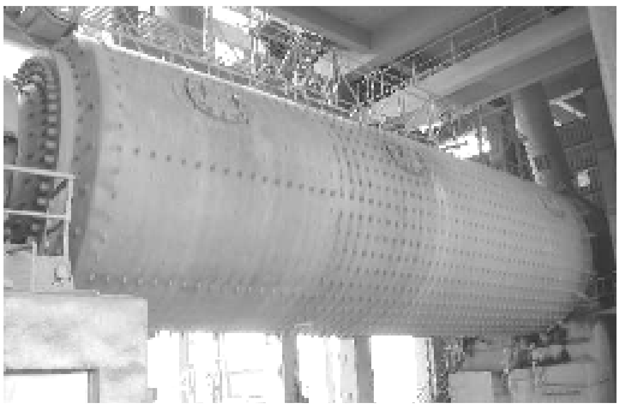
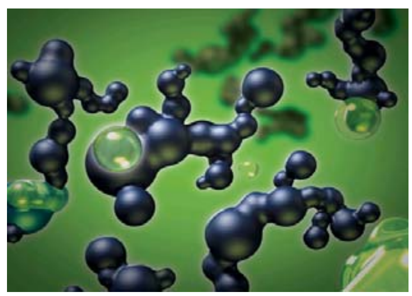
LAFARGE CEMENT

Technical

agenda





Advance levers: *Production & Process, Product & Quality, Energy*

Networks : *Process, Grinding, Product Managers, Product Development, Quality*

Study

GRINDING AIDS

June 2008 – Version 1.0

Foreword

Grinding aids are chemical products which have been widely used for more than 50 years. Grinding aids were developed for preventing cement particles agglomeration during the milling process. As a consequence grinding aids reduce mill retention time, improve separation efficiency, decrease energy consumption and increase production capacity (mill out-put).

In addition to the improvement of grinding efficiency a secondary benefit has also been appreciated (cement quality improvement: setting time reduction/early strength increase, late strength increase, workability improvement for masonry cements…).

Today the grinding aids can be divided on two Groups:

- **Process Grinding Aids (PGA)**, which are chemical products relevant for improving grinding efficiency,
- **Enhancing Grinding Aids (EGA),** which are chemical products relevant for enhancing both grinding efficiency and cement performance.

The expected benefits of grinding aids usage are:

- Increase cement production and therefore grinding capacity (mill out put increase, cementitious & limestone increase),
- Enable production of finer cements and hence increase C/K ratio,
- Reduce production cost (C/K increase, power consumption reduction),
- Reduce CO2 emissions (C/K increase…),
- Satisfy our customers by improving cement quality.

From the survey performed by the technical agenda members in the end of 2007, it was highlighted 3 major conclusions:

- About 20 millions tons of cement produced by our BUs in sold-out markets are not using any grinding aid. The generalization of the use of grinding aids will generate more than **1 million tons additional capacity, the equivalent of the production of one cement plant,**
- The grinding aids used are not always optimized: type, dosage and cost,
- The use of grinding aids in some sold-out BUs/plants is currently generating high saving for the Division:
    - About 5 millions US$/year benefit of grinding aids in India BU with a potential of more than 10 millions US$/year benefit if the use of GA is generalized,
    - About 9 millions US$/year benefit of grinding aids in VOL plant in Greece BU.

Therefore, the optimization and the generalization of the use of grinding aids within the cement Division will contribute to many strategic objectives:

- Reduce production cost and generate additional capacity,
- Improve C/K ratio and reduce CO2 emission,

- Satisfy our customer.

This technical agenda was performed under the lead of ATC with the contribution of all the technical centers (Product, Quality & Process teams), World wide strategic sourcing department, DPC & LCR.

How this study should be used

The document is aimed primarily at the plants for their implementation and at TC level to share their experience.

It is clear from the feedback that there are many plants that are not using grinding aids and would benefit significantly from their use. Grinding aids can be useful when the grinding capacity is a bottleneck for the plant production and there is cement market capacity available.

There are also some examples of plants using grinding aid with no real idea of the benefits, so they may be using GA in non optimized conditions, or using expensive GA for nothing.

In many cases the lack of quality control of the GA (so changes to water content, or modification of the composition, for instance, go unnoticed) doesn't allow optimum use of the product.

There are opportunities to improve the cost of grinding aids by a more co-ordinated approach with the involvement of World Wide Strategic Sourcing (WWSS) and eventually to consider the direct purchase of the chemical agents (don't forget to take into account of the availability and permanence of the product).

Also plants using GA for many years no longer know the benefits .With the support of TC (eventually) make trials to verify the efficiency of GA and to search for a new one , if needed (better compatibility : cement and GA / performances / price)

In any case the document should be used by all plants, with the support of TC if needed, to establish a strategy for use of GA:

1) If a plant is not using GA there should be a good reason, that is well understood and the situation is reviewed from time to time. The position of a plant not using GA should be challenged by the TC. The TA can be used to give some hints on what GA could be used for what benefits.

2) Contact with WWSS to discuss pricing/sourcing issues

3) Plants already using GA to be certain of their particular objective(s) and to make periodic re-trials, including testing of alternative products, (1 or 2 years intervals) to optimise the use and re-evaluate the benefits to be certain that they are sustained.

Changes in clinker chemistry, GA formulation, power price, cement market, cement target performance, GA price etc will all affect the justification of a particular GA.

4) Plants already using GA should implement a quality control of the GA

5) Trials, particularly for EGA, should be co-ordinated with the TC.

6) Protocols for trials should be in accordance with that in the TA

In addition the document serves as a good source of knowledge about grinding aids and their application and time should be taken by the TC quality and process teams to brief the TA during earliest opportunities.

We want to thank all contributors, and in particular:

- Abdellatif Boumiz – ATC (Leader of the study)
- Lakshmi Narasimhan – ATC
- Santosh Patel – World Wide Strategic Sourcing
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For their work on this study.

Gerard Cochet (P&Q manager)

& Colin Paxton (Process manager)

DPC - Direction des Performances Cimentières

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1. Executive Summary

1.1. Objectives

The objectives of this technical agenda are:

- To give the state of the art and the general knowledge on grinding aids,

- To perform a survey for evaluating the current usage, optimization and benefits of Grinding Aids (GA) within the division:
    - Level of usage of GA,
    - Suppliers, type, dosage and additional cost of GA,
    - Current practices when using grinding aids (safety, type of the dosing system, where the grinding aids is added to the cement mill, quality control…),
    - Impact of GA on grinding efficiency and product quality,
    - Global benefit of GA,
    - …

- To prepare a reference table summarizing for each grinding aid group and type, the expected performance, dosage and additional cost, using the current validated GA results performed in coordination with different TCs:
    - Output increase, power consumption reduction, cement performance improvement, additional cost per ton of cement…

- To develop a procedure for controlling grinding aids cost in coordination with Worldwide Strategic Sourcing department,

- To build a common guideline for grinding aids selection, optimization and usage
    - GA safety procedures, GA objectives, GA selection, GA performance evaluation & trials procedures, GA benefit evaluation, GA quality control…

- To give recommendations concerning the grinding aids installation
    - Feeding system & feeding point to the mill, CAPEX…

1.2. Results

1.2.1 General knowledge on grinding aids

The grinding aids commonly used can be divided on 2 groups:

Group 1 - Process Grinding Aid **(PGA)** which are grinding aids for increasing grinding capacity and reducing power consumption. Two chemical sub-groups, *Ethyleneglycols (EG) and Ethanolamines (EA),* are generally used by suppliers as the basis for producing grinding aids suitable for improving grinding efficiency.

The commonly used pure chemicals for producing PGA are *Triethanolamines* (TEA) and *Diethyleneglycol (*DEG). The usage of PGA has several benefits:

- Reduce or eliminate coating effect on grinding media,
- Improve in separator efficiency,
- Increase grinding capacity,
- Reduce power consumption,
- Improve material handling due to fluidity of cement particles,
- Decrease pack-set problems.

Group 2 – Enhancing Grinding Aid **(EGA)** which are formulated products containing one grinding function and one enhancing function (setting time reduction, early strength increase, late strength increase, air entrainment increase for masonry applications…). Three sub-groups are commonly used:

- **Grinding aids for reducing setting time and increasing early strengths:** Mixtures containing one grinding function and other products as Chloride, Nitrites, Thiocyanates (sodium or calcium salts). Chloride salts are low cost solution, but the dosage is generally limited by national standard to avoid concrete corrosion,

  PGA can be combined with the direct addition of sodium sulphates for early strength improvement. This is generally lower cost solution compared to formulated EGA.

- **Grinding aids for increasing late strength:** Mainly composed of TIPA (THEED) or PCE chemical products:
  - **TIPA (*Triisopropanolamine*)** type developed by Grace under CBA brand: TIPA acts on the C4AF hydration and hence increases late strengths. Thus, a minimum of C4AF is necessary to guarantee effectiveness (C4AF < 4 %: low to no impact of TIPA). Grace developed new product ESE brand based on **THEED (Diethanolisopropanolamine)** molecule for reducing air entrainment in concrete linked to CBA usage especially during cold periods.

- **PCE (Polycarboxylate Esther)** type has recently been developed by grinding aids companies (BASF, Sika…) for improving milling operations and increasing late strength. The mechanism of this new GA is not yet well understood. BASF product (Cementium 290LS brand) is currently used in Malaysia for increasing 28 day strength of fly ash cement (Mascrete Pro product). This grinding aid is under validation in different TCs regions and hence it is recommend to conduct rigorous testing trials before its usage.

- **Air entraining agents for masonry applications:** Beyond the grinding aid function, tensio-active molecules have been added to the formulated GA. Aryl (alkyl) sulfate, sodium Oleate, fatty acids…are used to generate in mortar high air entrainment level. This improves mortar workability which is appreciated for masonry applications.

In terms of grinding efficiency, the LCR study highlighted the following classification for the commonly and widely used GA compounds:

THEED > TIPA > TEA > DEG

Grinding efficiency

The efficiency of grinding aids depends also on the composition and grindability of blended cements constituents (clinker, limestone, slag, Pozzolan…).

1.2.2 Results of the survey on grinding aids usage within the Cement Division

The results of the survey performed by the TA members for evaluating the usage and benefits of grinding aids within the Division can be summarized as follow:

- Grinding aids are widely used in Lafarge BUs of developed countries like Western and Central Europe, North America and some Asia countries (Japan, Korea, India, Malaysia…). However there are many BUs for which the benefit of grinding aids is not fully explored (China, Africa, Eastern Europe, Latin America…),

- Lafarge BUs are supplied by many grinding aids companies (WR Grace, Chryso, Fosroc, Maipei, Sika, BASF…). Some BUs are also supplied by local suppliers or raw chemicals which are generally lower cost solutions.

- Many types of grinding aids belonging to PGA and EGA groups are used and are fully described in chapter 3 and in the annex. They are mainly used for:
    - Increasing output, reducing power consumption, improving C/K ratio and improving cement quality.

- More than **20 millions tons** of cement in sold out Lafarge plants are currently produced without using any grinding aid.

- The grinding aids dosage and type are generally not well optimised, leading to high additional cost of grinding aids for Cement Division:
  - The additional cost of PGA grinding aids varies from **0.1 to 0.5 US$/ton,**
  - The additional cost of EGA grinding aids varies from **0.4 to 1.5 US$/ton,**
  - The selection of relevant grinding aid (PGA or EGA) is not always done in a structured way in coordination with the corresponding technical centre.

- Some Lafarge plants are using directly pure chemicals for reducing the GA additional cost:
  - Mainly pure TEA and DEG are purchased in Austria, France and Germany and can be diluted in the plants (Germany),
  - Venezuela (Tachira plant) is using carbon LIGNITE type from local mine with very low additional cost: 0.02 to 0.04 US$/ton of cement. This interesting results need to be validated in other technical centers,
  - The tentative of using pure glycerine failed in many plants (CTEC & CTS regions) – See industrial trial results in the Annex.

- The grinding aids are currently used in many plants for improving C/K ratio
  - By increasing the Blaine allowing higher cementitious level,
  - By using EGA grinding aids (increase of early or 28 day strength).

- Some BUs/ plants are currently generating high saving from grinding aids usage
  - About 5 millions US$/year benefit of grinding aids in India BU (Arasmeta and Jojobera plants),
  - About 9 millions US$/year benefit of grinding aids in VOL plant in Greece.

- Only few data were received from the plants concerning the results & benefits when using grinding aids (mill output increase, power consumption reduction, quality improvement, Cementitious increase…).

- The validated quality and process data generated in coordination between different BUs and TCs was used in combination with current knowledge on grinding aids for defining the expected performance and additional cost of grinding aids (see the paragraph 1.2.3 described below).

1.2.3 Grinding aids expected performance and additional cost

The aim of this paragraph is to summarise the grinding aid validated performance results in terms of mill efficiency improvement, quality improvement as well as the additional cost of grinding aids.

There are many types and brands of grinding aids available and used in the cement Division (see chapter 3 and annex). Here we will focus only on the well known pure chemicals used for producing PGA and EGA.

Some GA brands are composed of several molecules for achieving several quality objectives: for instance increase early and 28 day strength. The results of this kind of grinding aid depend on the GA formulation and will not be described in this summary.

The performance and results of grinding aids depends on several factors (mill type, cement type (blended or OPC), clinker and cementitious grindability, cement quality…

The additional cost of grinding aids depends also on several factors (GA availability, distance to the plant, frame agreement, local GA supply, pure chemicals, level of water in GA…).

In this paragraph we will give only the general trends, which will help for selecting quickly relevant grinding aids for testing. We strongly recommend to perform the lab and industrial trials according to the common guideline developed in this TA before starting using any grinding aid.

The expected performance and additional cost of grinding aids can be summarised as follow:

- **Power consumption reduction (PGA and EGA)**: The power consumption reduction increases with blaine according to the following data and trends:
  - 1 to 3 kWh/ton mill power consumption reduction for cement produced at 3000 to 3500 blaine,
  - 3 to 5 kWh/ton mill power consumption reduction for cement produced at a fineness of 4000 to 4500 blaine.

- **Mill output increase (PGA and EGA)**: The increase of Mill out put also generally increases with cement fineness according to the following data and trends:
  - 4 to 8 % for out put increase for cement produced at 3000 to 3500 blaine,
  - 6 to 12 % for cement produced at 4000 to 4500 blaine.

- **Cement quality improvement (EGA):** the following table describes the expected performance and the additional cost of the main grinding aids belonging to the two groups (PGA and EGA). Only quality and costing are considered. The power consumption and mill output were already elaborated earlier.

  As described above, this table can be used as a reference by the TC/ BU/plant when selecting grinding aids for performing the lab and industrial trials.

  The dosage and the additional cost are based on a solid content of GA of about 30 %.

Group	Company/ Brand name examples	Main Chemical components	Expected quality impact	Side effect	Typical dosage range	Typical additional cost /ton of cement
PGA Power reduction & Output increase	Grace/HA2 Mapei/C166	TEA*	Slight setting acceleration		0.02 to 0.03 % 0.02 to 0.03 %	0.12 to 0.2 US$/ton 0.2 to 0.3 US$/ton
	Chryso/ADM3	DEG*			0.02 to 0.03 %	0.15 to 0.2 US$/ton
EGA Setting time reduction Early strength increase + Power reduction & Output increase	Sika/ VP4	TEA + DEA + Thiocyanate (formulated product)	10 to 15 % early strength increase 20 to 30 minutes setting time reduction** for a binder with an average setting time = 180 minutes.		0.03 to 0.04 %	0.4 to 0.5 US$/ton
	Grace/ TDA770	TEA + chloride	Reduce setting time & increase early strength	Concrete corrosion ***	0.1 to 0.15 %	0.5 to 0.7 US$/ton
EGA Late strength increase (7 and 28 day) + Power reduction &	Grace/ CBA1104	TIPA	5 to 10 % late strength increase	Entrainment of air in concrete at low temperature (champagne effect)	0.02 to 0.03 %	0.4 to 0.6 US$/ton
	Grace/ ESE****	THEED	5 to 10 % late strength increase		0.02 to 0.03 %	0.4 to 0.6 US$/ton

Output increase						
	BASF/ Cementium 290LS	PCE	5 to 10 % late strength increase		0.05 to 0.06 %	0.45 to 0.5 US$/ton
EGA Air entraining agents for masonry applications	AE500/Fosroc	Formulated product	12 to 18 % air in mortar		0.03 to 0.05	0.2 to 0.35 US$/ton

* Pure TEA and DEG can be purchased and used directly by the plants for reducing cost (Austria, France and Germany),

** See India experience,

*** Need to control the global chloride level for ensuring no concrete corrosion. For instance at optimum dosage rate of TDA770: at about 0.15 % dosage, TDA increases cement chloride level by 0.02 %,

**** It is recommended to use ESE family instead of CBA for avoiding champagne effect during cold periods.

We can notice that PGA grinding aids are generally lower additional cost compared to EGA grinding aids. However the decision of using PGA or EGA depends on the objective of the plant (mill output, power consumption reduction, C/K improvement, quality improvement…).

In addition to this, we can combine PGA grinding aids with raw minerals like sodium sulphates (to be added directly to the mill) for accelerating cement hydration and developing low cost EGA. This solution is already used in some Lafarge plants for producing slag cements (France, China…).

1.2.4 Grinding aids cost control and benefits

The main objectives of the purchasing strategy are:

- To reduce grinding aids cost,
- To allow grinding aids continuous supply,
- & to maximize the Division benefit when using grinding aids.

Several actions can be performed by the BUs for reaching the above objectives:

- ➢ To use the global framework suppliers and some local low cost reference suppliers,
- ➢ To use when possible, pure chemicals (TEA, DEG …),
- ➢ To qualify second or third supplier for ensuring continuous supply and competition between suppliers (see the step by step procedure developed in chapter 4),
- ➢ To estimate the annual cost of grinding aid per product and mill (chapter 4),

- To check annually, the quality improvement of cement (clinker reactivity improvement for instance) in-order to:
    - Reduce the EGA dosage, or suppress it (through industrial trials),
    - Reduce blaine for increasing output,
    - Increase Cementitious/limestone…

The benefit of grinding aid should be estimated using the business cases presented in chapter 4. The global benefit can be calculated using the following formula:

- **Global saving = Cement capacity increase saving (for sold out markets) + Cost reduction saving – Additional cost of grinding aid,**
- **Capacity increase = Mill output increase + C/K increase (volume),**
- **Cost reduction = C/K increase + power consumption reduction.**

In addition to the global saving described above, the increase of Cementitious/limestone leads to reduce CO_2 emission and hence is contributing to reach Lafarge CO_2 emission reduction commitment and can lead to an additional benefit for the plant (the cost of CO_2 in Europe is currently estimated at about 20 euros/ton).

1.2.5 Grinding aids guideline

Based on the experience of different technical centres, a common guideline was developed in order to optimize the use of grinding aids within the Cement Division (chapter 5). This guideline is composed of the following modules:

- Grinding aids safety during trials and usage,
- Definition of the grinding aids plant objectives,
- Selection of the grinding aid type/supplier,
- Grinding aids performance evaluation
    - Lab and industrial trial protocols preparation and implementation,
- Grinding aids benefit evaluation,
- Grinding aids quality control.

1.2.6 Grinding aids installation, equipments and CAPEX

The feeding system of liquid grinding aid to the mill is generally composed of 4 elements: Metering pump, Calibration column, Electrical box and Storage tank (chapter 6):

- The manual dosing system is useful for small grinding unit containing one mill. The investment is relatively low (approximately 6500 US$ - source Malaysia),
- The semi-automatic dosing system is relevant for the plants having more than two mills. Higher investment is required (approximately 25 000 US$ per unit and mill – source Korea)
  - Accurate dosage, no dedicated manpower, automatic control…

There is no obvious performance difference of different feeding points of grinding aids to the mill (main clinker belt conveyer, first chamber, reject line of the separator…). However the following precautions should be considered:

- In case of addition of GA to the main belt or to the reject line, to use a sprinkler for better dispersion of grinding aids (chapter 6),
- In case of addition of GA to the first compartment, be sure there is no water spray to the mill. The water spray has a negative impact on the efficiency of the GA for improving grinding operations.

  This solution is the cleanest one compared to the previous feeding points.

1.3. Recommendations

In order to maximize the benefits of the utilization of grinding aids within the cement division we recommend to all BUs & plants with the corresponding technical centre technical support to implement the following actions:

1. To quickly generalise the use of grinding aids in sold out plants which will lead to an important benefit for the Cement Division. This action will generate approximately one million ton additional cement capacity: **the equivalent of one medium size cement plant production**.
   a. The TC, in coordination with the World Wide GA sourcing and local purchasing departments, to support the BUs and plants by identifying relevant GA suppliers and performing the necessary laboratory and industrial trials according to the TA grinding aids guideline (chapter 5).

2. To quickly optimise the dosage and type of the currently used grinding aid~~s~~ by:
    a. Better defining the plant grinding aids objectives,
    b. Selecting the best grinding aids for use according to the TA grinding aids knowledge and the grinding aid expected performance/cost described in section 1.2.3,
    c. Optimizing/reducing the dosage and cost of the existing grinding aids: to perform the lab and industrial trial protocol according to the grinding aids guideline),
    d. Evaluating through lab and industrial trials (TA GA guideline), the best option in term of saving for the plants currently using EGA for increasing Cementitious/limestone (EGA are generally costly):
        i. To use PGA and to increase the Blaine,
        ii. To use EGA,
        iii. To use PGA and to add sodium sulphates or equivalent…

    This action must take into-account the plant grinding capacity.

    e. Implementing a rigorous quality control system for GA reception (see GA Guideline).

3. To strictly control the grinding aids additional cost by:
    a. Implementing the Division purchasing strategy described in chapter 4,
    b. Using the knowledge and data generated in this TA (see the grinding aid performance/cost table described in section 1.2.3 of the executive summary and more details in chapter 3 and the annex),
    c. Using when possible raw chemicals and minerals (pure TEA, pure DEG, Sodium sulphates…),
    d. Estimating the annual cost of grinding aid per product and mill & checking annually the quality improvement of cement (clinker reactivity improvement for instance) in-order to reduce GA dosage/cost or to increase cementitious/limestone,
    e. Controlling the level of water when receiving new GA batch.

4. For any new action/project of grinding aids optimization and qualification, we recommend:
    a. To apply the step by step procedure described in chapter 4, involving the plant/BU, Worldwide sourcing and the TC,
    b. To implement the grinding aid guideline described in chapter 5 including safety procedures,

c. To make a global saving evaluation using the business cases described in chapter 4 and the global saving formula.

- **Global saving = Cement capacity increase saving (for sold out markets) + Cost reduction saving – Additional cost of grinding aid,**
- **Capacity increase = Mill output increase + C/K increase (volume),**
- **Cost reduction = C/K increase + power consumption reduction.**

& to take into-account the CO_2 cost saving when increasing cementitious/limestone, especially in Europe or for the BU having a CDM (Clean Development Mechanism).

5. For the grinding aid installation, we recommend:
   a. To strictly follow the safety procedures according to the GA guideline (chapter 5),
   b. To use a sprinkler for better dispersion of GA, in case of addition to the main clinker belt or to the reject line of the separator (see chapter 6),
   c. To be sure there is no water spray to the mill, in case of grinding aid addition to the first mill compartment,
   d. To use the manual dosing system for small plants having one grinding mill (CAPEX),
   e. To use the semiautomatic dosing system for the plant having more than two mills (CAPEX).

2. General knowledge on grinding aids

2.1 Introduction

Grinding aids are chemical products which have been widely used for more than 50 years. Grinding aids were developed for preventing cement particles agglomeration during the milling process. As a consequence grinding aids reduce mill retention time, improve separation efficiency, decrease energy consumption and increase production capacity (mill out-put).

In addition to the improvement of grinding efficiency a secondary benefit has also been appreciated (cement quality improvement: setting time reduction/early strength increase, late strength increase, workability improvement for masonry cements…).

Today the grinding aids can be divided on two Groups:

- **Process Grinding Aids (PGA)**, which are chemical products relevant for improving grinding efficiency,
- **Enhancing Grinding Aids (EGA),** which are chemical products relevant for enhancing both grinding efficiency and cement performance.

The objective of this chapter is to give the stat of the art on grinding aids allowing reaching the above objectives & contributing to the three major cement division ambitions:

- Cost reduction and cement capacity increase,
- CO2 emission reduction,
- Customer satisfaction.

This chapter is composed of 2 subchapters:

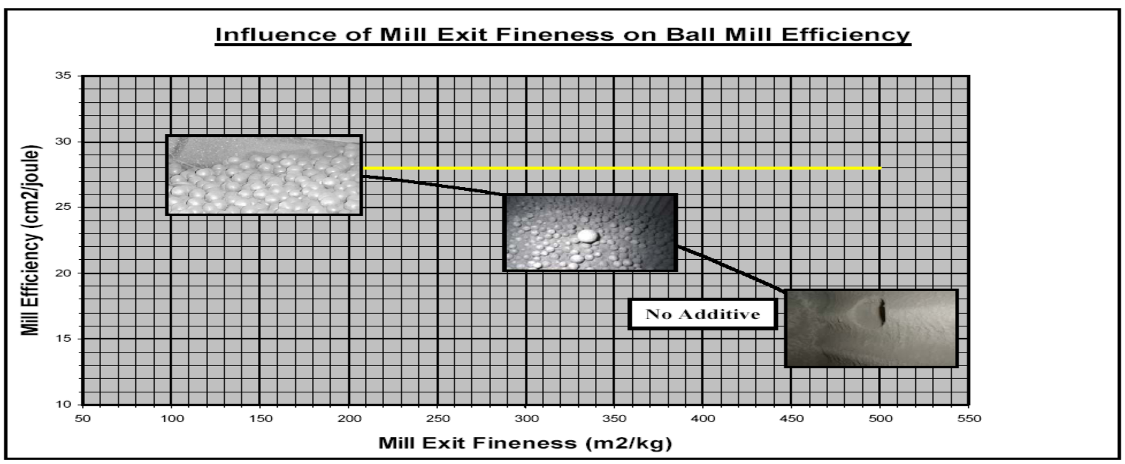
- General knowledge on Process Grinding Aids,
- & General knowledge on Enhancing Grinding Aids.

2.2 First group: Process Grinding Aids (PGA)

PGA grinding aids are relevant for reducing cement agglomeration and **improving grinding efficiency**.

During the cement grinding process, the rate of increase of specific surface proportionally decreases with the fineness increase. There is a direct proportionality within the grinding time and specific surface till a precise fineness (depending on the material and the grinding system). In practice, it is not possible to exceed some fineness value, not even by extending the grinding time. This is principally caused by the particles **agglomeration** that drastically reduces the process performance. The cement particles agglomeration acts on the grinding and on the mill lining as an abrasion resistant film, but also as fine particles, already grinded, agglomerated by electrostatic forces and local conditions of pressure and temperature. It is easy to understand how the film and particles agglomerates can reduce the mill balls effect, by absorbing bumps and dispersing the energy needed for the particles comminution.

Grinding Aid Mechanisms



According to Rittinger's law, beyond certain fineness, the relation between blaine and the power consumption is not any more a linear law (part of energy is lost in heat). At this point, the **agglomeration** of fine particles start and grinding becomes less efficient.

There fore, cement particles can:

- Coat the mill liners,
- Coat the grinding media and,
- Agglomerate and form small plates which absorb the impact (energy lost).

The cement particles agglomeration generally leads to:

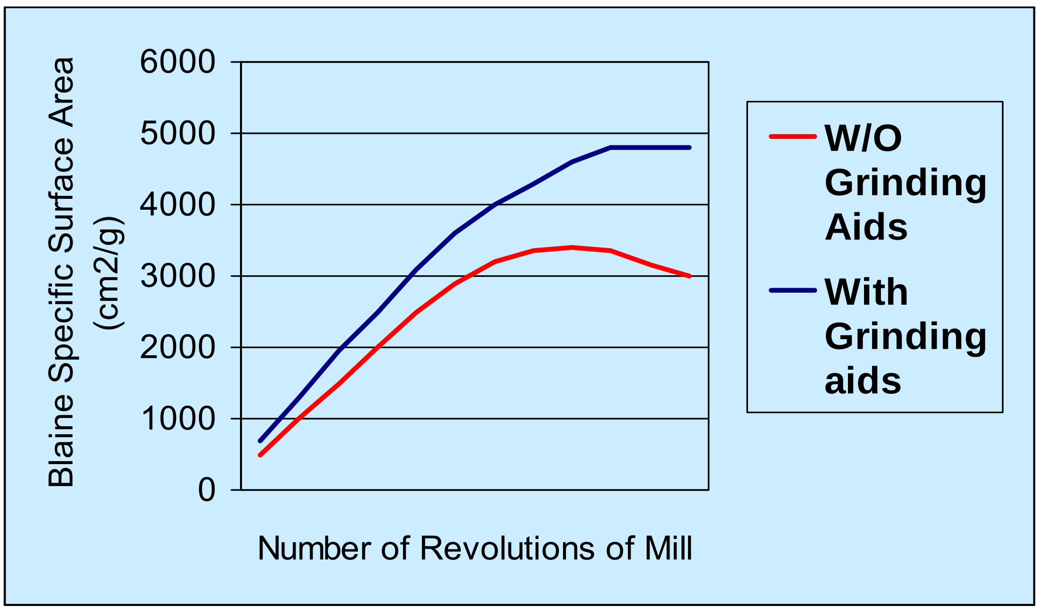
- Reduced efficiency of mill and separator, resulting in increased energy consumption,
- Widens particle size distribution for the same blaine.

The agglomeration phenomena generally depends on:

- Specific characteristics of materials to be ground,
- Mill type (ball mill, vertical mill etc.),
- Operating parameters of the mill,
- Efficiency & distribution of grinding media,
- Fineness of the cement particles,
- Internal operating conditions of mill (Temperature, ventilation, humidity, etc).

Cement grinding Aids are chemical products developed for reducing agglomeration and improving grinding efficiency.

The following figure shows the impact of the usage of grinding aids on the mill grinding efficiency.

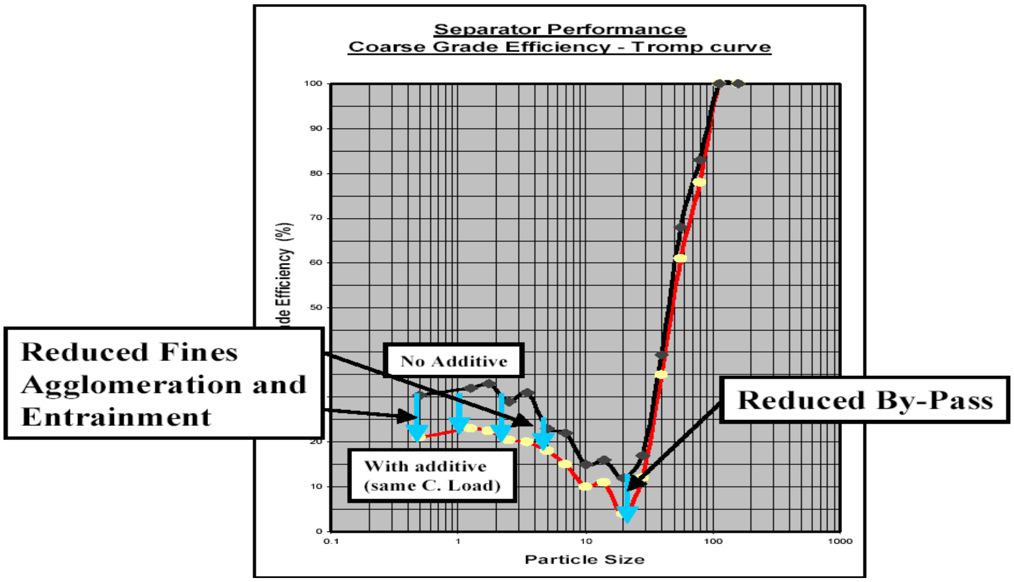


Based on **preventing the agglomeration of cement particles mechanism**, the grinding aids usage improves many of cement properties and grinding operations:

- **Reduce or eliminate coating effect on grinding media** which generally leads to improve the efficiency of the grinding workshop,

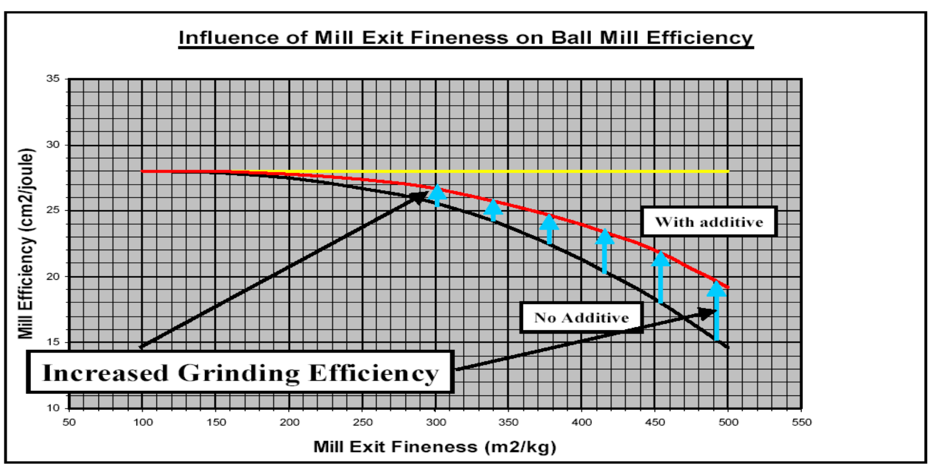
- **Improve in separator efficiency**: When agglomeration occurs, particle agglomerate would be seen as coarse particles and swept out by the separator. With the addition of GA the particles are separated and passed as fine particles suitable for the final product,

Grinding Aid Mechanisms



- **Increase grinding capacity**: Output increase reduces specific energy costs. The increase in production could be used to cover market demand especially in sold out markets (increased sales), to reduce production costs (grinding during lower energy cost periods for instance) and to reduce maintenance costs.
-

Grinding Aid Mechanisms



- **Reduce power consumption**: generally leads to reduce production cost,
- **Improve material handling due to fluidity of cement particles**,
- **Decrease pack-set problems.**

Two chemical sub-groups, **Ethyleneglycols (EG) and Ethanolamines (EA),** are generally used by suppliers as the basis for producing grinding aids suitable for improving grinding efficiency: two pure chemicals are commonly used:

- DEG = Diethyleneglycol,
- TEA = Triethanolamine.

2.3 Second group: Enhancing Grinding Aids (EGA)

Grinding aids for enhancing cement performance, in addition to grinding efficiency. There are several types of EGA grinding aids:

- Setting time reduction,
- Early strength increase,
- Late age strength increase (7, 28 days),
- Air entrainment increase for workability improvement (masonry cements),
- Other properties improvement (Setting retardant, Cement weathering prevention…).

The EGA are formulated products containing one grinding function and one enhancing function. Two sub-groups are commonly used:

- **Grinding aids for reducing setting time and increasing early strengths**: Mixtures containing one grinding function and other products as Chloride, Nitrites, Thiocyanates (sodium or calcium salts) and other compounds like DEA, TEA... Chloride salts are low cost solution, but the dosage is generally limited by national standard to avoid concrete corrosion.

  Sodium sulphates can be combined with PGA for early strength improvement. This is generally lower cost solution compared to formulated EGA.

- **Grinding aids for increasing late strength:**
  a. **TIPA (***Triisopropanolamine***)** type developed by Grace under CBA brand: TIPA acts on the C4AF hydration and hence increases late strengths. The efficiency of TIPA is reduced when the level of C4AF of clinker is low. TIPA can leads to high entrainment of air in mortar and concrete during cold periods “champagne effect” affecting the quality of customer products. Grace developed new product ESE brand based on **THEED** (Diethanolisopropanolamine) molecule for reducing air entrainment in concrete,

  b. **PCE (Polycarboxylate Esther)** type has recently been developed by grinding aids companies (BASF, Sika…) for increasing late strength. The mechanism of this new product is not yet well understood. BASF product (Cementium 290LS brand) is currently used in Malaysia for increasing 28 day strength of fly ash cement (Mascrete Pro product). PCE is under trials validation, in several ASIA countries.

- **Air entraining agents for masonry applications:** Beyond the grinding aid function, tensio-active molecules have been added to the formulated GA. Aryl (alkyl) sulfate, sodium Oleate, fatty acids…are used to generate in mortar high air entrainment level. This improves mortar workability which is appreciated for masonry applications.

The utilization of GA for increasing strengths can be used for reducing fineness, increasing output and improving workability. Tin addition, the strengths enhancers & setting time reduction EGA can be used for increasing C/K ratio in addition to the improvement of cement quality.

In terms of grinding efficiency, the recent study carried out at LCR highlighted the following classification for the commonly and widely used compounds:

THEED > TIPA > TEA > DEG

Grinding efficiency

The efficiency of grinding aids depend on the composition and grindability of constituents (clinker, limestone, slag, Pozzolana):

- The grinding energy of clinker increases with C2S level, Alite size and SO3/alkalis ratio…
- Slag is generally harder to grind than clinker,
- Fly ash, limestone and some Pozzolans (Pozzolans mixed with sedimentary rocks) are generally easier to grind than clinker,
- Some Pozzolans have equivalent to higher grinding energy than clinker (in particular glassy pozzolans).

There is little available information concerning the impact of grinding aids on cementitious materials (slag…).

Co-grinding of fly ash or silica fume with clinker could help for improving grinding efficiency.

The following attachment of LCR report describes more in details the mechanisms of grinding aids.

Grinding Aids review

3. Results of the survey on grinding aids usage within the Cement Division

3.1 Introduction

The inventory of grinding aids usage within the Division was necessary for:

- Identifying the brand, type, dosage and additional cost/ton of cement of grinding aids used,
- Evaluating the results/performance per group and type of grinding aids
  - (i) Determining the level of optimization of grinding aids,
- Identifying sold-out the plants who are not using or partially using grinding aids,
- Sharing experiences between different BUs.

The data were collected by all the cement division technical centres using a common grinding aids survey document prepared by the technical agenda team members.

This chapter represents a summary of the results of the survey, the detailed information and results are described in the annex. This chapter is composed of the following 7 subchapters:

- Brand and type of grinding aid used within the division
- PGA grinding aids performance and additional cost,
- EGA grinding aids performance and additional cost,
- C/K improvement,
- Grinding aids Business case,
- Experience of the use of pure chemicals,
- Estimation of the potential capacity increase (sold out plants/products not using grinding aids).

3.2 Brand and type of grinding aids used within the Division

Grinding aids are widely used in Lafarge BUs of developed countries like Western and Central Europe, North America and some Asia countries (Japan, Korea, India, Malaysia…). However there are many BUs for which the benefit of grinding aids is not fully explored (China, Africa, Eastern Europe, Latin America…),

Lafarge BUs are supplied by many grinding aids companies (WR Grace, Chryso, Fosroc, Maipei, Sika, BASF…). Some BUs are also supplied by local suppliers or raw chemicals which are generally lower cost solutions.

Many types of grinding aids belonging to PGA and EGA groups are used and are fully described in the annex. They are mainly used for increasing output, reducing power consumption, improving C/K ratio and improving cement quality.

The following chapters will describe only the fundamental and important brand & pure chemicals used for designing these brands, their results, their additional cost…

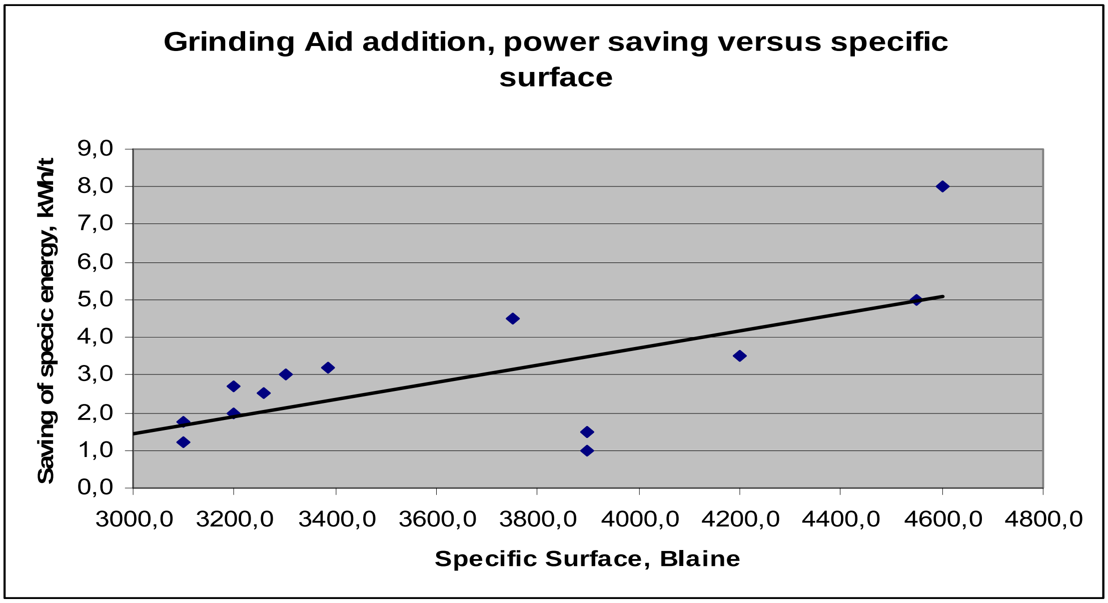
3.3 PGA Grinding aids performance and additional cost

With PGA, broad experience is available whereas EGA is used only in some countries. The level of utilization and optimisation of grinding aids varies from one BU to another. Hereafter are listed the main findings concerning grinding aid usage and benefits in the Cement Division:

- **Power consumption reduction (PGA and EGA)**: The power consumption reduction increases with Blaine according to the following data and trends:
    - 1 to 3 kWh/ton mill power consumption reduction for cement produced at 3000 to 3500 Blaine,
    - 3 to 5 kWh/ton mill power consumption reduction for cement produced at a fineness of 4000 to 4500 Blaine.

- **Mill output increase (PGA and EGA)**: The increase of Mill out put also generally increases with cement fineness according to the following data and trends:
    - 4 to 8 % for out put increase for cement produced at 3000 to 3500 Blaine,
    - 6 to 12 % for cement produced at 4000 to 4500 Blaine.

The graph below describes the impact of Blaine on power consumption reduction (source – CTEC data).



The nominal dosage of PGA grinding aids is about 0.03 % (assuming 30 % solid content of grinding aid) which generally leads to about **0.2 US $/ton of cement additional cost**. However a large variation of the dosage was reported (**0.02 to 0.07 %**) corresponding to a variation of **0.1 to 0.5 US$/ton**. This variation depends on the Blaine target but also on the level of optimisation of the grinding aids usage.

The data described above are indicating the possibility of reducing PGA grinding aids cost by optimizing the currently used GA.

3.4 EGA grinding aids performance and additional cost

The nominal dosage of EGA grinding aids depends on the quality objectives (customer need), the type of grinding aids (setting time, early strength, late strengths…) and the quality of cement which will be treated. There is a large variation of the dosage and additional cost of EGA used in Lafarge worldwide:

- The dosage varies from **0.02 % to 0.15 %,**
- The additional cost of EGA varies from **0.4 to 1.5 US $**/ton of cement

There is also a potential for reducing EGA grinding aids additional cost. This can be done by performing rigorous lab and industrial trials according to the guideline described in chapter 5.

The performance and results of grinding aids depends on several factors (mill type, cement type (blended or OPC), clinker and cementitious grindability, cement quality…

The additional cost of grinding aids depends also on several factors (GA availability, distance to the plant, frame agreement, local GA supply, pure chemicals, level of water in GA…).

In this paragraph we will give only the general trends, which will help for selecting quickly relevant grinding aids for testing. We strongly recommend to perform the lab and industrial trials according to the common guideline developed in this TA before starting using any grinding aid.

Group	Company/ Brand name examples	Main Chemical components	Expected quality impact	Side effect	Typical dosage range	Typical additional cost /ton of cement
PGA Power reduction & Output increase	Grace/HA2 Mapei/C166	TEA*	Slight setting acceleration		0.02 to 0.03 % 0.02 to 0.03 %	0.12 to 0.2 US$/ton 0.2 to 0.3 US$/ton
	Chryso/ADM3	DEG*			0.02 to 0.03 %	0.15 to 0.2 US$/ton
EGA Setting time reduction Early strength increase + Power reduction & Output increase	Sika/ VP4	TEA + DEA + Thiocyanate (formulated product)	10 to 15 % early strength increase 20 to 30 minutes setting time reduction** for a binder with an average setting time = 180 minutes.		0.03 to 0.04 %	0.4 to 0.5 US$/ton
	Grace/ TDA770	TEA + chloride	Reduce setting time & increase early strength	Concrete corrosion ***	0.1 to 0.15 %	0.5 to 0.7 US$/ton
EGA Late strength increase (7 and 28 day) + Power reduction &	Grace/ CBA1104	TIPA	5 to 10 % late strength increase	Entrainment of air in concrete at low temperature (champagne effect)	0.02 to 0.03 %	0.4 to 0.6 US$/ton
	Grace/ ESE****	THEED	5 to 10 % late strength increase		0.02 to 0.03 %	0.4 to 0.6 US$/ton

Output increase						
	BASF/ Cementium 290LS	PCE	5 to 10 % late strength increase		0.05 to 0.06 %	0.45 to 0.5 US$/ton
EGA Air entraining agents for masonry applications	AE500/Fosroc	Formulated product	12 to 18 % air in mortar		0.03 to 0.05	0.2 to 0.35 US$/ton

* Pure TEA and DEG can be purchased and used directly by the plants for reducing cost (Austria, France and Germany),

** See India experience,

*** Need to control the global chloride level for ensuring no concrete corrosion. For instance at optimum dosage rate of TDA770: at about 0.15 % dosage, TDA increases cement chloride level by 0.02 %,

**** It is recommended to use ESE family instead of CBA for avoiding champagne effect during could periods.

3.5 C/K improvement

Both PGA and EGA are used for increasing the level of limestone/cementitious:

- PGA are generally used for grinding cement finer and thus increasing the level of mineral additions,
- Depending on market need, the type of additions and the reactivity of the cement, two types of EGA grinding aids are used for improving the C/K ratio
  a. Grinding aids for reducing setting time and increasing early strengths – recommended when clinker reactivity (early strength) is low,
  b. Grinding aids for increasing late strength. This is relevant for increasing the level of low reactivity mineral additions (limestone, Pozzolan class F fly ash…). This is especially recommended when the clinker long term reactivity is low (7 and 28 day strength),
- The benefit in term of cementitious and limestone increase linked to EGA and PGA usage varies from one plant to another,
- Up to 7 % increase was reported in ATC zone,
- No available data in the other TCs regions,
- The decision of using PGA or EGA depends on the balance performance/cost and the market requirement (this topic is well documented in the GA guideline – chapter 5).

3.6 Grinding aids business cases

The global benefit of grinding aids can be calculated as follow:

- **Global saving = Cement capacity increase saving (for sold out markets) + Cost reduction saving – Additional cost of grinding aid,**
- **Capacity increase = Mill output increase + C/K increase (volume),**
- **Cost reduction = C/K increase + power consumption reduction.**

In addition to the global saving described above, the increase of Cementitious/limestone leads to reduce CO2 emission and hence is contributing to reach Lafarge CO2 emission reduction commitment **and can lead to an additional benefit for the plant (the cost of CO2 in Europe is currently estimated at about 20 euros/ton).**

The BUs having a CDM (Clean Development Mechanism) should also use CO2 emission reduction in the global saving calculation.

Significant global saving can be achieved especially in sold-out markets. The following paragraph described the savings achieved in some BUs/Plants:

ATC regions - Example of India BU: The optimization and the use of Sika grinding aid by India BU with ATC support is leading to an important benefit for the company: about **5 millions US $/year** with a potential of more than 10 millions US$/year savings if the use of GA is generalised to all the plants

- India BU is currently using Sika VP4 grinding aid which is an EGA for increasing mill output, reducing setting time & increasing early strength, leading to increase the level of slag and fly ash in Indian binders,
- This grinding aid is currently used in Arasmeta for all products and partially in Jojobera plants.

CTEC regions – Example of VOL plant: The use of EGA grinding aids (type TIPA) are leading improve late strength, to increase out put by 10 % and to reduce power consumption by 4 kWh/ton. This is leading to a global saving of **9 millions US$/year** for about 4 millions tons capacity.

3.7 Experience of the use of pure chemicals

Some Lafarge plants are using directly pure products for reducing the GA additional cost:

- Mainly pure TEA and DEG are purchased in Austria, France and Germany and can be diluted in the plants (Germany),
- Venezuela (Tachira plant) is using carbon LIGNITE type from local mines as grinding aid. According to the plant, they started using it a long time ago, to improve milling process (levels of production, SSB…). No secondary effects were observed related to this GA, like changes in cement or concrete setting time, cement colour or stain formation in concrete. The additional cost of GA is very low 0.02 to 0.04 US$/ton of cement. This interesting results need to be validated in other technical centers,
- The tentative of using pure glycerine failed in many plants (CTEC & CTS regions) – See industrial trial results in the Annex.

3.8 Estimation of the potential capacity increase

In the frame of this technical agenda, all the TCs did a survey (end of 2007) for evaluating the level of usage of Grinding aids and the main benefits. It was highlighted that many of Lafarge plants are not using any grinding aids. This is critical, especially for sold out markets, where the increase of cement production can lead to an important benefit for the company. Below are summarised the results of the survey of the main sold out plants:

- **ATC regions**: The global volume of cement for which there was (end of 2007) no addition of GA in ATC regions sold out plants is about 10 millions tons (mainly the new Chinese plants),
- **CTEC regions**: There is no addition of grinding aid to about 8.4 millions tons of cement in sold out plants (mainly Jordan, Romania and Russia),
- **CTEA regions**: The global volume of cement in 2007 – without any GA addition – represents about 6.8 millions tons including 1.4 millions tons sold-out for Africa (Benin, Nigeria and Zimbabwe),
- **LATAM regions**: Many plants are not using any grinding aids (Brazil, Chile, Venezuela, Honduras),
- **CTS regions:** All the plants are using grinding aids.

More than 20 millions tons of cement in sold out markets are produced without using any grinding aid.

The generalisation of the use of PGA grinding aid in sold out markets of the cement division will lead to the increase of the production capacity of more than one million tons, the equivalent of the production of one medium size cement plant.

The above result was obtained by supposing an average increase of mill output of 5 % when using PGA grinding aids.

To notice that the above results correspond to the results of the survey made in the end of 2007. All TCs already launched or are launching action plans for generalizing the use of grinding aids.

4.0 Grinding aids cost control and benefits

4.1 Objective

The following section is to provide guidelines to each Lafarge Business Unit on the purchasing strategy and the worldwide framework agreements.

4.2 Worldwide Purchasing Strategy

The worldwide (WW) sourcing strategy is to provide Lafarge Business Units with a list of global suppliers who will partner with each Lafarge plant in the identification of a product which will improve the plants total cost of ownership (TCO). The total cost is defined as dosage rate, unit cost, power

- Specifically, the goal is to identify a list of local and global suppliers who can provide Lafarge Business Unit with a consistently manufactured high quality product at the optimum cost.

4.3 Global Cost Optimization

In order to maximize the benefits, it is important to know the GA cost per ton of cement produced. In the case of PGA, the financial benefit needs to be evaluated by taking into account the reduction in power consumption (increase of TPH) and increase cement sales if applicable against the cost of GA. In the case of EGA – because the benefits (cement properties enhancement) are not so easily quantified in financial terms – the overall financial benefit is more difficult to estimate. However, when using EGA, for increasing the level of Cementitious/limestone, the same approach than PGA must be used for estimating the financial benefits.

The following formula should be used:

$$\text{Cost of Treated Cement} = \frac{\text{Total Annual Cost of Grinding Aids}}{\text{Total Annual Production of Mill}}$$

Total Annual Production of Mill (in MT)

Total Annual Cost of Grinding Aids for each mill (annual dosage rate (MT) multiplied by $/MT).

** It is important to note that the ratio of cost of treated ton of cement needs to be statistically validated based on the regional requirements. WWSS should be contacted to assist with the evaluation.

When the plant is using EGA for improving cement quality and/or increasing Cementitious/limestone, it is important to make a yearly check of the dosage of grinding aid required.

In fact, with the technical centre support the plant generally improves the cement quality (clinker reactivity…). New industrial trials must be performed for:

- Reducing the dosage of grinding aids or suppressing it depending on the current cement quality,
- Increasing Cementitious/limestone
- …

4.4 Global Framework Suppliers

Currently, there are six global framework suppliers for the supply of grinding aids:

- o Chryso (global)
- o Fosroc (Europe, ME, and Asia)
- o Mapei (Europe, ME, and Asia)
- o Quality Grinding Aids (North America Only)
- o WR Grace (global)
- o Sika (Global)
- o Etc (contact WWSS for other suppliers)

It is important to note, Lafarge has established relationships with pure chemical suppliers such as BASF and Huntsman and local country specific suppliers. The use of pure chemical suppliers could be a key strategy for Lafarge business units who have decided to manage the mixing and handling systems at the plant level (e.g. Lafarge Germany and Austria BU). As part of the global framework agreement, the framework suppliers are intended to provide technical services at no cost to Lafarge. The sales engineers from each supplier should regularly visit to the plant as required but also look to provide technical seminars to Lafarge at no cost. Lafarge Group Purchasing will coordinate with Technical Centers the coordination of free seminars and the frequency of the need.

In addition, in some case depending on the supplier's market share, WW Purchasing and Local Purchasing can look to negotiate additional services such as dosage equipment.

4.5 Global Commercial Strategy and Qualification Process

A key commercial strategy to manage costs and ensure competition is to ensure each Lafarge Business Unit has at least one secondary source qualified at the plant. Many Lafarge plants have at least 3-4 qualified sources for each mill. While there are a number of reasons for this strategy the main reasons are:

- Secure a secondary source in the event there is a disruption in supply or there is a quality issue,
- Develop competition between suppliers,
- To know the performances of several GA suppliers in a particular plant.

Therefore, prior to qualify a secondary supplier the following process must be followed:

- Step 1: Contact the technical center to inform them regarding the need for a grinding aid trial,
- Step 2: Contact the local purchasing department to determine the list of potential suppliers to consider for a lab and industrial trial-Plant and TC to select suppliers complying with criteria as : GA type (PGA or EGA), availability, cost…
- Step 3: Inform the current supplier (if applicable) the need to qualify a secondary supplier which can lead to recommendation of new commercial offer: cost, product efficiency, … or new product.
- Step 4: Perform the lab and industrial trials based on Grinding Aid TA protocols (see TA guideline in chapter 5) with the current supplier (if applicable) and other suppliers as identified by local purchasing. When necessary the TC to prepare relevant trials protocol especially for EGA grinding aids.
- Step 5: Share the results with the technical center and the BU for approval.
- Step 6: Once results have been approved, local purchasing will provide the test results and the list of suppliers which are qualified and cost evaluation to WW Purchasing. During this exchange it is important to include key information from the test result such as:
    - Brand name of product,
    - Product characteristics (Product Data Sheet & Material Safety Data Sheet),

- Dosage rate,
- Impact on cement quality characteristics,

➢ At this time, the BU with the technical center support should quantify the benefit of the grinding aids versus the current status quo (no grinding aid, or by comparison to the existing grinding aid). The business case should be completed and sent to the Worldwide purchasing.

Business Case Tool for Grinding Aids

In case of cementitious/limestone increase objective, the benefit of grinding aids should be calculated using the following formula (see attached Arasmeta plant from India BU as a reference).

The global benefit of grinding aids can be calculated as follow:

- **Global saving = Cement capacity increase saving (for sold out markets) + Cost reduction saving – Additional cost of grinding aid,**
- **Capacity increase = Mill output increase + C/K increase (volume),**
- **Cost reduction = C/K increase + power consumption reduction.**

Arasmeta plant case – India BU

➢ Step 7: WW Purchasing for consolidation and final negotiations with suppliers.

➢ Step 8: Once negotiations have been completed, a business case will be presented by Worldwide Purchasing to the Lafarge Business Unit.

5.0 Grinding aids Guideline

5.1 Introduction

The objective of this guideline is to recommend the process and methodology for optimizing and using grinding aids within the cement division.

This guideline is composed of the flowing modules:

- Grinding aids safety
- Definition of the grinding aids plant objectives,
- Selection of the grinding aids and the suppliers,
- Grinding aids performance evaluation,
- Grinding aids benefit evaluation,
- Grinding aids quality control.

5.2 Grinding aids safety

It is recommended to follow the safety guidelines described in the MSDS given by the supplier to avoid any problem during the usage of GA in the plant trial and laboratory trial. The technical data sheet and MSDS data sheet given by SIKA are attached here as a reference.

Technical Data Sheet

MSDS Sika Grindaid

<u>Safety at the site</u>

- The installation of the GA nozzle on the belt or in the mill requires full safety attention: Any manipulation during the mill operation is completely forbidden,
- Any calibration of the nozzle has to be made in a safe distance to the moving belt conveyor or the mill,
- Samples have to be taken from a safe point (installed and dedicated sampler) or in accordance with plant safety engineers and experienced shop personal by using full PPE and dedicated tools. The samples can never been taken from an operating belt conveyor. Hot samples have to be taken with heat protection only,

- Opening from air slides for sampling can only be done with full heat and dust protection, as overpressure may occur. The shop can only be accessed together with an experienced plant member,
- For any work on the mill circuit itself
    - The shop responsible has to be informed,
    - Safety procedures have to be checked,
    - The mill shop has to be stopped,
- The mill sequences have to be logged out and a restart has to be tested negatively (LOTOTO),
- Safety procedures as working on height, contact with hot materials, confined space, personal protective equipment, and local safety procedures have to be respected.

5.3 Definition of the grinding aid plant objectives

Before starting using grinding aids, the BU and the plant must clearly define the objectives in collaboration with the technical centre. Depending on the type of grinding aids, we can target one or several of the following objectives:

- Increasing cement productivity (sold out markets),
- Increasing Cementitious & limestone levels,
- Improving product performances.

When the plant objectives are well defined, it is recommended to identify potential grinding aids suppliers near the plant & to evaluate (in coordination with the TC) the level of the technical centre support

- The plant has never used grinding aids,
- The plant is already using grinding aids.

5.4 Selection of the grinding aid type/supplier

Well defined objectives will help the TC to recommend relevant type of grinding aid:

- Grinding aids for Mill out put increase (TEA, DEG…),
- Grinding aids for quality improvement (TIPA, PCE…).

When the type of grinding aid is well defined, the plant/BU team, in coordination with the corresponding TC and Worldwide Sourcing/local purchasing has to identify potential suppliers near the plant for conducting the trials.

It is recommended to use the grinding aid purchasing guideline described in chapter 4 for selecting the supplier offering the lower cost solution (frame agreement…).

5.4.1 GA Selection- Precautions to be considered

The usage of grinding aid can cause different problems:

- Clogging of filter bags → differential pressure increase,
- Increase of moisture in the gas circuit with higher (moist) feed,
- Clogging in the mill inlet chute and trunion.

Therefore, it is recommended to set precautions for prevention or at least to consider the following issues to reduce the bag filter pressure:

- More purging cycles in the filter,
- Maintain good quality filter bags,
- Increase area of filter surface in case of undersized filter area.

5.4.2 GA – Usual limitations

There are many limiting factors and comments in respect to the use of grinding aids:

- C1 filling level: volume expansion in the first compartment to be controlled by el. Ear,
- Moisture: heat balance for mill, has to be done if the feed moisture is > 1%,
- Heat: maintain mill and separator ventilation,
- Separator capacity – Tromp curve: if separator is already overloaded,
- Transport system,
- Filter performance: as the usage of GA can cause a kind of greasy-oily filter cake, filter supplier can react with two different options to be able to run the filter cleaning cycle in unchanged mode:
  - Usage of extremely fine fibres on filter surface,
  - Special chemical treatment of the filter surface.

5.5 Grinding aids performance evaluation

For mill out put increase, it is recommended to run directly an industrial trial, while for quality improvement or Cementitious increase it is recommended to perform first the lab trial & to use the results for defining the industrial trial protocol.

5.5.1 Grinding aids laboratory trial protocol

This protocol is composed of three sections:

- Preparation of the laboratory trial protocol,
- Laboratory cement samples preparation,
- Evaluation of the performance and usage qualities of the laboratory cements samples.

5.5.2 Preparation of the laboratory trial protocol

- Analyse at-least the last three months plant quality data: physical & chemical test results, usage quality test results…
- Establish the binder (s) mix design and the quality targets for the lab trial using the plant objectives, the plant quality data and the plant quality contract,
- Prepare a detailed lab protocol (by TC) and diffuse it to the plant team
  - Recommendations for different dosage of grinding aids,

SL.NO	GA dosage %
1	Blank
2	Level 1
3	Level 2
4	Level 3
5	Level 4

  - Recommendations for cement samples preparation,
  - Recommendations for the testing methods,
- Ensure the availability and the good condition of the lab ball mill,
- Ensure the availability of the laboratory manpower for conducting the new laboratory trial,
- Ensure the availability of the newly proposed grinding aid (s),

- Ensure all the lab testing methods are calibrated and the instruments are in good working condition,
- Ensure the stability of temperature and humidity in the testing and curing rooms,
- Collect sufficient quantities of clinker, gypsum and cementitious materials for testing
    - The quality of raw materials must be representative of the normal, production (for instance = average of the lat 3 months production)
    - A single source of materials must be used for the entire lab trial,
    - Store all the samples in a well sealed plastic bags or plastic containers,
    - The clinker sample has to be cool down before storage in plastic bags
    - Gypsum and Cementitious materials has to be dried before storage in plastic bags,
- Carryout the following raw materials characterisation before the laboratory trial
    - Clinker: Grindability (BB10), XRF or wet chemistry, soluble alkalis, LOI, free lime, IR and mineralogy analysis (Rietveld XRD and microscopy analysis),
    - Gypsum : complete chemical analysis, LOI, IR and purity,
    - Cemetitious materials and limestone
        - Slag: grindability, XRF or wet chemistry and glass level by Rietveld XRD method,
        - Pozzolan: grindability, XRF or wet chemistry, Insoluble Residue, LOI, clay level (methylene blue method). The reactive silca could be performed according to the national standard for conformity,
        - Fly ash: XRF or wet chemistry, glass level by Rietveld XRD method, IR, LOI, PSD, Blaine and density,
        - Limestone: XRF or wet chemistry, LOI, IR, clay level (methylene blue).

- For the methods which are not available in the plant, send small samples to the TC lab for testing (consult the TC for defining the quantities)
        - Grindability, Rietveld XRD, microscopy…

5.5.3 Laboratory cement samples preparation

The following step by step procedure is recommended for performing the actual laboratory trial

- Before starting the lab trial be sure that all the conditions cited in the preparation phase are satisfactory
    - All the raw material samples must be dried before the trial,
- Carry out the trials as per the details mentioned in the table above **(5.5.2),**
- Start with the blank sample without grinding aid and prepare the required cement quantity (10 kg for instance) using lab ball mill by inter-grinding clinker, gypsum and cementitious materials,
- Analyse the cement samples for following parameters:
        - Blaine,
        - SO3,
        - LOI,
        - PSD and 45 micron residue,

  - Record the time and power required to reach the desired Blaine,
- Add the grinding aids to the raw materials (trial 2) and repeat the operation by analysing and controlling cement sample as mentioned above,
- Store all the lab trials samples in a air tight back for testing.

5.5.4 Evaluation of the performance and usage qualities of the laboratory cement samples

The following analysis should be carried out for all the laboratory trial samples:

- Chemical characteristics: XRF or wet chemistry, LOI, IR, free lime,
- Physical characteristics: Water demand, Blaine/ PSD, setting time, compressive strength according to the national standard (1, 3, 7 and 28 days for instance), expansion test.

Optional testing for checking the cement usage qualities:

- Micro concrete: Temperature of Micro concrete just after mixing, Water demand for reaching a given slump/spread, workability at 5, 15, 30,60 and 90 minutes, compressive strength at 1,3,7, and 28 days,
- For Micro concrete and/or concrete studies**,** it is recommended to use the general concrete mix design adopted for normal construction applications,
- The optimum dosage of GA dosage for the industrial trial has to be selected based on the performance evaluation results of all trial samples.

5.6 Grinding aids industrial trial protocol

The industrial trial protocol is composed of four sections

- Modes of feeding grinding aids to the cement mill (see chapter 6),
- Preparation of the industrial trial for GA addition,
- Performing actual industrial trial for GA addition,
- Evaluation of the performance and usage qualities of the industrial trial cements samples.

5.7 Preparation of the industrial trial

Before staring the industrial trial for GA addition, it is important to make a good preparation for ensuring the success of the trials:

- Ensure the availability of the mill and silo (s) for the trials,
- Ensure the availability in the plant of the dosing pump of the grinding aid and its calibration with the grinding aids which will be used in the industrial trials,
- Ensure the weigh feeders calibration,
- Check the availability in the plant of the newly proposed grinding aid,
- Ensure the availability of the quality/production managers and the manpower for conducting the trials,

- Ensure all the lab testing methods are calibrated and the instruments are in good working condition,
- Ensure the stability of temperature and humidity in the testing and curing rooms,
- Collect the following general process information about the cement mill separator and feed material data,

Parameter to be Monitored		
Before the trial	**Feed**	PSD of the final cement
		moisture of feed
		Rate (t/h)
		Material Temperature
	Mill	Power (kw)
	Sepeator, Roller press and Bag filter	Separator Feed PSD
		Separator reject PSD
		Separator product PSD
		Efficiency
		Bypass
		Acuity
		Imperfection
		Sep speed
		Bag filter pressure drop
		Roller press power
		Separator ventilation details

- Collect and analyse at-least the last three months plant quality data corresponding to the concerned cement for the trial: physical & chemical test results, usage quality test results…

- Use the following excel software for determining the tromp curve which will evaluate the performance of the separator,

The above attachments explain how to calculate the tromp curve of separator for determining the separator performance. PSD data of Separator feed, separator rejects and separator product has to be measured before and after GA addition. The evaluation of parameters like bypass, Imperfection, Acuity Limit and Rosin-Rammler slope value will give a clear indication about the separator performance.

- Use the following excel (a model example) for determining the specific power consumption reduction when GA is added in the cement mill

GA Power

The above attachment explains how to calculate the reduction in specific power consumption when using GA. Power reading either from the control panel or using energy meter has to be recorded during the entire trial with and without GA addition for all the machineries associated with mill section.

- Define the binder (s) mix design and the **quality targets** for the industrial trial using:

    a. The plant grinding aids objectives,

    b. The product mix design currently used or optimised during the lab trial,

    c. The plant quality data and the plant quality contract,

    d. The mill capability (to consult process/production department of the plant).

- Prepare a detailed industrial trial protocol (by TC) and diffuse it to the plant team – when the grinding aid is dedicated to increase mill out put only the industrial trial could be prepared by the plant team and validated by the TC.

    a. Recommendations for different dosage of grinding aids,

SL.NO	GA dosage %
1	Blank
2	G1
3	G2
4	G3
5	G4

    b. Recommendations for the binder (s) mix design (PSD, 45 microns, observe Blaine, cementitious/limestone increase…),

    c. Recommendations for the testing methods.

- Have the agreement of the plant team before organizing the mission for the industrial trials implementation.

5.8 Performing the actual industrial trials

Before performing the industrial trials, some precautions have to be taken:

- To run the mill in normal production (normal process setting),
- To use representative raw feed materials including the clinker normal temperature,
- To make an hourly sampling and to stabilize the residue at 45 microns for instance (at least two equal results on residue),

- The duration depends on the objectives (C/K improvement…), the stability of the mill,

- ➢ To not forget to make one trial with the blank sample or the current grinding aid,
- ➢ To prepare in advance the quality targets
    - 45 microns = x+/- 1 for instance…

The following step by step procedure is recommended for performing the industrial trials:

Step 1: Before the trials

1. Be sure that the mill is running in normal production: measure the following process parameters using relevant process instruments and compare with CCR reading
    a. Mill main motor Kw,
    b. Mill out let temperature,
    c. Mill pressure (static and dynamic),
    d. Reject flow or bucket elevator power,
    e. Separator power and separator RPM,
    f. Roller press power (if any),
    g. Bag filter inlet and outlet pressure,
    h. Tromp curve of the separator.

2. Collect representative raw feed material samples for analysis
    a. **Clinker (10 kg):** Grindability, XRF or wet chemistry, soluble alkalis, LOI, free lime, IR and mineralogy analysis (Rietveld XRD and microscopy analysis),
    b. **Gypsum (5 kg):** complete chemical analysis, LOI, IR and purity
    c. Cemetitious materials and limestone (10 kg of each)
        i. Slag: grindability, XRF or wet chemistry and glass level by Rietveld XRD method,
        ii. Pozzolan: grindability, XRF or wet chemistry, Insoluble Residue, LOI, clay level (methylene blue method),
        iii. Fly ash: XRF or wet chemistry, glass level by Rietveld XRD method, IR, LOI, PSD, blaine, density,
        iv. Limestone: XRF or wet chemistry, LOI, IR, clay level (methylene blue),
    d. For the methods which are not available in the plant, send small samples to the TC lab for testing
        i. Grindability (BB10), Rietveld XRD, microscopy…

Step 2: During the trials

Carry out the trials as per the protocol and the reference table **(section 5.8)** based on the data analysis:

- ➢ It is recommended to start with the blank trial first (without addition of GA) or using the current grinding aid,

- Collect samples from the finished product for every 30 minutes or 1 hour (depending on the plant lab manpower availability) and analyze the cement samples for following parameters until the mill is stabilized:
    - 45 micron residue,
    - Blaine for observation only (value will vary),
    - SO3,
    - LOI.

- Ensure the stable operation of the mill by checking the above parameters for every 30 minutes or 1 hour. The mill is stabilized when you reach at least 2 times equal results,

- At the end collect **200 kg cement sample** for evaluating the performance and usage qualities
    - 200 kg is necessary for change in cement composition objective,
    - 30 to 40 kg is recommended when no change in cement composition,

- It is recommended to make proper arrangements with good safety conditions for taking such bulk quantity of samples
    - Sampling safety procedure to be followed,

- **In addition it is recommended to conduct at least 12 hour duration when the GA is used as performance enhancer EGA (6 hours minimum in stable conditions),**

- **At least minimum 6 hour duration of trial is recommended when GA is used only for increasing the production (PGA),**

- Measure all the relevant process parameters during **each trial** (use the below table as reference) or recommended to use the plant standard log sheet,

Parameter to be Monitored	
After the trial	Mill power / kW
	Mill out put t/h
	Temp prod mill
	Temp mill outlet
	Temp prod sep
	Temp rejects
	Mill ventilation
	Sep ventilation
	Sep speed
	Moisture finish prod
	Separator Product PSD
	Separator Reject PSD R45
	Separator feed PSD
	Product Blaine
	Product strength at different ages
	Product workability

	Product setting time
	Sep Tromp Curve
	Bag filter pressure drop
	Roller press power

- Repeat the operation for trial no 2 with desired GA addition and at the end of each trial collect relevant quantities of cement samples,
- Cool down all the cement samples and store it in well sealed containers or plastic bags,
- Store all the cements produced in the dedicated silo.

Step3: After the trials - evaluation of the performance and usage qualities of the industrial trials samples

The following analysis should be carried out for all the industrial trial samples

- Chemical : Full chemical analysis, LOI, IR, free lime, soluble alkalis, gypsum/hemihydrate repartition,
- Physical: Blaine, PSD, Water demand, setting time, compressive strengths of mortar for 1, 3, 7 and 28 days, expansion,

Optional testing for checking the cement usage qualities:

- Microconcrete: Temperature of MC just after mixing, Water demand, workability at 5,15,30,60 and 90 minutes, compressive strength at 1,3,7, and 28 days,
- Concrete: Temperature of concrete just after mixing, workability at 5,15,30,60 and 90 minutes, compressive strength at 1,3,7, and 28 days, Air content and Bleeding,
- For Micro concrete and concrete studies it is recommended to use the general concrete mix design adopted for normal construction applications,
- If the grinding aid/accelerator is leading to a significant change of the concrete usage qualities, it is recommended to test the product in customer sites through blind tests.

Process follow up for the mill operator consist in:

- Observation of the mill recirculation by following the recommended bucket elevator load (A) and/or, separator load (kg/m³) and reject flow weighing (t/h),
- It is expected, that the mill empties when GA is added, that means the recirculation rate will decrease,
- Stabilization of the reject flow by variation of the fresh feed (t/h),
- Observation of the mill sensor as electrical ear not to overfill the first grinding compartment (%),
- Stabilization of the fineness preferably residue at 45µm or 63 µm by variation of the separator speed, but not the fineness in SSB (variation expected versus residue at 45µm),
- The mill is stabilized, when the former recirculation (t/h) and fineness (residue at 45µm) is reached and can be kept. The SSB level is expected to decrease slightly,

- Evaluate the separator performance by determining the Tromp of separator using the following excel software.

5.9 Grinding aids benefit evaluation

The following formula quantifies the energy saving in terms of money (US$/Ton of cement).

Global savings = **Cement capacity increase saving (for sold out markets) + Cost reduction saving – Additional cost of grinding aid**

Capacity increase = **Mill output increase + C/K increase (volume)**

Cost reduction = **C/K increase + Power consumption reduction**

In addition to the global saving described above, the increase of Cementitious/limestone leads to reduce CO2 emission and hence is contributing to reach Lafarge CO2 emission reduction commitment and can lead to an additional benefit for the plant (the cost of CO2 in Europe is currently estimated at about 20 euros/ton).

The optimum dosage of GA has to be selected based on the performance evaluation results at lower cost.

5.10 Grinding aids quality control

For testing the quality of grinding aid in the plant quality lab the following tests have to be performed:

- Specific Gravity,
- pH,
- Deformulation – Samples to be sent to the TC for deformulation analysis.

The analysis has to be crosscheck with the supplier product data sheet.

At least water content (specific gravity) has to be controlled for each new grinding aid batch.

6.0 Grinding aids installation and equipments

6.1 Grinding aids feeding system to the mill

Grinding aids are generally in liquid form and have to be dosed through a metering pump onto the conveyer belt, the rejecting line of the separator or directly in the first chamber of the mill.

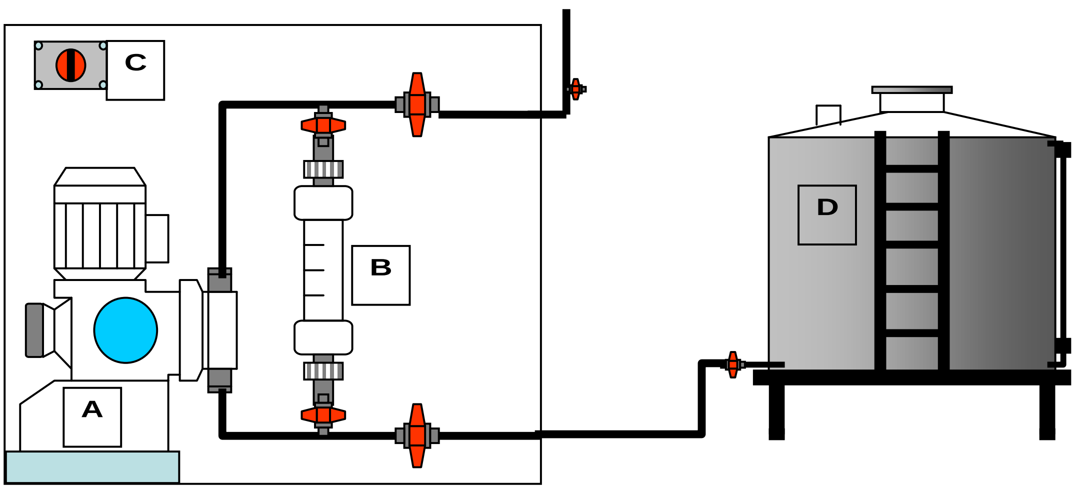
The GA feeding system should contain:

A) Metering pump: The capacity of the dosing pump depends on the mill type and TPH,

B) Calibration column: The calibration system consists of measuring device for adjusting the flow of GA to the mill system,

C) Electrical box,

D) Storage tank: The storage system consists of big tank with indicator for measuring the volume of the GA in the tank.



The whole manual feeding unit a), b) and c) should be assembled in a single metal box container in order to withstand the dusty environment of the cement plant.

6.2 GA feeding location

- **Feeding in the main belt conveyer & in the rejecting line:** This is the simplest system and allows a direct visual control of the flow. The additive must not wet the conveyor, to avoid crusts whose thickness may enlarge on the return and support rolls. The most frequent problems are caused by high dosage additives and on quick conveyor belt (with a low material layer): In this case it is necessary to adopt the flow as per below arrangement to have a better distribution so that the additive avoid drops falling onto the bare belt.

- **Feeding into the 1st chamber of the mill:** This is the "cleanest" dosage system. One of the best ways to introduce grinding aid into the milling system is the use of an aspirator. The aspirator is made of black iron pipe. This system need a good air pressure regulator to maintain the 70 to 100 kpa necessary to spray – and not vaporize – the grinding aid solution into the mill. The aspirator should be installed above the centre line of the mill, sloping at a slight angle down into the mill to prevent any solution from running back along the outside of the pipe and dripping on the mill trunion. The pipe should be angled across the feed chute to direct the grinding aid into the cascading material.

6.3 GA installation CAPEX

The following table shows approximate cost of the normal grinding aid dosing system and the following attachments shows regular dosing system implemented in the plant. This type of dosing system needs a dedicated manpower for monitoring the flow of GA to the mill and it is recommended for a plant having one single mill and small grinding capacity.

COST OF NORMAL GA DOSING SYSTEM		
SL.NO	**ITEMS**	**COST**
1	GRINDING AID DSING PUMP (MAX 200lit/Hr)	**APPROXIMATE COST = 6500 US$**
2	CALIBRATION SYSTEM	
3	ELECTRICAL ACCESSORIES	
4	STORAGE TANK (MAX 1000 LIT/CAPACITY)	

For bigger grinding units or plants having many cement mills the interlocking of GA feeding system with the mills operations is the best way for effective utilization of GA which needs a high investment. However a semi – automatic dosing system also much be useful for accurate control. The below attachments shows the complete information of semi – automatic dosing system implemented at Harbor plant in Korea (5 mills).

GA Feeding system

The semi – automatic system consists of big storage tank, a dosing pump, a filter for removing unwanted material and an accurate flow meter. The flow meter controls the flow rate of grinding aid and it is interconnected to the pump. Both pump operation and flow meter operation are controlled from CCR room. There is also a digital indication of the volume of the grinding aid stored in the big tank which can be viewed from the CCR room. However this system is not interlocked with mill operation and if there is a stoppage in the mill then control room operator can immediately cut down the flow of the grinding aid. The total cost of one unit is approximately 25,000 US$. This is a very accurate dosing system and it is recommended to implement such a dosing system in the plants having more than 2 mills.

Annex - Grinding aids usage & benefits within the Division worldwide

A1 - ATC Regions

Three regions are covered by ATC namely

- ASIA: Bangladesh, India, Philippines, Japan and Vietnam,
- ASIA KMS : Korea and Malaysia,
- CHINA: All Chinese plants.

There are many grinding aids suppliers in ATC regions

- Grace being the dominant supplier for the majority of plants in Philippines, Japan, Korea and China,
- The Indian market is fully dominated by Sika,
- BASF and Fosroc started supplying grinding aids to some plants in Malaysia,
- ATC is planning/performing industrial trials with BASF in Korea, Japan, Vietnam, Philippines, Bangladesh and China.

Only the usage of grinding aids in India, Philippines, Korea and China will be discussed in this chapter. The results received from the other BUs are not sufficient for preparing a summary.

India BU

Grinding aids usage in India

The following table shows the grinding aid utilisation in the Indian plants. Lafarge is having 3 plants in India. Both Arasmeta (ARA) and Sonadih (SON) are integrated plants and Jojobera (JOJ) is a big grinding station. All the plants are producing only fly ash cements (PPC) and slag cements (PSC): **100 % blended cements.**

COUNTRIES , PLANT AND TYPE OF PRODUCT			GA Supplier / Type	Dosage of GA	Additional cost of GA (US$ /TON)	Annual GA usage (KTONS)	% of CEMENTITIOUS materials increase	Decrease in Power (kWh/T)	Increase in TPH	1D strength increase	28D strength increase	Setting time reduction (min)
INDIA	ARA	PPC	SKA VP4	0.03	NA	0.5	3	NA	NA	15%	10%	30-40
		CONCRETO		0.05	NA	0.07	3	NA	NA	15%	10%	na
	SON	PPC		No GA								
	JOJ	PPC		0.035	0.45	0.3	3	1	5	15%	5%	20
		PSC - Concreto		0.05	0.73	0.3	5	0.8	4	15%	5%	20

- Arasmeta and Jojobera plants are using Sika Grinding aid VP4, especially designed for Lafarge India. The usage of Sika grinding aid VP4 is leading to:
  - 4 to 5 % mill output increase,
  - 0.8 to 1 kWh/ton power consumption reduction,
  - 3 to 5 % increase of cementitious materials,
  - 20 to 30 minutes setting time reduction,
  - Significant increase in early strengths and moderate to low increase of 28 day strength with some exceptions.

- The additional cost of Sika grinding aids is in the range of 0.45 US$/ton – 0.73 US US$/ton depending on the type of the binder.

Sika grinding aid de-formulation

The analysis of Sika grinding aid done by ATC in collaboration with LCR, showed the presence of TEA, DEA, Thiocyanate. Thiocyanate is an accelerator & generally leads to an important setting time reduction & early strengths increase. TEA also contributes slightly to setting time reduction & early strengths increase.

The results obtained in the laboratory at 20 ^{o}C using fly ash cement (32 % of FA) and 0.04 % of VP4 Sika grinding aid are described in the table below. There is a significant impact of Sika VP4 grinding on fly ash cement setting time. and early strengths. There is low impact of this grinding aid on microconcrete water demand, workability retention (slump evolution) and later age strength.

New formulations of VP4 grinding aids were developed later by Sika for further increasing early strengths.

	Saint Pierre La Cour cement + 32 % Jojobera ash + 2.5 % SO3	
	Without VP-4 grinding aid	With 0.04 % VP4 grinding aid
BSA (cm2/g)	3970	4102
Cement paste water demand	0.26	0.27
Paste setting time (EN standard, T = 20C)	235 min	190 min
Microconcrete water demand	0.55	0.56
Microconcrete slump 5 min (cm)	10	9.3
Microconcrete slump 15 min (cm)	8	8.2
Microconcrete slump 30 min (cm)	6.8	7.5
Microconcrete slump 60 min (cm)	6.8	6.8
Microconcrete setting time	5h47min	4h54min
Microconcrete 1 day strength (Mpa)	7.4	9.9
Microconcrete 28 days strength (Mpa)	37.5	39

Industrial trial results at Arasmeta Plant with Sika grinding aid

India BU with ATC technical support, performed many industrial trials for optimizing the use of Sika grinding aid. The following table summarise the results obtained when optimizing the grinding aid dosage in PPC cement (fly ash cement) in Arasmeta plant.

Industrial Trial at Arasmeta Plant with Sika Grinding Aid

Cement Mill Trials	CaO	SO3	Fly ash	45m R	Blaine	IST	3 Days	7 Days	28 Days	Prod.	SPC
Description	%	%	%	%	M2/Kg	Minutes	MPa	MPa	MPa	M.T./Hr	M.Motor
Blank	43.4	1.5	29.0	14.0	343	215	24.5	32.0	46.0	118	24.9
Sika (0.05%) PPC	43.3	1.48	30.2	11.5	328	160	26.5	34.0	50.0	126	23.1
Sika(0.03%)	41.98	1.58	32.2	12.4	332	200	25.4	33.0	48.5	127	23.0
Sika(0.04%)	41.76	1.52	32.5	11.4	328	190	25.8	33.5	49.5	128	23.0

Main results obtained

1. Decrease in setting time,
2. Increase in strengths
3. Increase in prod by **7-8%** and reduction in power consumption by 6- 7%

Increase in CM addition with better IQP's parameters (IST and CS) compared to the blank trial.
Decrease in 45 micron residue

In addition to the increase of mill out put and the reduction of power consumption, Sika grinding aid VP4 allowed reducing setting time and increasing early strength.

Cost benefit analysis of Sika grinding aid

Nearly 5 MUS$ savings has been achieved by Arasmeta and Jojobera plants by addition of Sika grinding aid. The following attachment show the complete calculation details of GA benefit based on the data received from Arasmeta plant.

The Benefits was calculated using the following formula (for more details, see the excel file attachment):

Global savings = Cement capacity increase saving (for sold out markets) + Cost reduction saving – Additional cost of grinding aid

Capacity increase = Mill output increase + C/K increase (volume)

Cost reduction = C/K increase + Power consumption reduction

Arasmeta plant case – India BU

The benefit of Arasmeta plant was about 3.1 Millions US$/year for 2007 and is estimated to be about 4 Millions US$/year in 2008.

Sika grinding aid is also partially used in Jojobera plant generating about 1.5 Millions US$/year benefit.

The generalization of the use of Sika grinding aids in all the plant and all products will lead to more than 10 millions US$/year benefit.

Philippines BU

Grinding aids usage in Philippines

Lafarge is having 5 integrated plants in Philippines. All the plants are producing Type-I cement (OPC) and Type IP & type P blended cements.

The following table shows the grinding aid utilisation in Philippines plants:

- All Philippines plants are using Grace grinding aids except Iligan Plant (one product is using a local grinding aid). Recently Batangas plant has started using Mapei GA,
- Grace grinding aids used by most of the Philippines plants are Amine based (ESE and CBA are TIPA base which leads to 28 day strength increase),
- Batagans plant and Bulcan plant are using DEG base and TEA base grinding aids respectively.

COUNTRIES AND TYPE OF PRODUCT			TYPE OF GA	SUPPLIER NAME	DOSAGE OF GA	ADDITONAL COST OF GA (US$/TON)	ANNUAL CONSUMPTION OF GA (KTONS)	POWER REDUCTION (kWh/Ton)	INCREASE IN TPH	1D STRENGTH INCREASE	28D STRENGTH INCREASE	REDUCTION IN SETTING TIME
PHILIPPINES	NOR	PPC	ESE 258	Grace	0.02	NA	NA	NA	2	18.00 %	16.51%	20
	ILG	OPC	CBA 1110	Grace	0.02	NA	NA	6.17	8	5%	5%	30
		PPC	ARC 600S3	STANDPHIL	0.02	0.10	0.018	NA	NA	5%	5%	NA
	TER	OPC Bulk	CBA 1110	GRACE	0.03	0.5	0.26	NA	NA	NA	NA	NA
		PPC CEMENT	CBA 1110	GRACE	0.03	0.4	NA	NA	NA	NA	NA	20
	BAT	OPC	MAGC 166	MAPEI	0.025	Na	0.342	NA	NA	N/A	N/A	N/A
	BUL	OPC & T-IP	HEA 243	GRACE	0.025	NA	NA	2.8	4	NA	NA	NA

- The usage of grinding aids in Philippines is leading to:
    - 2 and 8 % mill output increase (only 2 plants data),
    - 2.8 to 6 kWh/ton power consumption reduction,
    - 28 day strengths increase (manly ESE and CBA types),
    - Setting time reduction and early strength increase, however need to precise if this phenomenon is linked to the increase of the blaine especially when using CBA and ESE type based on TIPA/ THEED pure chemicals relevant for increasing 28 day strength,

The additional cost of Grace grinding aids is in the range of 0.4– 0.5 US$/ton which is very high compared to the additional cost of the local grinding aid (0.1 US$/ton). For comparison the optimal additional cost of conventional grinding aids (DEG and TEA) is about **0.2 US$/ton.**

Korea BU

Lafarge is having one integrated plant (Okke) and 2 grinding stations (Phang and KwangYang) in Korea.

The two grinding stations namely Pohang and KwangYang are having vertical mill for slag grinding and the Okke plant is producing only OPC with minor addition of limestone.

The table below describes the data received from Okke plant. The usage of grinding aids is leading to:

- 3 % increase of limestone,
- Strengths increase.

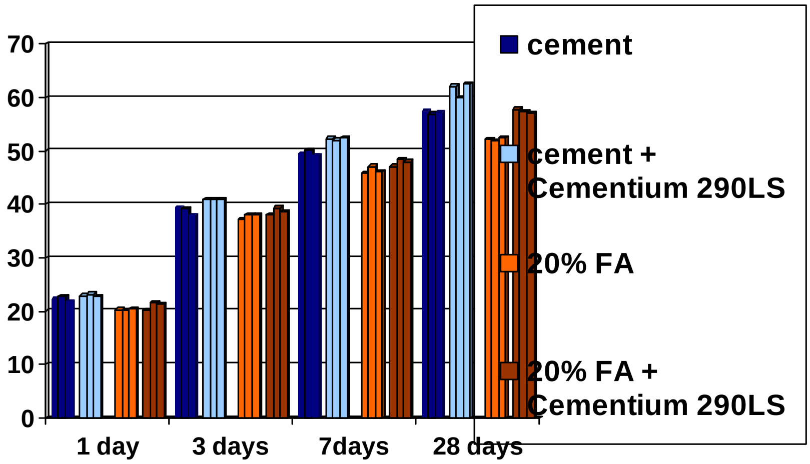
TYPE OF GA	SUPPLIER NAME	DOSAGE OF GA	ADDITONAL COST OF GA (US$/Ton)	ANNUAL GA ULITLISATION (KTONS)	% OF CEMENTITIOUS MATERIAL INCREASED	INCREASE IN TPH	1D STRENGTH INCREASE	28D STRENGTH INCREASE	IST (Before GA addition)	IST (After GA addition)
ESE	GRACE	0.02	0.4 – 0.5	1.3	3	NA	13%	6%	235	220

The additional cost of Grace grinding aid is in the range of 0.4– 0.5 US$/ton,

The plant, in coordination with ATC decided to replace CBA by ESE (both grinding aids are from Grace Company).

In fact, CBA grinding aid was leading to the generation of air bubbles in concrete “champagne effect”.

In coordination with BASF and ATC, Korea BU performed some lab testing for qualifying Cementium 290 LS based on PCE molecule.
The results reported in the following graph showed an improvement of late strength of about 7 % for OPC. The results seems to be better with fly ash cement.



China region

Information about GA utilization in China

- In 2007, the total cement production in China reaches about 13 550 kilo tons, of which 4 264 kilo tons were produced with grinding aids, representing 31% of the total cement production. The grinding aids are used in the following plants: HUA, SHU, BFS, HCN, NAN, DJY,
- Some plants have already tested in lab or by industrial trials, and have the intention to use grinding aids for the production of the cements representing another 4 000 kilo tons, or 29% of the total cement production in 2007. These plants are: DWP, ERQ, FLP, QJP, DXP, GXP, JYP, DJP,
- At this moment the grinding aids are mostly used in the production of PO type cements, particularly PO42.5(R) cement (Portland cement with a maximum of 15 % additives),
- The total amount of grinding aids used in the cement production in 2007 is as high as 1 275 tons, with a potential additional consumption of about 800 tons (estimation based on theoretical dosage of 0.02%).

Supply, effect and cost of using grinding aids

- Grace is the main supplier of grinding aids for Lafarge cements plants in China. Grace also has a very close contact with the plants that have the intention to use grinding aids,
- The grinding aids already used in the plants are based on DEG, TIPA and TEA compounds, except this used in BFS which contains accelerators for slag cements
    - HEA2 is based on both DEG and TEA base: grinding enhancer only
    - CBA1115 is TIPA base and other chemicals: increase 28 day strength, grinding enhancer,
    - CBA1104. This is mainly TIPA base, normally only for 28 days strength enhancement,
    - TDA770. It is TEA base. At typical dosage, the contribution to cement chloride is around 180g/t (ppm). It is for early strength and grinding aid.
- The use of grinding aids generally leads to an additional cost of about **0.4 US$/ton,** except for slag cement in BFS grinding station for which the additional cost is higher because the plant is adding 0.5 % sodium sulphates,
- The addition of grinding aids leads
    - To an increase of 2 to 7 % cementitious materials.
    - To a decrease of power consumption by 1-3 kWh/ ton of cement.
- However, the information on the output increase of the cement mill is very limited.
- The information on the quality of product is summarized and the result indicates that:
    - The use of grinding aids generally improves the early strength by 2 to 6%, corresponding roughly to 0.5 to 1.5 MPa.
    - The effect of grinding aids on 28d strength is lower than early strength.

Action plan for Industrial trial /Lab trial results at Chinese plants

Since China is a sold out market, it has been decided to increase the production by using grinding aids in the plants which are not using GA at this moment. An action plan with Grace has been launched, especially in ChongQing BU.

Another action plan with BASF is under development.

Conclusion and next steps in ATC zone

Many of ATC zone plants are using grinding aids not only for increasing mill output, but also to improve cement performance. Only few data are available concerning mill output increase and power consumption reduction. Also, the quality of some data received from the plants is questionable.

The data reported can be summarized as follow:

- 4 to 8 % mill output increase,
- 0. 8 to 2 Kwh/ton power consumption reduction,
- 2 to 7 % increase of limestone and cementitious materials,
- Improvement of cement performances (reduce setting time, increase early strength, increase 28 day strength),
- 0.4 to 0.5 US$/ton additional cost of grinding aids.

The grinding aid supply is dominated by Grace and Sika (India) who are generally promoting the grinding aids for improving cement performances which are costly. At a nominal dosage of 0.03 %, the additional cost of conventional grinding aid (TEA, DEG) is about 0.2 US$/ton which is 2 times lower than the average additional cost of grinding aids in our regions. There is a potential for reducing grinding aids cost by checking plant/plant and product/product if the dosage and the type of grinding aid is optimized.

However, it is important to highlight that the usage of EGA grinding aids can generate high saving for some BUs (example of India BU). The decision of using EGA and PGA must be studied case by case depending on the market context, C/K objective…

The following table is summarizing the inventory of the plants of ATC regions that are not using or partially using grinding aids in their products.

Many of sold out plants are not using any grinding aid (mainly the new Chinese plants). If we suppose that the usage of PGA grinding aids will lead to 5 % increase of mill output, the global volume which will be generated by the sold out plants by using grinding aids is about 0.5 millions tons/year. **This is equivalent to the annual production of one grinding station or one small plant.** The generalization of the use of grinding aids in ATC regions will lead to a very important benefit for the company.

BU	PLANT		SOLD OUT (YES/NO)	VOLUME (MTONS) (2007 YEAR)	OUTPUT INCREASE	CAPAICTY INCREASE (TONS)
MALAYSIA	RAWANG	OPC	YES	509866.5	5	25493.33
	KANTHAN	PHONEIX CEMENT	YES	853363	5	42668.15
	PASIR GUDANG	OIL WELL CEMENT	YES	44288	5	2214.40
PHILIPPINES	ILIGAN	TYPE-P CEMENT	YES	112712	5	5635.60
BANGLADESH	SURMA	CEM II-A/L	No	1000000	5	0.00
CHNINA	SHU	PC32.5(R)	YES	60000	5	3000.00
	BFS	PS32.5(R)	YES	120000	5	6000.00
	DWP	PO52.5(R)	YES	81322	5	4066.10
		PO42.5(R)	YES	996377	5	49818.85
		PO32.5(R)	YES	542029	5	27101.45
		PC32.5(R)	YES	4844	5	242.20
		PMH42.5	YES	11815	5	590.75
	ERQ	PO42.5(R)	YES	187067	5	9353.35
		PO32.5(R)	YES	148257	5	7412.85
		PF32.5(R)	YES	129572	5	6478.60
	FLP	PO42.5(R)	YES	81950	5	4097.50
		PO32.5(R)	YES	146520	5	7326.00
	HCN	PO52.5(R)	YES	1902	5	95.10
		PO32.5(R)	YES	76113	5	3805.65
		PF32.5(R)	YES	26725	5	1336.25
		PC32.5(R)	YES	109986	5	5499.30
	NAN	PO32.5(R)	YES	19137	5	956.85
		PC32.5(R)	YES	12274	5	613.70
	QJP	PO52.5(R)	YES	41621	5	2081.05
		PO42.5(R)	YES	311456	5	15572.80
		PO32.5(R)	YES	135185	5	6759.25
		PC32.5(R)	YES	153981	5	7699.05
	DXP	PO42.5(R)	YES	108040	5	5402.00
		PO32.5(R)	YES	54790	5	2739.50
		PC32.5(R)	YES	196220	5	9811.00
	SCP	PO52.5(R)	YES	14483	5	724.15
		PO42.5(R)	YES	835597	5	41779.85
		PO32.5(R)	YES	55582	5	2779.10
		PC42.5(R)	YES	57741	5	2887.05
		PC32.5(R)	YES	225196	5	11259.80
		PMH42.5	YES	64661	5	3233.05
	XPP	PO42.5(R)	YES	280000	5	14000.00
		PO32.5(R)	YES	100000	5	5000.00
		PC32.5(R)	YES	80000	5	4000.00
	DJY	PO32.5(R)	YES	100000	5	5000.00
		PF32.5(R)	YES	300000	5	15000.00
		PC32.5(R)	YES	600000	5	30000.00
	GXP	PO42.5(R)	YES	246240	5	12312.00
		PO32.5(R)	YES	227097	5	11354.85
		PC32.5(R)	YES	194241	5	9712.05
	JYP	PO52.5(R)	YES	20000	5	1000.00
		PO42.5(R)	YES	700000	5	35000.00
		PO32.5(R)	YES	400000	5	20000.00
		PC32.5(R)	YES	200000	5	10000.00
	DJP	PO52.5(R)	No	100000	5	0.00
		PO42.5(R)	No	229400	5	0.00
		PS42.5(R)	No	103500	5	0.00
		PS32.5(R)	No	223700	5	0.00
		M22.5+slag powder	No	100000	5	0.00
RRODUCTION (MTONS)				11.735		0.499

A2 - CTS Regions

The grinding aids market in North America is shared by major worldwide suppliers, namely CHRYSO, GRACE and QUALITY GRINDING AIDS (QGA). Historically the plants have been dealing with the selection of the grinding aids (type and supplier) at a local level with occasional implication of the Technical Centre.

Unfortunately very few plants has answered the questionnaire because a majority of them have been using GA's for many years and find it difficult to assess the impact on operations. However, the general trend in North America has been inferred based on the feedback of 2 Canadian plants (Saint-Constant and Bath) and 4 US plants (Roberta, Ravenna, Harleyville and Alpena).

- Both Triethanolamine (TEA) and Diethylene glycol (DEG) based grinding aids are used in North America. They are injected at rates that range from 290 to 700 g/t approximately,
- The annual total consumption averages 300 to 500 tons at an additional cost of 0.2 to 0.5 US$/t. This is equivalent to a total annual cost of 200000 to 500000 US$ for an average 1MT capacity plant, but can cost as much as 700000 US$ for a plant like Ravena.
- The main objective for using grinding aids in North America is to increase the output. The impact on output was reported to be 4 to 8% increase average, although not always confirmed by formal trials. Also, it was reported having a positive impact on coating.
- GA's are seldom used for quality purposes (e.g. strength enhancement etc.) and virtually no impact on quality was observed (Blaine, cementitious increase…) according to plants observations.
- Besides, none of the plants reported any impact on specific power consumption except Harleyville: -3kWh/t.

The following table shows the information on the utilization of GA from CTS region

COUNTRIES AND TYPE OF PRODUCT			MILL TYPE	MAIN PURPOSE OF ADDING GA	FEED POINT	TYPE OF GA	SUPPLIER NAME	DOSAGE OF GA	ADDITONAL COST OF GA (US$/TON)	ANNUAL CONSUMPTION OF GA (KTONS)	% OF CEMENTITIOUS MATERIAL INCREASED
CANADA	STC	GU (10)	BALL MILL	OUTPUT + COATING	FEED PIPE	TEA	CHRYSO	1.30	0.391	NA	7.90
	BTH	TYPE 10 - 2MA - 30	BALL MILL	OUTPUT + COATING + PACK SET	MAIIN CLINKER BELT	AMINE + GLYCOL BASED	QGA	400 / 660	NA	0.372	NA
USA	ALP	TYPE I/II	ROLLER PRESS + BALL MILL	OUTPUT + OTHER	1ST COMPARTMENT	AMINE + DEG	GRACE	480	0.06	9.1	0
	HRL	TYPE I/II/III/S	BALL MILL	OUTPUT	1ST COMPARTMENT	TEA	GRACE	500	0.22	0.357	0
	RBT	TYPE I/II + MASONRY	BALL MILL	OUTPUT + COATING	1ST COMPARTMENT	DEG	QGA	NA	0.50	0.494	0
	RVN	TYPE I/II	BALL MILL	OUTPUT + STRENGTH + COATING	1ST COMPARTMENT	DEG	CHRYSO	290	0.424	0.528	0

COUNTRIES AND TYPE OF PRODUCT			DECREASE IN POWER	INCREASE IN TPH	COATING TENDENCY OF	CLOGGING	DELTA PRESSURE
CANADA	STC	GU (10)	NA	NA	NONE	NONE	NA
	BTH	TYPE 10 - 2MA - 30	NA	5 - 8	Decreased	NO	NA
USA	ALP	TYPE I/II	NA	5	DECREASING WITH GA USE	OCCASIONALLY AROUNG GA INJECTION PIPE	NA
	HRL	TYPE I/II/III/S	- 3	1 - 3	NA	RARELY	NA
	RBT	TYPE I/II + MASONRY	0	10	DECREASING WITH GA USE	RARELY	NA
	RVN	TYPE I/II	NA	NA	DECREASING WITH GA USE	NO	NA

The only feedback about quality was from Alpena plant. It is summarized in the table below:

COUNTRIES AND TYPE OF PRODUCT	1D STRENGTH INCREASE	3D STRENGTH INCREASE	7D STRENGTH INCREASE	28D STRENGTH INCREASE	IST (Before GA addition)	FST (Before GA addition)	IST (After GA addition)
USA	14.2+-0.8	26.6+-1.6	32.4+-1.7	39.9+-2.0	NA	NA	105+-5

Industrial trial /Lab trial results in CTS region

3 North American plants reports are presented here

Saint-Constant

Objective

To Evaluate the impact of a Triethanolamine Acetate grinding aid from Quality Grinding Aid in replacement of a CHRYSO grinding aid with a similar chemical composition. The test lasted 75 hours. The table below summarizes the results (Q is QGA and C is CHRYSO). The trial was carried out in FM1 and FM2 and the results are given below

n coefficient	1.3
CIMENT 1 - Blaine (ref)	390.0 m^2/kg

		Periode	Débit (t/h) Type 20	Kw Elevator	Blaine	Débit (t/h) corrége
01 Nov	C	1h00 à 8h00	60.2	30.0	392.2	60.7
	trans	**9h00 à 13h00**	**59.2**	**30.1**	**384.7**	**58.2**
	Q	14h à 21h00	59.1	30.0	392.6	59.6
04 Nov	Q	3h00 à 11h00	51.8	29.8	379.2	49.9
	trans	**12h00 à 16h00**	**52.8**	**29.6**	**378.5**	**50.8**
	C	17h00 à 24h00	51.2	30.3	378.0	49.1

n coefficient	1.6
CIMENT 2 - Blaine (ref)	390.0 m^2/kg

		Periode	Débit (t/h) Type 10	Kw Elevator	Blaine	Débit (t/h) corrége
01 Nov	C	1h00 à 8h00	104.1	50.1	386.2	102.7
	trans	**9h00 à 13h00**	**101.8**	**50.2**	**389.4**	**101.6**
	Q	14h à 21h00	112.4	50.8	394.9	114.3
04 Nov	Q	3h00 à 11h00	103.3	50.9	397.0	105.7
	trans	**12h00 à 16h00**	**107.0**	**49.0**	**396.8**	**109.4**
	C	17h00 à 24h00	104.7	49.3	396.7	107.0

Conclusion

It is very difficult to draw any conclusions given that changes occurred in operating conditions. However, the tables above show that the utilization of the CHRYSO grinding aid instead of the QGA one did not have a significant impact on the finish mills performance.

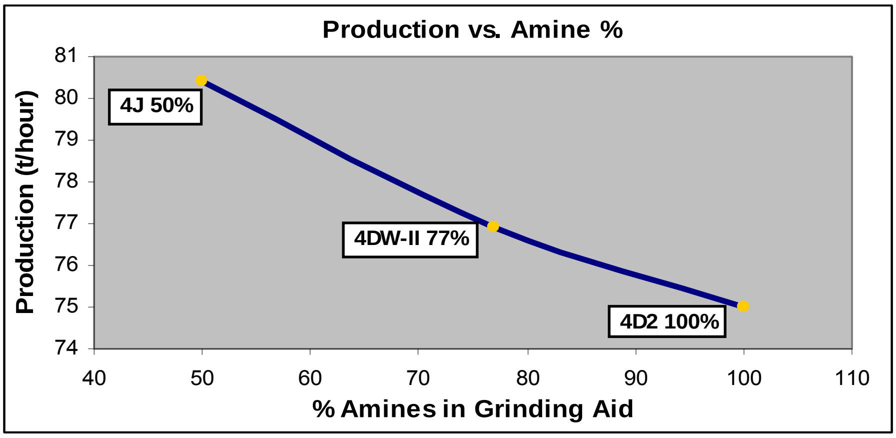
Sugar Creek

Objective

To increase the efficiency in FM4 is important due to the cost considerations of hauling clinker to the less efficient Sugar Creek River Plant. A grinding aid trial was performed to determine whether an alternate grinding aid would provide enhanced production and efficiency while remaining either financially equivalent or advantageous. CHRYSO CGA 4DW-II and CGA 4D2 were tested during this trial and compared to the current grinding aid CHRYSO CGA 4J.

Results

The average production rate during the first trial (4DW-II) was 76.9 tons/h and the grinding aid flow rate was 673.2 mL/min, while during the second trial, (4D2), the production was 75.0 tons/h with an average grinding aid usage of 593.6 mL/min. After the first trial the reduced production was thought to be partially because of a decrease in C3A during the trial. The second trial showed us more clearly that the drop in production was more likely due to the high amine composition in the grinding aid.



Conclusion

- Based on these financial considerations continued trials which utilize grinding aids higher in glycols are recommended
- CGA 4DW-II and 4D2 are priced significantly lower than the current grinding aid
- The loss in production with these grinding aids eliminate all potential cost benefits
- Physical and chemical properties of cement were unaffected by the grinding aid switch in both trials

Ravena

Objective

The purpose of these grinding aid trials was to determine if we could obtain a reliable supplier to provide the Lafarge Ravena plant with a similar product comparable to our current CHRYSO grinding aid without sacrificing cement quality or production loss and to reduce the plant's costs. Also another goal is to have a second supplier of choice in case of a shortage of product by CHRYSO. These trials consisted of testing new grinding aids by three different companies: GRACE, CHRYSO, and QUALITY GRINDING AIDS. The ability to increase cement mill efficiency and Ravena production are important considering the high costs of our facility.CHRYSO has been a reliable supplier with consistent product quality. The chart shows the anticipated amount of money that would be spent on grinding aid each year for the Ravena plant.

	Baseline Chyrso 2S-5A @ .032%	Chryso 2S-R @ .032%	Grace LGA-N50 @ .032%	Quality GLB @ .036%
Production (tph)	61.7	66.5	61	75
GA Addition %	0.032	0.032	0.032	0.036
GA/ Cement Produced (lb GA/ton cement)	0.64	0.64	0.64	0.72
Cost of GA per ton cement ($/ton cement)	0.47	0.38	0.42	0.35
GA Cost Year Est.[$]	$767,693	$626,688	$689,357	$571,200
[$]Based on avg cement amount produced = 1,632,000t				

A3 - Latin America Regions

Brazil BU

General information about grinding aid

Grinding aid data has been received from 6 Lafarge plants from Brazil BU and the grinding aid has been widely used in all the plants. The following attachment shows the complete information about GA utilisation.

Brazil

- All most all the Brazilian plants are using Grinding aid except two plant s (MOC and SLU) and also one product in ARJ Plant
- The Brazilian grinding aid market is shared by Grace, Sika and Chyrso and increase in productivity is the main purpose of the addition of GA
- The additional cost for adding grinding aids are in the range of 0.25 US$/ton – 1.5 US US$/ton depending on the type of the binder.
- Nearly 2 to 8 TPH increase in production has been reported by Brazilian plants and this is high compared to other regions
- The use of GA is not associated with increase in cementitious material content in Brazilian plants. GA is used only to improve mill output.
- The plants which are not using the GA are not sold out market

There is a big opportunity for reducing grinding aids cost.

Chile BU

General information about grinding aid

Chile

Grinding aid data has been received from one Lafarge plant from Chile. The following attachment shows the complete information about GA utilisation in Lafarge plant

- Most of the plants are using Sika grinding aid only
- The additional cost of Sika grinding is in the range of 0.40 US$/ton,
- 5% increase in production and 5 % decrease in power consumption has been achieved by the addition of Sika grinding aid.
- Even though all the products are sold out market the plant are not using GA regularly and GA is being used based on the demand of the product

Mexico and Antilles BU

General information about grinding aid

Grinding aid data has been received from three Lafarge plant from Mexico and two plants from Antilles. The following attachment shows the complete information about GA utilisation in Lafarge plant in Mexico and Antilles.

Mexico – Antilles

- The local grinding aid is used by all the plants in Mexico (Poliquimicos) and the additional cost for adding grinding aids are in the range of 0.22 US$/ton to 0.70 US/Ton depending on the type of binder
- Only Chyrso grinding aid is used by Antilles plants and the additional cost ins 0.5 US$/Ton
- All the products in Antilles are sold out market and some products in Mexico are not sold out market
- Nearly 5 % increase in production has been achieved by the addition of GA in both Mexico and Antilles BU
- The power consumption is reduced by 3 to 4 kwh/ton in the case of Mexico and 5 KWH reduction in the case of Antilles
- The use of GA is not associated with increase in cementitious material content. GA is used only to improve mill output.

Ecuador and Venezuela BUs

General information about grinding aid

Grinding aid data has been received from one Lafarge plant from Ecuador and one plant from Venezuela BU. The following attachment shows the complete information about GA utilisation in Lafarge plant in Ecuador and Venezuela.

Venezuela – Ecuador

- Sika grinding aid is used in Ecuador plant and a local grinding aid is used by Venezuela plant. The additional cost for adding grinding aids are in the range of 0.5 to 0.6 US$/ton for Sika and 0.78 to 1.06 US$/ton for the local carbon based grinding aid,
- to 7 % TPH increase has been reported by Venezuela plant and 3 to 6 % has been reported by Ecuador plant
- Nearly 1 Kwh/Ton decrease in power consumption has been reported by Ecuador plant. 2 to 3 Kwh/ton reduction in power has been reported by Venezuela plant.
- Especially for Venezuela, they use carbon (coal) as GA for a long time and it improves mill production, SSB and sieve retention. No secondary effects were observed related to this GA, like changes in cement or concrete setting times, cement colour or stain formation in concrete.

Plants not using GA

The following table provides the information about the plant not using GA in their products during 2007

GRINDING AIDS IN LATAM CEMENTS - 2007				
COUNTRY	PLANT	CEMENT TYPE	Production	Sold Out (Yes / No)
Brazil	ARJ	ARJ CPIII 32	*NO GRINDING AID USED*	Yes
	MOC	MOC CPII F		No
	SLU	SLU CPIII 32		No
		SLU CPIII 40		
Chile		LCA Super		
Venezuela	OCU	OCU Type I		Yes
		OCU Type IR		
		OCU Eco Plus		
Honduras	PIA	PIA Type I		Yes
		PIA HE Type		
		PIA GU mill 1		
		PIA GU mill 2		
	SLO	SLO GU		Yes

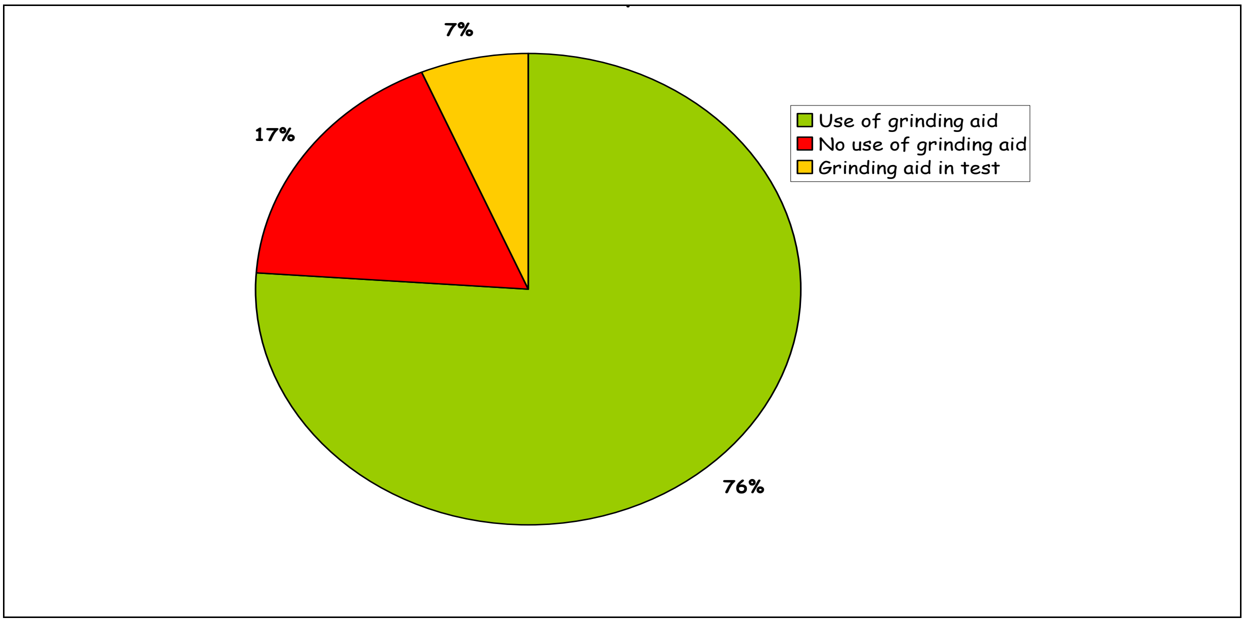
Conclusion:

The optimization of the dosage and the nature of grinding aids will lead to an important cost reduction.

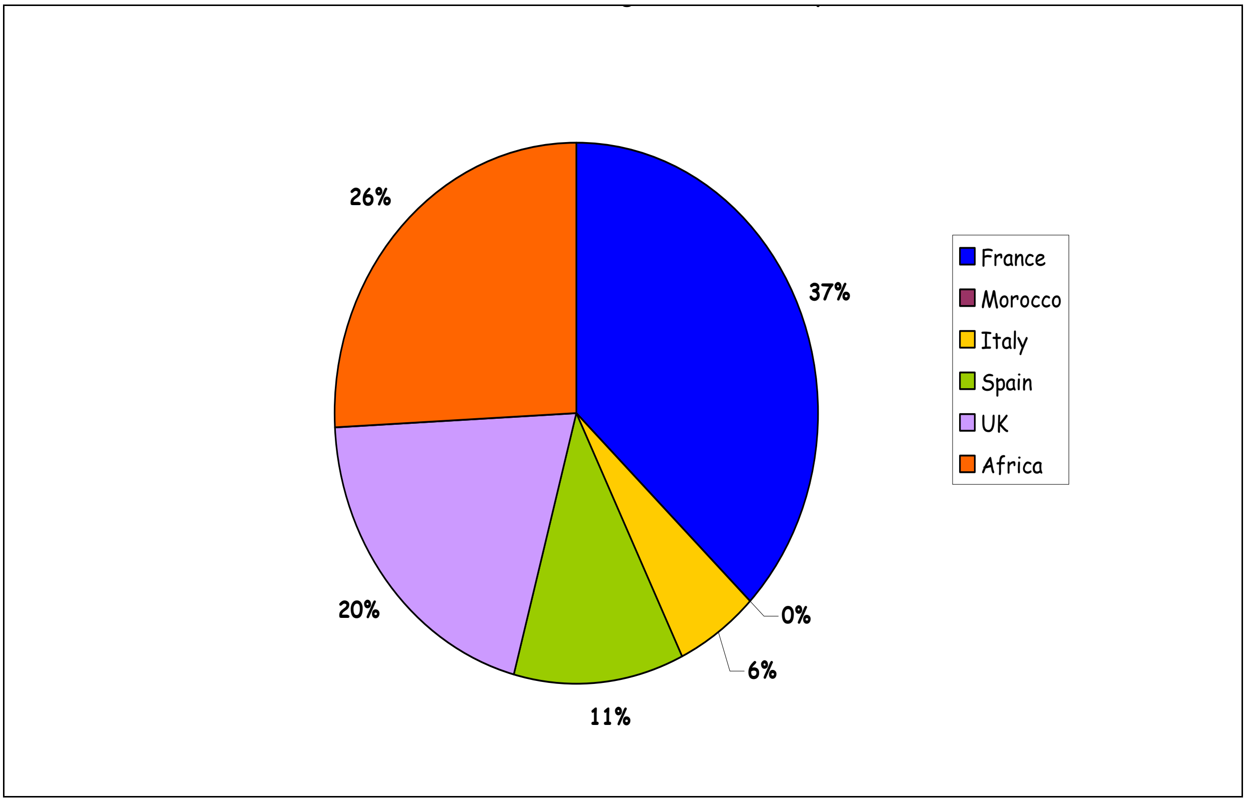
A4 - TCEA Regions

Grinding aid general information

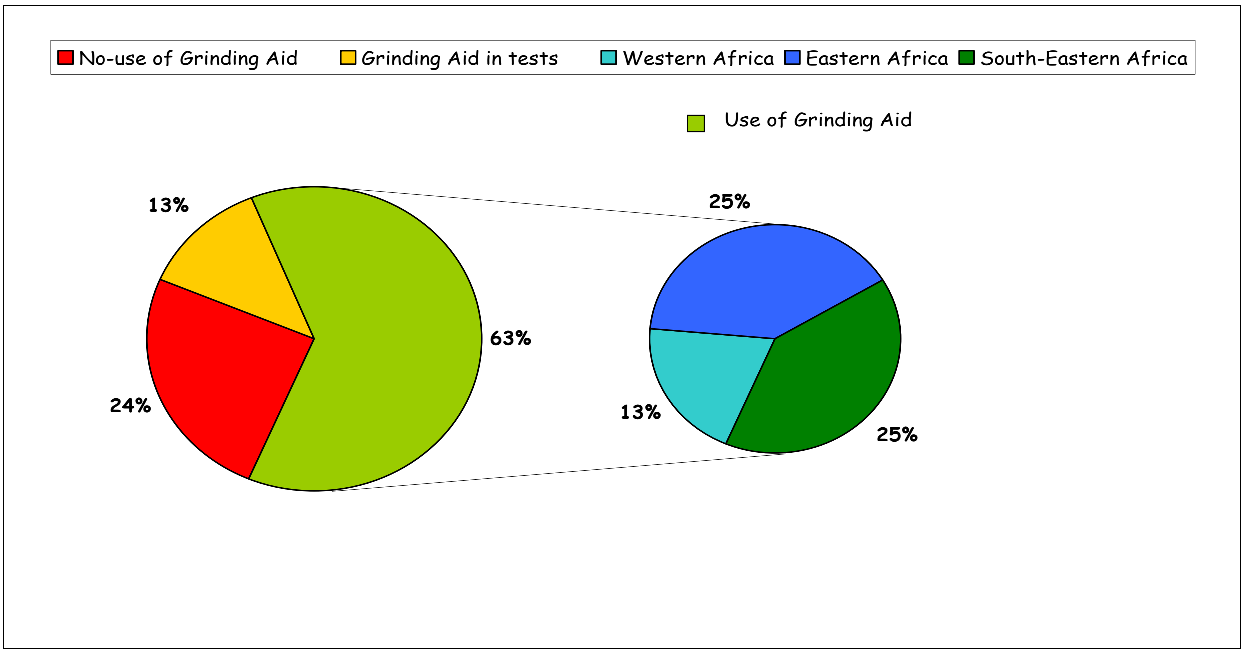
- There are two major regions for TCEA : Africa and Europe
- There are two major suppliers in TCEA area: WR Grace and Chryso. Both of them are "grinding aids" suppliers for a long time and are also present in concrete admixtures market.
- On 46 plants and grinding stations in TCEA region 76% are using Grinding Aids for all products they make (except sometimes in UK, one cement of the plant can be produced without any chemicals; we don't know the reasons).
- 17% are NOT using Grinding Aids : they are plants where not a single GA product is used; they are grinding without any chemicals,
- 7% are doing trials with Grinding Aids.



Country / Continent	Total number of plants and grinding stations	Distribution %
FRANCE	13	28
ITALY	2	4
SPAIN	4	9
UK	7 (without Barnstone)	15
MOROCCO	4	9
AFRICA	16	35
TOTAL TCEA AREA	46	100

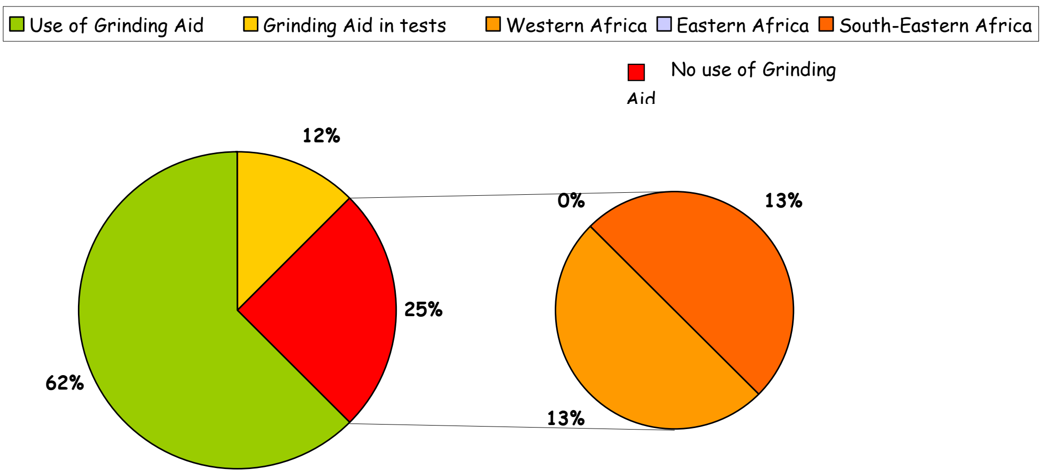


Distribution of grinding aids in AFRICA



- From Africa plants data, the estimation of the number of plants using Grinding Aids is 63% which is not so bad, 24% of the plants are NOT using Grinding Aids and approximately half of these last ones are doing trials with products (13%).

- It is quite interesting to focus on African Plants using grinding aid to see if there is any correlation with their geographical location : among these 63%, there is an equivalent distribution between South-Eastern Africa (25%) and Eastern Africa (25%), areas close to Chryso and WR Grace African Headquarters (both around Johannesburg in South Africa), 13% are represented by Western Africa.



- On the other hand, if we focus to African plants which are NOT using grinding aids, half are represented in Western Africa and the other half in South-Eastern Africa. The 12% remaining – grinding aids on trials – are located in Western Africa, in

Nigeria. This particular distribution in Africa, in two blocks – Eastern-Africa and South-Eastern Africa - is probably linked to their maturity in terms of economy, history (Blue Circle influence,..?), etc.

Potential benefits of TCEA region

Increasing plant capacity

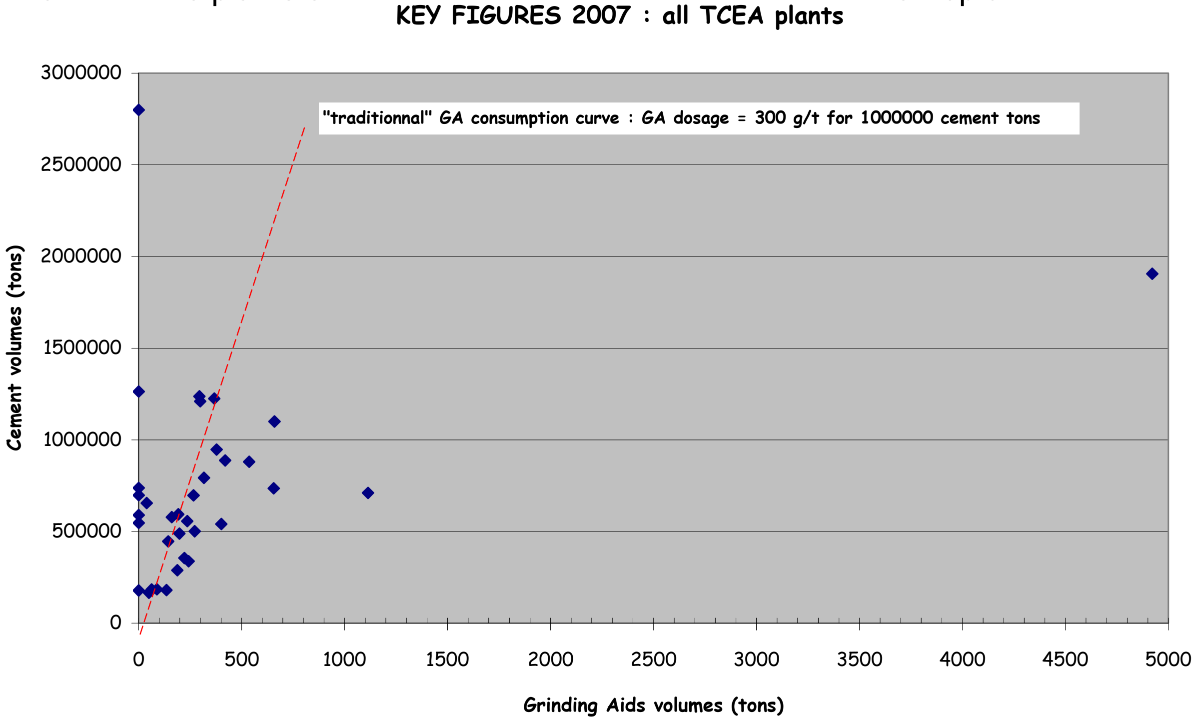
BU	Plant	sold out yes/no	GA usage yes/no	Production volume (2007)tons	Assumed output increase, if GA used %	Capacity increase tons
NIGERIA	ASH	yes	no	697154	5,0	34858
ZIMBABWE	MAN	yes	no	178016	5,0	8901
BENIN	ONI	yes	no	546777	5,0	27339
Production in tons				**1421947**		**71097**

Plants/Grinding stations not using GA	Yearly cement volumes (tons)	+ 5% output due to hypothetic GA use	Total estimated increase of cement volumes (tons)
Onigbolo	546777	574116	27339
Manresa	178016	186917	8901
Tetouan	737536	774413	36877
Tanger	589750	619237	29487
Bouskoura	2783441	2922613	139172
Meknes	1263151	1326309	63158
Ashaka	697154	732012	34858
TOTAL	6795825	7135616	**339791**

The current global volume of cement for which no Grinding Aid was used in 2007 is about 6.8 millions tons. For Morocco BU, there is currently no benefit for using GA - even if the cement market increased a lot – because of the fineness of their cement (SSB less than 4000) and the cost of GA in Morocco : the savings on capacity increase will not balance the GA cost.

GA optimization

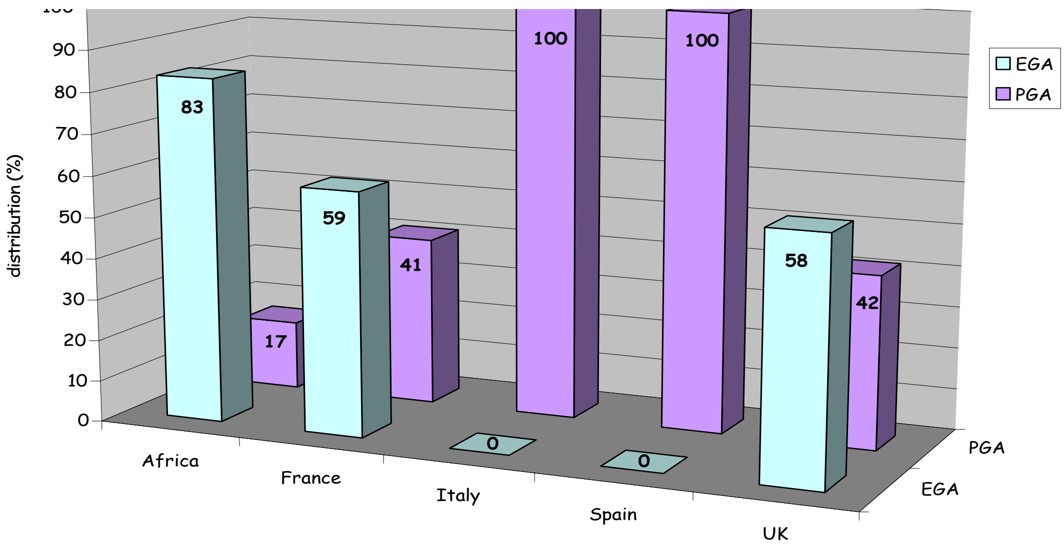
The next graph shows clearly the need of optimization of grinding aid usage: TCEA will work with the plants on that topic.



Most of TCEA plants are using correctly GA (GA dosage close to 300 g/t), some of them are a little bit far from the target due to specific constraints (EGA usage for instance) or lack of optimization. One plant is really out of the target. According to the data obtained from the plants and the data from MMP database, the consumption and the cost of Grinding aids evaluated per plant are given in TCEA report (in Appendix). At the moment, the total cost of grinding aids on TCEA area – taking into account that a lot of data from plants are still missing - is about “9 277 873 US$”.

Distribution of grinding aids type

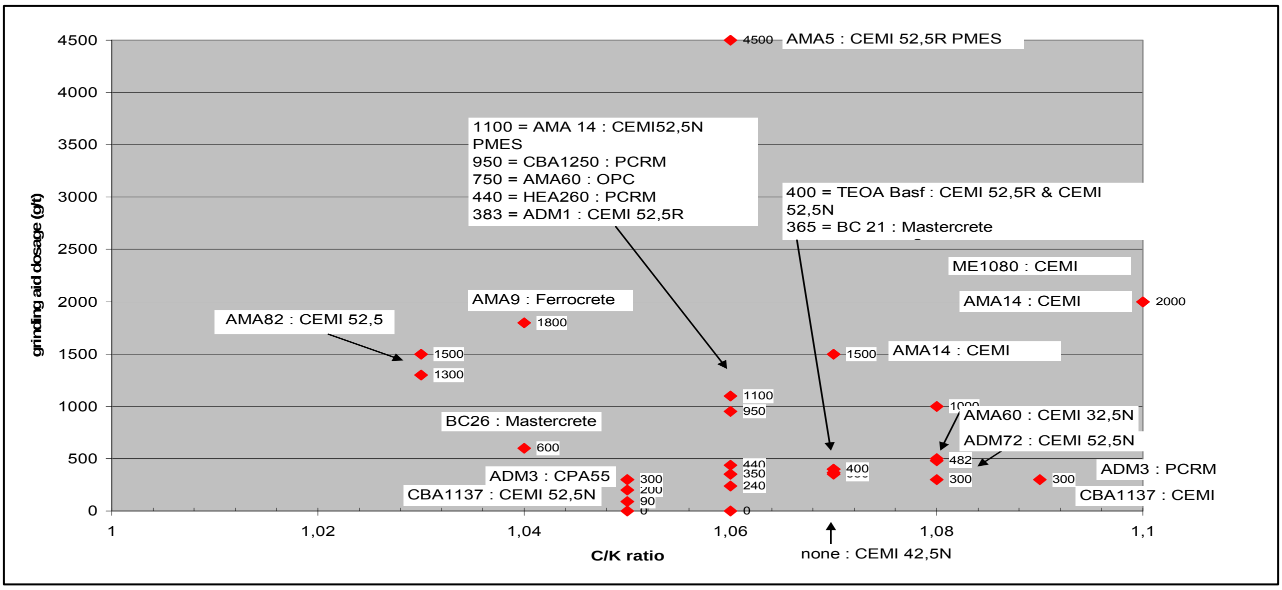
There are two type of grinding aids: traditional ones which will provide a better milling with saving energy – Process Grinding Aid (PGA) - and particular ones which can provide, besides a better milling, enhancement and improvement of cement performances (increase of compressive strength at early and/or late age, decrease of the initial setting time, reduction of the cement water demand, and so on) – Enhancer Grinding Aid (EGA). There is a similar distribution of PGA (Process Grinding Aids) and EGA (Grinding Aid Activators). Per suppliers, this distribution becomes as following:



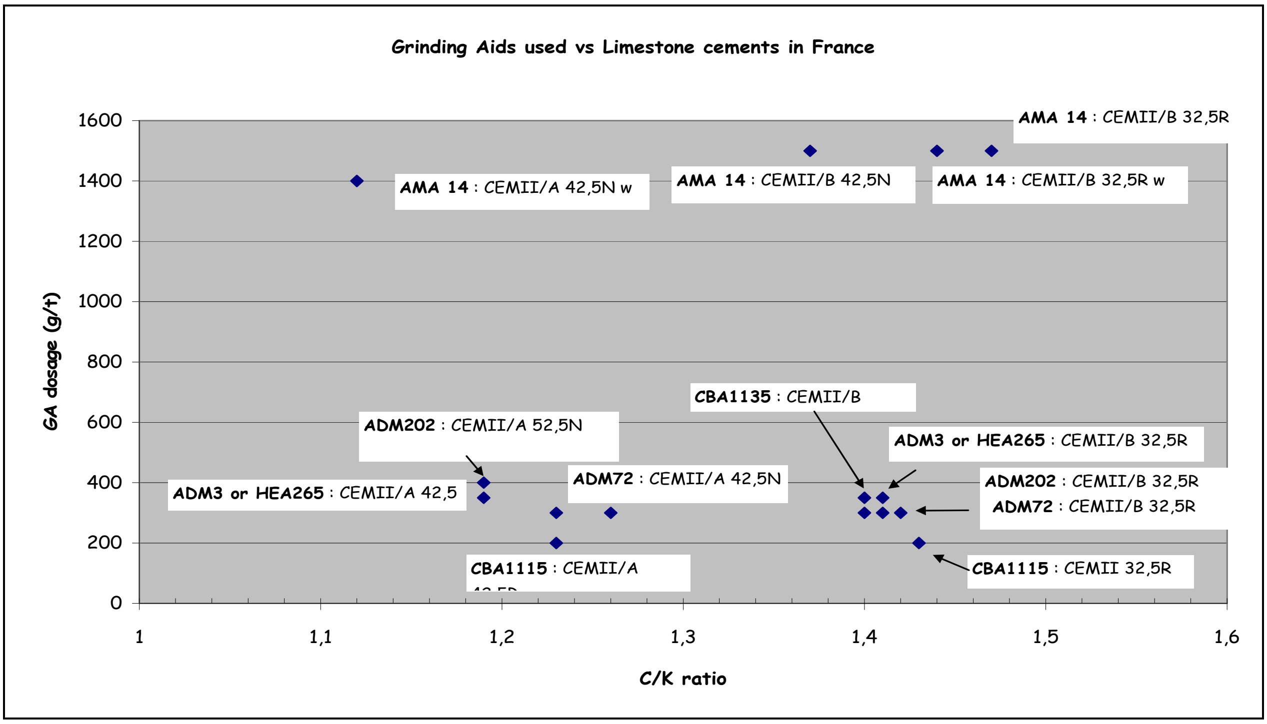
Chryso provides 29% of EGA and 28% of PGA and WR Grace provides 26% of EGA and only 9% of PGA (in this case, the EGA are mainly CBA products with TIPA base). The Mapei, BASF, etc… provide only PGA and not more "technical" products. In term of grinding aid use, UK and France plants work with same kind of products: 58% of EGA and 42% of PGA. Italy and Spain are more traditional, they mainly use PGA products. Africa plants are not using grinding aids for a long time, it is quite new. The main observation is they are using more EGA than PGA: 83% of EGA products present there while EGA represent in France or UK ("mature" countries) only 58%. The basic grinding aids (PGA) are in the minority (17%). EGA will not be able to improve strongly poor cement performances due to poor clinker.

Distribution of grinding aids type vs cement classes

For "pure" cements



For limestone cements

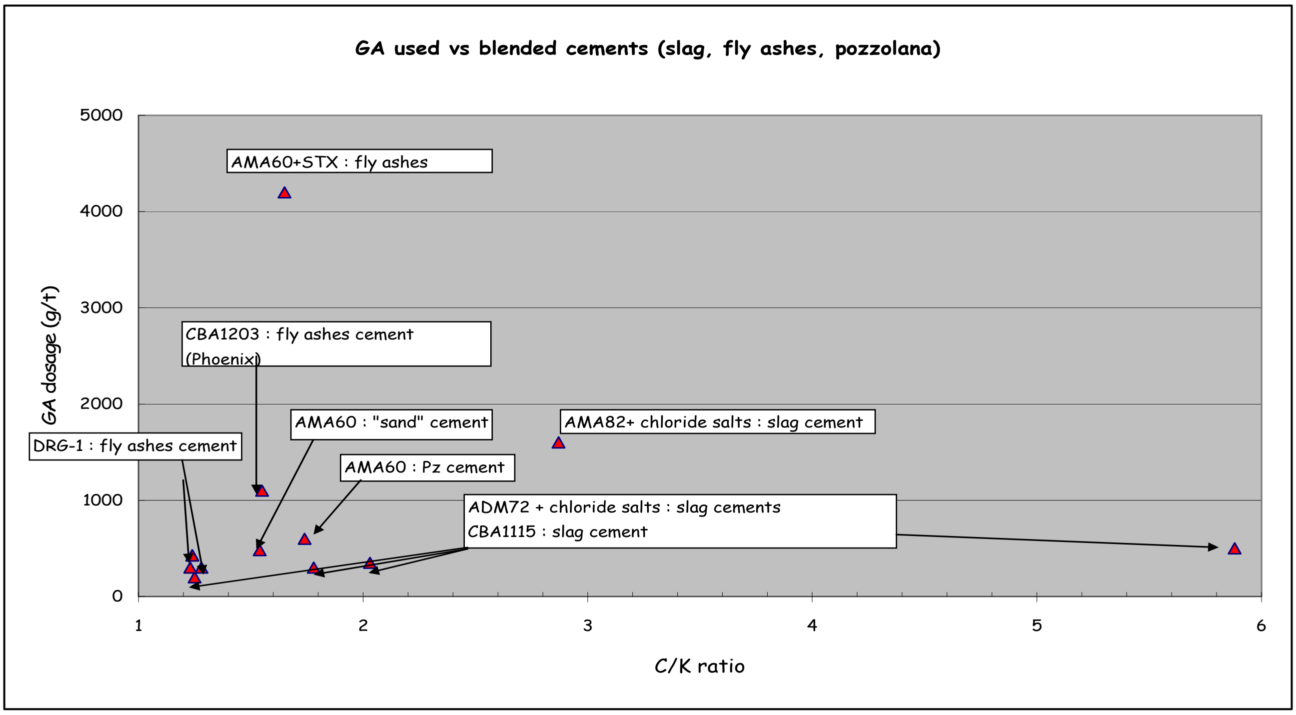


For some type of cements – CEMII/A or CEMII/B, 32.5 or 42.5 class – it can be observed that most of the GA dosages are in the same range between 200 and 400 g/t whatever the GA used (ADM series from Chryso or CBA series from WR Grace), except when AMA14 is used (EGA series from Chryso, only used in Le Teil plant) : for a same C/K ratio, AMA14 dosage is more than 5 times the one of ADM product or CBA product.

Plant	GA	GA Composition	% dry matter	GA dosage used (g/t)	GA cost /ton of cement US£
FR Le Teil, La Malle	AMA14	PEA*, DEA, Na Thiocyanate, Chlorides (10%)	35.5	1500	0.6 - ?
FR Saint Pierre La Cour	ADM3	TEA acetate, DEA (<5%), free acetic acid	35.6	350	?
FR Contes, Val d'Azergues	ADM72	TEA acetate, DEA (<5%), MEG,free acetic acid	28.5	300	0.392
FR Martres	ADM202	TEA acetate, DEA (<5%), TIPA acetate, free acetic acid	35	300	0.54
FR Frangey	CBA1135	TEA acetate, TIPA acetate, free acetic acid	27.4	350 to 850	0.39 to 1.04
FR La Couronne	CBA1115	TEA acetate, DEA acetate (<5%), TIPA acetate, TEG (<5%),free acetic acid	31.8	200	?

- *PEA : polyethanolamine*

Blended cements: slag, fly ashes and pozzolana cements



Apart from "AMA60+STX" grinding aids combination, all the other GA permit to work with a dosage lower than 1000 g/t. There is no GA product which seems to be more adapted to the cementitious nature. **To notice that one plant is using grinding aid at about 0.4 % dosage leading to very high manufacturing cost.**

Examples of Lab Industrial trial in different plants

Tarragona Grinding Station (SPAIN): Type GA: SG-98 from SIQSA and DRG-1 from Chryso

Cement	GA dosage (g/t)	Additional cost of GA (US$/cement ton)	Benefits
CEMI 42.5N	223	0.44	Mill output : +6%
CEMII/A-L 42.5R (12%L)	334	0.73	Cementitious content : +1% and CS7d= +4%, CS28d=+4%
CEMII/B-L 32.5R (31%L)	334	0.73	Cementitious content : +1% and CS7d= +4%, CS28d=+4%

Ewekoro & Shagamu plants (NIGERIA) : Type GA = MAGAC106 from Mapei

GA cost ex works = 1.2 Euros/kg = 1.8 US$/kg

Cement	GA dosage (g/t)	Additional cost of GA (US$/cement ton)	Benefits
Ewekoro : OPC with limestone (C/K =1.22)	400	0.72	Milling : +7% in average; decrease of 0.8 kWh/t SSB before = 3610 cm2/g – SSB after = 3443 cm2/g Cement performances : CS 2d = +13%, CS 7d = 17%
Shagamu : OPC with limestone (C/K=1.16)	400	0.72	Milling : +10% in average; decrease of 6 kWh/t SSB before = 3470 cm2/g – SSB after = 3435 cm2/g Cement performances : CS 2d = +2%

Ndola plant (ZAMBIA) Type GA = AMA60 from Chryso

Cement	GA dosage (g/t)	Additional cost of GA (US$/cement ton)	Benefits
Limestone cement C/K=1.26	500 to 750	0.57	Milling : +11% in average; for nearly same fineness Cement performances : seems that there are benefits at early age CS but need to be validated

A5 CTEC Regions

Grinding aid general information

Brand and type used:
Related to the number of cements in more than 50 % of the cases TEA based GA are used in CTEC area followed by DEG based GA with a portion of about 27 %. In three cases the usage of TIPA based products has been mentioned. With regard to brands GRACE HEA 275 is the one most frequently mentioned one. Other types mentioned are:

BASF
Chryso (ADM 3)
Chryso (QI 10)
Grace (HEA 2 75)
Grace (HEA2)
Grace (CBA 1110)
HolderChem
Mapei (Maga C 150)
Nanjing Hongbaoli
Prochema, Joli & Co
TKK Srpenica (Cementit C)

The quantities added range from 150 to 1500 g/t with an average of 400g/t. The water dilution was not well expressed and therefore the solid content is not known.
The average additional cost calculated from the data received is about 0,23 ct/t.

TC involvement:
Up to now there is almost no involvement of CTEC in validating and implementing the use of GA in plants. The plants deal with GA on a local level. Sometimes it happened that reports of industrial trials executed in the plants have been provided either by the plant or by the GA supplier. As an exception, CTEC/Quality Department was involved in trials with Glycerine (waste product from bio-diesel production) in MDF and KAR. A report on the trials in MDF is available in TWS.

Use of grinding aid in CTEC region

Basing on the feedback on the questionnaire most of the plant use grinding aid, or have it tested. There are only few plants (4) left having no experience with grinding aid at all.(concerning 20% of the cement volume).

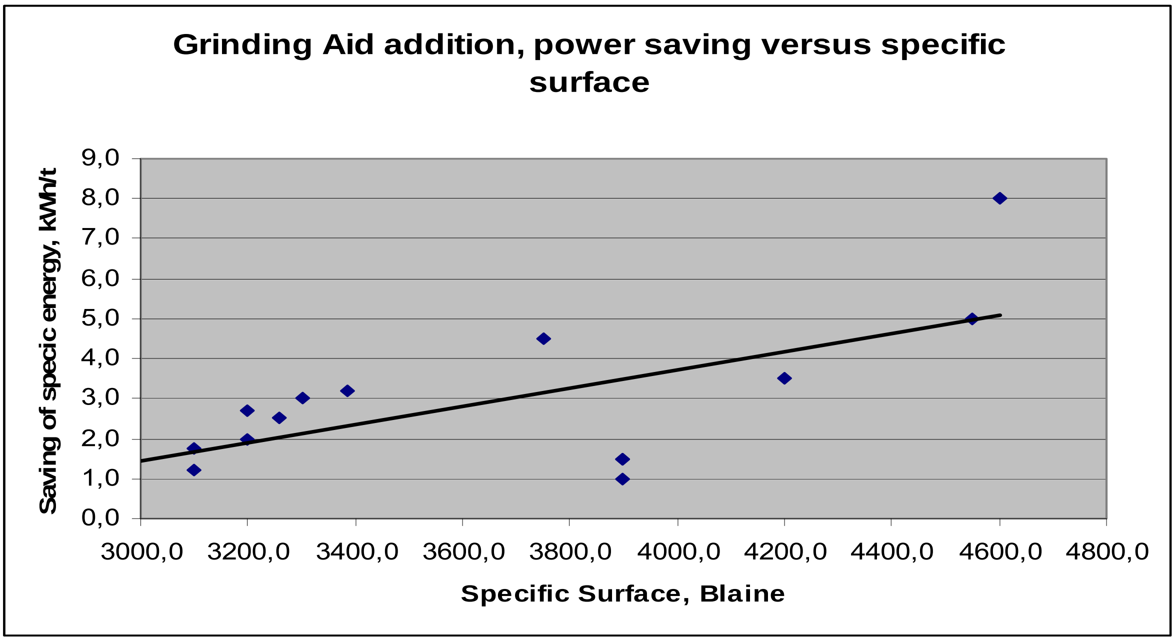
Most of the plants use grinding aid to increase production, or to decrease specific energy. Additional benefits as reduced coating, reduced clogging, higher material flow, reduced mill temperature, or reduced water injection are welcome. Quantification of this additional benefits is difficult, but most of the plants can define the benefit in energy saving or in output increase. Values were not given by all the plants. It is also not clear which percentage of the whole production of each plant uses GA.

Benefits in CTEC region

General observations

The average saving in specific energy was calculated with 3,9 kWh/t. This corresponds to a general saving of 8% in reference to the average specific energy of the CTEC region (48,9 kWh/t). This corresponds also with the increase in capacity shown in the survey. An increase of 8t/h versus an average output of 86 t/h was calculated.

Another observation made was that saving is dependent on the surface of the cement produced. So higher the fineness, so higher the saving can be. Vice versa, the production of high specific surface cements suffer if no grinding aid is added, while for lower fineness the saving or increase in output is lower.



A correlation in terms of grinding aid added versus the increase in output was not given. It seems that the addition rate in most of the applications was optimized.

The cement volume concerned in the report with full or partial addition of grinding aid includes 30 of 36 Million tons. Few of the plants (VOL, MIL) are using GA as strength enhancement with good results. There is a benefit of fineness reduction in the range of 200 cm2/g, therefore additional energy saving in the range of 4 kWh/t and a capacity increase in the range of 10% (VOL). With a specific cost of power with 0,055 $/kWh a total saving of 1,280 Millions $/year considering an output of 4,0 Mio. t/y was achieved. On top additional 0,4 Mio. t of cement can be produced and sold.

Possible benefits

All plants in CTEC region can be considered as sold out. Four of these plants have reported not to use GA or just having done some testing up to now. Assuming that the usage of PGA could lead to an production increase of about 5 % only these four plants could count for an production increase in CTEC region of about 420 kt, which again (like in ATC region) is a volume like produced by a small cement or grinding plant. However, a pre-condition for such an increase is that no other workshop of the plant is the bottleneck in production.

BU	Plant	CKHC Production volume (2007) t	Assumed output increase, if GA used %	Capacity increase t
Jordan	RAS	1946482	5	97324
Romania	MED	1911085	5	95554
Russia	VOS	1665189	5	83259
	KOR	1657240	5	82862
Ukraine	MYK	1197800	5	59890
Total volume in t		**8377796**	**Increase in t**	**418890**

For the other cement plants optimization of GA usage has been reported being done quite a long time ago in some cases. Therefore, benefits could be generated re-checking type, dosage and supplier. In contrast for Greece it seems that the usage of GA in the plants has been quite optimized with the help of EKET.

Different grinding aids from different suppliers are used. Moreover besides PGA also EGA are used. But, compared to France and UK the usage of EGA is quite uncommon in more mature countries like Austria, Germany, Czech Republic and Poland. Possibly here the biggest improvements can be made, if strength enhancing GA allow lower fineness and therefore higher output or cementitious increase resulting also in higher output. Unfortunately for these cases benefit is hard to estimate due to missing experience.

Experience from plant trials

➢ MDF and KAR trials with Glycerine

In MDF and KAR industrial trials with Glycerine have been executed in 2007. Glycerine is very cheap and could therefore be used in a much higher dosage than GA used so far. Main observation was a slight decrease in production and possibly a slightly decreasing strength of cement. From KAR plant severe effect of very high dosages on cement quality have been reported. Especially an ugly odour and oily surfaces of prisms for standard strength test have been mentioned. Basing on that, further efforts to use Glycerine have been stopped.

➢ DAR trial

In DAR recently some trials have been executed using their current GA (Chryso QI 10) and the GA of one of their competitors (called CEGA). Focus of the investigations was the impact on quality, where no special influences could be observed. But one main outcome was, that for grinding CEM I 42,5 R they use no GA anymore in the Horomill because there was no benefit.

BU	Plant	Cement type	Cement strength	Blaine	Mill type: 1) OC 2) CC 3) RP 4) VRM 5) other	Separator generation 0) OC 1) 1st 2) 2nd 3) 3rd	Mill capacity t/h	Decrease power consumption kWh/t	Increase output t/h	Purpose: 1)OP 2)OP+ST 3)ST 4)BallCoa 5)Other	GA type 1) Alkalime Based 2) Chloride based 3) TEA based 4) DEG based 5) TIPA 6) others	Supplier of GA	Dosage	Additional cost incured?
Egypt	ALX	CEM II	42,5	3385	CC	2	95	3,2	8	2	4	Mapei (DEG)	200	0,18
Egypt	BSF			2950	OC	0	120	1,5	10	1	3	Mapei	200	0,11
Jordan	FUH	CEM II	42,5	4700	CC	2	200	2,4	22	2	3	HolderChem	500	
Jordan	FUH	CEM I	42,5	3200	CC	2	175	2,7	17					
Greece	MIL	CEM II	42,5	3900	CC	2	102	1,0	10	2	3	Mapei (Maga C150?)	200	
Greece	MIL	CEM I	42,5	3900	CC	2	105	1,5	10	2+4	5	Hongbaoli (TIPA type)	200	
Greece	HAL	CEM IV	32,5	3750	CC	3	106	7,0	15	1+4	3	Mapei	200	0,20
Greece	HAL	CEM II	42,5	4000	CC	3	83	6,5	21	1+4	5	Hongbaoli	200	0,40
Greece	VOL	CEM II	42,5	3900	CC	3	80	4,5	7	2+4+5	5	Hongbaoli (TIPA type)	150	
Greece	VOL	CEM IV	32,5	4650	CC	3	140	4,0	13	2+4+5	3	Mapei (Maga C150-C98-C99)	110	
Greece	VOL	CEM II	42,5	4550	CC	2	110	5,0	10	2+4+5	3	Mapei (Maga C150-C98-C99)	150	
Greece	VOL	CEM V	32,5	4650	CC	1	33	8,0	3	2+4+5	6	Hongbaoli (TIPA type)	150	
Turkey	DAR	CEM III	32,5	3260	CC	3	73	2,5	5	2	3	Chryso (QI 10)	120	0,07
Turkey	DAR	CEM III	42,5	4370	CC	3	90	2,5	5	2	3	Chryso (QI 10)	1500	0,36
Turkey	DAR	CEM V	42,5	4670	CC	3	88	2,5	5	2	3	Chryso (QI 10)	1500	0,36
Turkey	ERE	CEM II	32,5	3400	CC	3	31	1,8	1	2	3	CHRYSO	1100	0,14
Turkey	ERE	CEM II	42,5	3700	CC	3	32	1,8	1	2	4	CHRYSO	1101	0,14
Serbia	BEO	CEM I		4200	CC	3	90			1	3	Grace (HEA2)	288	0,11
Serbia	BEO	CEM II	42,5|	4400	CC	3	90		6	1	3	Grace (HEA2)	288	0,11
Serbia	BEO	CEM II	42,5	4300	CC	3	90			1	3	Grace (HEA2)	288	0,11
Czech Rep.	CIZ	CEM II	42,5	3900	CC	3	110	1,5	9	1	4	Chryso (ADM 3)	250	0,33
Romania	HOG	CEM I	42,5		CC	3	100	7,0	15,5	1	4	Grace (HEA 2 75)	370	0,39
Romania	HOG	CEM II	42,5	4223	CC	3	100	11,4	7	1	4	Grace (HEA 2 75)	380	0,39
Romania	HOG	CEM II	42,5	4006	CC	3	100	12,7	23,5	1	4	Grace (HEA 2 75)	320	0,33
Romania	TGJ	CEM II	32,5	4100	CC	2	65	1,8	3	1	4	Grace (HEA 275)	275	0,19
Romania	TGJ	CEM II	42,5	4100	CC	2		0,8	3	1	4	Grace (HEA 275)	385	0,27
Romania	TGJ	CEM I	32,5	3100	CC	2		1,8	3	1	4	Grace (HEA 275)	275	0,19
Moldavia	REA	CEM II	42,5	3000	OC	2	90	4,3	10	1	6	Chryso (ADM 3)	333	0,30
Moldavia	REA	CEM II		3100	OC	2	90	1,2	5	2	6	Grace (CBA 1110)	311	0,43
Germany	KAR	CEM I	42,5	3000	CC	2	81			1	3	BASF (pure TEA)	300	
Germany	KAR		32,5	3800	CC	3	58			1	3	BASF (pure TEA)	600	
Germany	KAR	CEM II	42,5	5000	CC	3	38			1	3	BASF (pure TEA)	600	
Germany	SOT	CEM I		3000	CC	3	40			1	3	BASF (pure TEA)	430	0,56
Germany	SOT	CEM II	42,5	3650	CC	3	25			1	3	BASF (pure TEA)	430	
Germany	WOS	CEM II	42,5	4200	CC	2	52	3,5	6	2+4	3	BASF (pure TEA)	350	
Austria	MDF			4740	RP	2	50		5	1	4	Prochema (pure DEG)	420	0,34
Austria	MDF	CEM II	42,5	4690	RP	2	50		5	1	4	Prochema (pure DEG)	260	0,34
Austria	MDF	CEM II	42,5	4490	CC	3	100	6,0	10	1	4	Prochema (pure DEG)	260	0,34
Slovenia	TRB	CEM I	42,5	4000	CC	3	80		3	1+4	3	TKK Srpenica (Cementit C)	500	
Slovenia	TRB	CEM II	32,5	3900	CC	3				1+4	3	TKK Srpenica (Cementit C)	500	
Slovenia	TRB	CEM II	32,5	3700	CC	3				1+4	3	TKK Srpenica (Cementit C)	500	
Poland	KUJ	CEM I	42,5	3200	CC	3	75	2,0	6,5	1	3	Grace (HEA 275)	300	
Poland	KUJ	CEM II	42,5	3700	RP	3	225	3,5	20	1	3	Grace (HEA 275)	300	
Poland	KUJ	CEM II	32,5	4000	RP	3	230	3,5	20	1	3	Grace (HEA 275)	300	
Poland	MAL			3300	CC	2	77	3,0	7	1+4	6	Mapei (Maga C 150)	300	0,42
Poland	MAL			3400	CC	2	63		6					
Poland	MAL			3700	CC	2	73		7,5				402	0,27