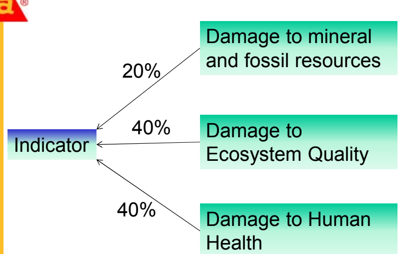
CML 2001

Impact Catagories Assessed	Meaning/ Significance

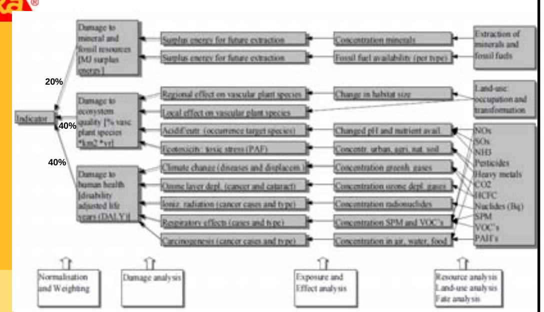
CML 2001

Impact Catagories Assessed	Meaning/ Significance
Abiotic depletion potential	**Reduction** in **non renewable resources** ie, fossil fuels, metals, minerals etc
Acidification Potential	Acidification of soil and water due to pollutents resuting in **low pH** and **damage** to **ecosystem**
Eutrophication Potential	Eutrophication means **enrichment in nutrients**. When **effects** are **undesirable** it is considered a form of **pollution**
Global Warming Potential	**Sum** of emission of **greenhouse gases**
Human Toxicity Potential (HTP)	HTP is calculated by **adding** the **releases**, which are **toxic to humans**, to three different media, i.e. air, water and soil
Ozone Depletion Potential (ODP)	The relative amount of **degradation** to the **ozone layer** that can be caused
Photochem. Ozone Creation Potential	Indicator of ability of a **VOC** to **contribute** to photochemical **ozone** formation. **Harmful** for **humans** and **vegetation**.
Primary Energy Demand	Quantity of **energy drawn** from various sources without any anthropogenic change

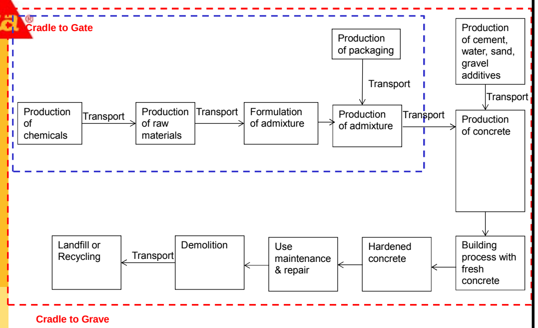
Eco-Indicator 99



Eco-indicator 99



The Concrete Admixtures LCA Model



Functional Unit: 1 lb admixture (packed) OR 1 cyd concrete

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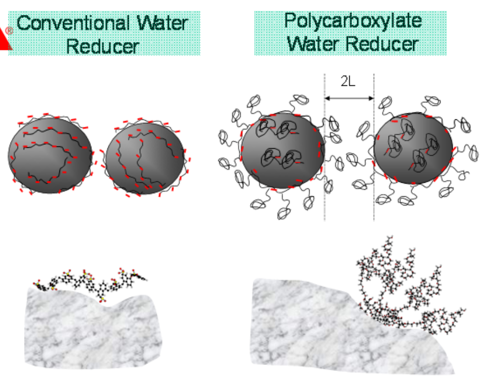


Test Setup – Case Study I

- LCA were conducted on 2 concrete mixes with same w/c
- Mix I (Control), Mix II (PCE admixture)
- Functional unit of LCA was 1 m^3 of concrete
- For Mix II, all raw materials, production processes and packaging of the PCE admixture was taken into account.

Mix Design I (Control)

Mix Design	**Quantity, kg/m3 (lbs/cyd)**
	Mix I
Cement	350 (590)
Coarse Aggregates	1092 (1841)
Fine Aggregates	782 (1318)
Water	182 (307)
Admixture	-
W/Cm	0.52

Case Study I: Mix Design

Energy Demand and CO_2 Emission contribution by each constituent in 1m^3 concrete mix

			kg	MJ	kg CO_2	% weight	**% MJ**	**% CO_2**
	MJ/kg	kg CO_2/kg	per m^3 of concrete					
Aggregates[1]	0.083	0.0048	1,092	90.64	5.24	46.4%	6.4%	1.7%
Sand[1]	0.081	0.0048	728	59.0	3.5	31.0%	4.2%	1.1%
Water[1]	0.01	0.001	182	1.8	0.2	7.7%	0.1%	0.1%
Cement[2]	3.59	0.85	**350**	1,256.5	297.50	14.9%	**89.2%**	**97.1%**
Admixture[3]	0	0	0.00	0.0	0.0	0.0%	0.0%	0.0%
			2,352	1,408	306	100%	100%	100%

1) Inventory of Carbon & Energy v2.0 University of Bath
2) WBCSD Cement Sustainability Initiative 2009
3) EFCA, Environmental Declaration Superplasticisers

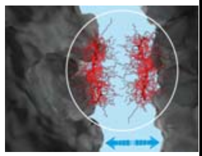
Comparison of Concrete Mixes

Mix I – Control
Mix II – With PCE admixture

Mix Design	Quantity, kg/m3 (lbs/cyd)		Difference, kg/m3 (lbs/cyd)
	Mix I	Mix II	
Cement	350 (590)	280 (472)	-70 (118)
Coarse Aggregates	1092 (1841)	1145 (1930)	+53 (89)
Fine Aggregates	782 (1318)	830 (1399)	+48 (81)
Water	182 (307)	146 (246)	-36 (61)
HRWR (PCE based)	-	3.36 (5.66)	-3.36 (5.66)
W/Cm	0.52	0.52	-

Concrete mixes I and II with:

- same workability
- same w/c



Results – Life Cycle Assessment

CML 2001

Impact Category	Mix I	Mix II	% Reduction
Abiotic Depletion (elements) [kg Sb-Equiv.]	0.0005	0.0004	19%
Abiotic Depletion (fossil) [MJ]	1204.52	1057.60	12%
Acidification Potential [kg SO2-Equiv.]	0.49	0.42	15%
Eutrophication Potential [kg Phosphate-Equiv.]	0.08	0.07	14%
Global Warming Potential (100 years) [kg CO2-Equiv.]	295.46	242.12	18%
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]	10.49	9.17	13%
Ozone Layer Depletion Potential [g R11-Equiv.]	0.01	0.01	16%
Photochem. Ozone Creation Potential [kg Ethene-Equiv.]	0.05	0.04	12%
Primary energy demand (net cal. value) [MJ]	1481.00	1292.85	13%
Eco-Indicator 99	5.50	4.74	14%

Results Analysis – Case Study I

- Mix II has an overall better environmental performance than Mix I in every impact category
- In CML 2001, the relative improvement is between 12-19% for all impact categories
- Use of PCE based admixtures can reduce the environmental impact of concrete by cement reduction.

Case Study II: Mix Design

Mix Design	Quantity	
	kg/ m3	lbs/cyd
Cement	300	506
Coarse Aggregates	1170	1972
Fine Aggregates	780	1315
Water	150	253
W/Cm	0.5	0.5

Admixture Type	Water Reduction Potential, %	Dosage to acheive same workability	
		% by wt. of Cm	fl.oz/100 lbs of Cm
Water Reducer (Lignin)	5-10	1.1	14
High Range Water Reducer (Melamine/ Naphthalene)	10-20	0.6	7.7
High Range Water Reducer (PCE based)	20-40	0.3	4.25

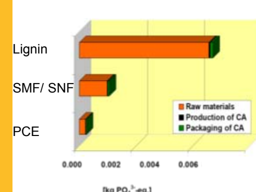
Ref: MS Thesis – L Doster

Case Study II

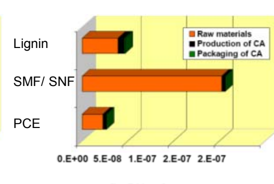
- Environmental impact categories assessed for 1m[3] of concrete:
  - Eutrophication Potential
  - Ozone Depletion Potential
  - Global Warming Potential
  - Primary Energy Demand

Test Results

Eutrophication Potential

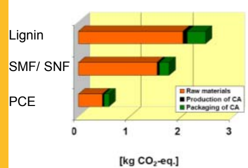


Ozone Depletion Potential

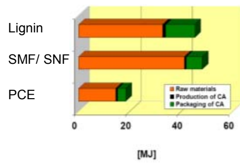


Test Results

Global Warming Potential



Primary Energy Demand



Results Analysis – Case Study II

- PCE admixtures had smaller material intensity since lower amount of material and packaging goods are required.
- PCE admixtures contain lower amount of embodied energy to produce a product with the same effect as compared to other technologies.
- Environmental impacts of PCE admixtures are lower than other technologies.

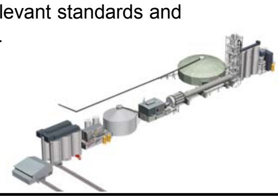
Contents

Case Study: Grinding Aids

Cement mill

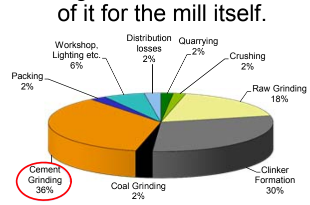
Introduction

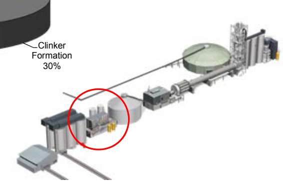
- **Cement manufacture** is a highly technical process in which every part has a decisive impact on the product quality as well as on economical and ecological production parameters**.**
- The **cement grinding process** is the final chance to adjust the cement quality to meet the demands set by relevant standards and cement customers.



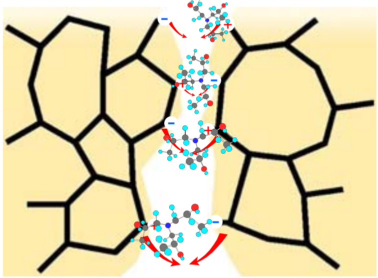
Introduction

- The cement grinding process consumes high amounts of electrical energy, most of it for the mill itself.



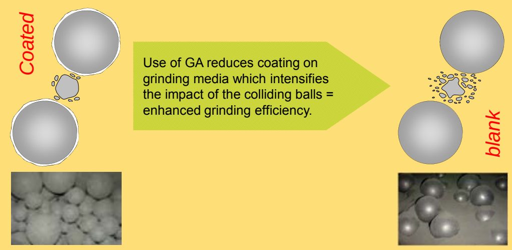


Working principle grinding aids (GA):
GA support the cracking



⇨ ensured cracking of particles leads to a faster grinding

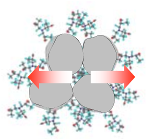
Working principle grinding aids (GA):
GA reduce coating of mill equipment



⇨ reduced coating intensifies the grinding process

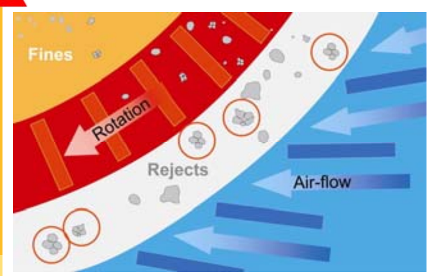
Working principle grinding aids (GA):
GA reduce re-agglomeration phenomena

Grinding aids are based on substances of high polarity which neutralize the electric charges.



The resulting lower attraction forces lead to a better particle dispersion and cause different effects:

Working principle grinding aids (GA):
GA improve separator efficiency

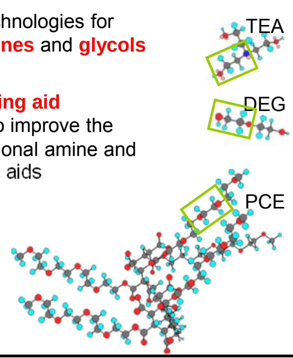


working principle 3rd generation separator

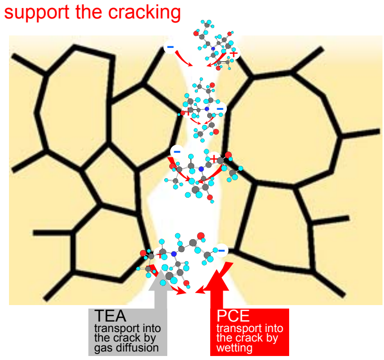
⇨ improved separator efficiency increases production rate

Working principle grinding aids (GA):
Traditional and new Technologies

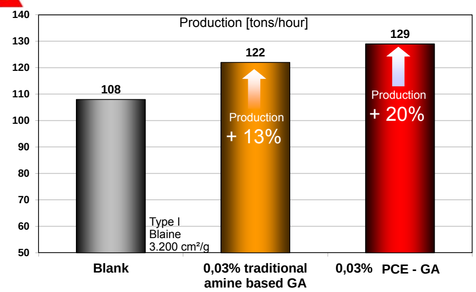
- Proven traditional technologies for grinding aids are **amines** and **glycols**
- **PCE powered grinding aid technology** is able to improve the performance of traditional amine and glycol based grinding aids



Working principle of PCE grinding aids (GA):
GA support the cracking



Increased mill output with PCE powered based GA



⇨PCE powered GA increases the production significantly

Higher mill output / reduced specific energy with PCE powered GA

Specific energy consumption of mill drive without grinding aid (blank):

$$p = \frac{5.140\ kW}{108\ t/h} = 47{,}6 \quad [kWh/t]$$

Specific energy consumption of mill drive with trad. Amine based grinding aid:

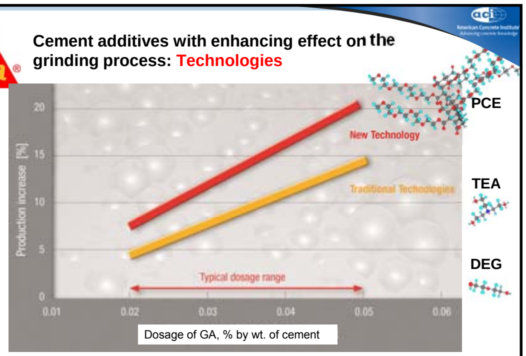
$$p = \frac{5.140\ kW}{122\ t/h} = 42{,}1 \quad [kWh/t]$$

Specific energy consumption of mill drive with PCE based GA:

$$p = \frac{5.140\ kW}{129\ t/h} = 39{,}8 \quad [kWh/t]$$

⇨PCE powered GA reduce the specific energy consumption significantly!

Cement additives with enhancing effect on the grinding process: Technologies



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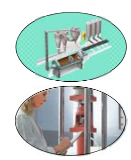
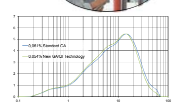
WEB SESSIONS

Working principle grinding aids (GA): Traditional and new Technologies

The major benefits versus the traditional grinding aid technologies are

- Maximized Mill Production
- Enhanced Strength Development
- Improved particle size distribution
- Higher clinker replacement
- Improved powder flowability/ bulk density
- Improved concrete workability

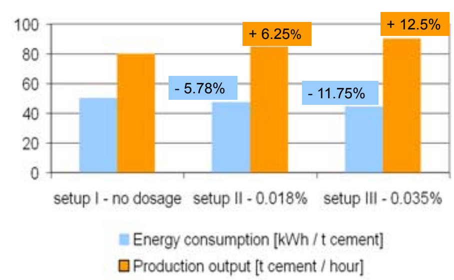




Test Set up

- LCA was conducted on 3 cement grinding setups.
- First setup was the Control (no grinding aid), the next two setups had a different dosage of the PCE powered grinding aid.
- Production output and energy consumption were measured for each setup.
- The functional unit of each LCA is one ton of ground cement.
- For the grinding aid, all raw materials, production and packaging processes had been taken into account

Test Results - Efficiency of grinding process



Results – Life Cycle Assessment

Impact Category	Setup I (No GA)	Setup II (0.018%)	Setup III (0.035%)
Eco-Indicator 99	100%	95%	91%

Results Analysis

- Considering Eco-indicator 99 score, Setup III, with the highest dosage of PCE grinding aid has the best environmental performance
- PCE based grinding aids can improve the environmental impacts of cement by reduction in energy consumption

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Conclusion

- PCE polymer based products offers different opportunities to improve the environmental footprint of concrete at all stages of concrete production.
- Based on the LCA calculations, PCE polymers allow for overall environmental improvement in cement grinding and concrete mix design.
- New developments drive the need for PCE polymers
  - Ultra High Performance Concrete
  - Blended cements
  - Recycled aggregates
  - High SCM replacement levels in cement & concrete

Thank you

Questions?