# 1. Grinding Aid Trial Guideline

## Summary

Grinding aids and performance enhancers/quality improvers have the potential to generate significant cost savings for a cement plant when applied correctly. This guideline has been developed to enable the maximum cost benefit from the use of cement processing additives to be obtained through increasing the output and efficiency of the grinding process and improving the performance, quality and handling of the finished cement.

This guideline and accompanying appendices provide the tools necessary to achieve this goal and includes information on:

### Initial contact

- General objectives/Identification of potential opportunities and products

### Pre-Trial

- Background information from the plant e.g. mills systems etc.
- Laboratory evaluation of potential products
- Defining specific goals/targets for the trial
- Necessary equipment for trial e.g. dosing system
- Determination of dosing point/dilution ratio

### Trial guideline

- Identification of required personnel
- Trial protocol including sampling requirements e.g. location/type/frequency, baseline testing and key parameters to be monitored

### Post-trial

- Laboratory testing of trial cement in mortar/concrete
- Evaluation of performance against define goals/targets
- Determination of the cost benefit/value added
- Documentation and reporting
- Implementation after a successful trial
- Periodic review of performance
- Identification of additional/future opportunities

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## 2. Introduction

This guideline has been developed to enable the maximum cost benefit from the use of cement processing additives to be obtained through increasing the output and efficiency of the grinding process and improving the performance, quality and handling of the finished cement.

In order to ensure the maximum cost benefit is obtained it is essential the trials are performed in a systematic way ensuring that all relevant parameters are recorded and a thorough evaluation of the results is made. This guideline and accompanying appendices provide the tools necessary to achieve this goal.

The cost benefit is the total cost saving (or added value), considering all relevant factors, that the use of a cement processing additive generates after consideration of the treatment cost (i.e. additive cost x dosage). It is important to remember that the lowest treatment cost does not always yield the maximum cost benefit.

Cement process additives can be divided into three categories:

1. Grinding Aids, where the principal application concerns mill output and dry cement handling.
2. Cement Performance Enhancers or Quality Improvers, where, in addition to a grinding aid effect there is an intended influence on cement performance properties, such as set time and strength development.
3. Cement Functional Additives, where the additive imparts a specific property, such as air entrainment in masonry cement or chromium reduction.

NB: Cement Functional Additives are not considered in this guideline.

Cement additives are used for a diverse range of applications and possible uses include:

- Increase in cement mill output
- Reduction in mill run hours for a target cement volume
- Reduction in cement mill specific power consumption in kWh/t
- Reduction in repair & manufacturing costs
- Matching production capacity to sales volume
- Improving cement performance
- Improving cement flowability (reduce pack-set)
- Reduction in distribution costs (e.g. faster unloading times)
- Increase use of CM (cementitious materials)
- Reduction in the clinker factor

The most significant cost benefits will result from reducing the clinker / cement factor (and consequently the amount of CO2 produced per tonne of cement) and increasing market volume (more tonnes/hour if the production is limited by mill capacity or more cement volume per tonne clinker if the production is limited by clinker capacity).

NB: Cement processing additives are commonly referred to as grinding aids, therefore for simplicity all additives will be called grinding aids in this guideline.

## 3. Initial Contact

The first contact can be initiated by either the plant or the supplier, but there needs to be clear communication to ensure that the plant obtains the information that is needed / wanted. This is also a time when opportunities (or additional opportunities) can be identified, for example, increasing the CM content.

There are a range of products available that may be able to provide the plant with the necessary / desired requirements. Information from suppliers along with information from this report can be used to identify those which have worked in similar situations in the past.

With some knowledge of the capabilities of the various grinding aids and a thorough examination of a specific cement plant operation it should be possible to identify ways in which grinding aids could provide the highest net financial benefit. Key questions to consider are:

- Will improved cement flowability contribute to reduced handling problems, faster unloading and thus lower distribution costs? (Or will excessive flowability be a negative issue?).
- How much benefit will be achieved by providing maximum mill output, either from grinding efficiency improvement or SSA reduction? (Considering influence on run hours, kWh/t, kWh cost, maintenance costs).
- Can clinker factor be reduced by using a higher amount of CM? What is the influence on compositional costs, lower CO2/t, increased cement volume? But what cement properties are adversely influenced, e.g. water demand, setting time, early strength or 28-day strength?
- Can clinker cost be reduced (e.g. lower LSF, alternative fuels/materials) and any adverse cement properties be treated by cement additive?

# 4. Pre-Trial

Before the trial takes place it is essential that all stages are thoroughly planned. The suppliers typically require some key information from the plant regarding not only clinker chemistry and cement type, but also regarding the mill and transport systems.

Specific targets should be set for the trial. Saying only that we require an increase in early strength for example can often lead to discussions after the trial as to whether it was successful or not. It is far better to state that an improvement of, for example, 2 MPa at 1 day is required in which case the outcome of the trial can be clearly assessed.

It is also essential to ensure that all the necessary equipment and personnel are in place for the trial, for example, dosing pumps and sample containers. Finally, a risk assessment and safety precautions have to be considered.

## Background information from the plant

Before starting the grinding aid trial, background information regarding the cement type and mill system must be collected and reviewed. The required data is listed below. This information should provide a good overview of the situation and help to identify any existing bottlenecks.

### Cement Type: Cement specific background information required

- Market objectives, application
- Composition: % CM, % Sulfate carrier and sulfate type (anhydrite / gypsum)
- Clinker: C3S; C3A; C4AF; SO3; Na2Oeq., Free Lime
- Cement SO3; LOI; Blaine SSA; Residue

### Mill System: Mill specific background information required

- Mill Type: Ball Mill, VRM, Roller Press
- Ball Mill Configuration: Mill power, Chambers, Ball sizes, Void filling
- Circuit Layout: Separator type, Mill ventilation, Static separator
- Typical Operation: Feed rate, Circulating load, Temperatures, Water cooling, Additive
- Mill System Control: Auto; Manual, Total feed set point
- Mill Vent Dust Handling systems: Bag filter, ESP, dust return in circuit
- Product Conveying System:Screw pump, blow tank, conveyor belt incline
- Sampling Access

The trial and sampling programs should be reviewed together with the type and frequency of the material analysis that are to be done. It is also important to verify that the field instrumentation is working properly and that measuring equipments are accurate (e.g. the weigh feeders).

## Laboratory evaluation of potential products

In many cases, a thorough review of the background information can provide most of the details required to select a product for testing on the plant. However, in some complex or less clear situations it is beneficial to make a laboratory screening of cement additive options. This can be made using simple mix water testing of the additive in a single cement sample. Laboratory grind tests can also be used

where additive-free cement is not available or CM % is varied. Laboratory screening can provide more information and a clearer choice of similar products thereby allowing easier selection of lower cost options. However, it can prolong the overall process and therefore it is often beneficial to run a laboratory screening in parallel to a 1st plant trial.

## Defining specific goals / targets for the trial

Once an opportunity has been identified for a specific mill system, cement type and additive(s) the trail objectives should then be set for: mill output, cement performance (e.g. water demand, setting time, early strength, 28-day strength and other key properties). At this point it is also possible to gauge the potential cost benefit obtained from using the grinding aid from previous supplier experiences and based on the set objectives.

## Necessary equipment for trial

If no grinding aid dosing system is currently in place then a temporary system must be installed. For most trials a peristaltic or diaphragm pump can be sited with either a 205 litre drum or 1000 litre container and in most cases can be borrowed from the additive supplier. If a grinding aid dosing system currently exists then this must be checked for availability and suitability during the trail, e.g. verification that the grinding aid dosing equipment can handle the volumes required during the trial. Additionally, if a current grinding aid dosing system is to be used it is essential to thoroughly clean the system and to check the compatibility of the two products to avoid unwanted formation of reaction products.

Additionally, there should be sufficient space in a suitable (ideally isolated) cement silo to ensure that a minimum of 12 hours continuous cement production can be accommodated. However, sufficient space for 24 hours continuous operation is recommended in case any technical difficulties are encountered.

## Determination of dosing point/dilution ratio

During the trial it is suitable for the grinding aid to be added directly onto the clinker weigh feeder belt just before the mill inlet. However care needs to be taken to ensure that the additive only comes into contact with material and there is no risk of “wetting” the transport belts or chutes which could lead to build-ups of the additive.

The grinding aid should be added to clinker that has a temperature below 100 °C. For temperatures between 100 and 150 °C care needs to be taken that evaporation losses of the additive do not occur. Addition of grinding aid to clinker with temperatures greater than 150 °C should be avoided.

In cases where clinker temperature is too high, addition of the grinding aid to other material feed streams (e.g. CM or gypsum) should be considered. If there is no suitable dosing possibility onto the material feeds, the grinding aid can be aspirated directly into the first chamber of the ball mill.

## Risk assessment

A complete risk assessment as per the local procedure on the plant should be performed before all grinding aid trials.

## Safety procedures

All local safety procedures must be clearly communicated to all the necessary personnel (including additive supplier employees) as per the local requirements.

# 5. Trial Guideline

In order to ensure that a trial is performed in a systematic and representative manner it is essential that certain steps are taken. These steps are detailed in this section and cover the personnel and processes required to obtain the necessary reference and trial samples thereby enabling an accurate evaluation of the grinding aid used during the trial.

## Identification of required personnel

The following staff from the plant should be present / accessible during the grinding aid trials:

- An experienced cement mill operator who is familiar with the limitations of the mill system on which the trial is being performed
- A laboratory staff member for sample collection and analysis
- An electrician for connection of dosing pump to power supply etc, if necessary
- Additional personnel may be required depending on the plant organisation and these people should be clearly identified before the trial commences.

## Trial protocol

### Sampling requirements

For a grinding aid trial the most important samples are those which enable an assessment of the mill system operation to be made. The required samples are from the:

- Separator Feed
- Separator Reject
- Separator Product
- Mill Discharge
- Finished Product

During the grinding aid trial it is recommended that any automatic sampling system is switched off to enable the necessary trial samples to be taken as and when required. The proposed sampling scheme should be the same during both the baseline and the grinding aid trial periods.

A 100 g sample from each of the following sampling points every hour: separator feed, separator reject, separator product and if required mill discharge. Additionally, a 300 g sample of finished product should be taken every hour. (If trial performance in concrete is required then a 600 g sample of the finished product should be taken every hour).

During the trial period the hourly samples should be analysed for: SSA, 45 and 90 µm residue (and/or PSD) and SO3 content.

### Testing periods

The testing periods can be divided into 4 phases:

1. Initial baseline trial period
2. Initial grinding aid trial period

3. Post trial baseline period
4. Grinding aid optimization trial period(s)

### *Baseline trial period*

The initial baseline (or reference) trial period should be conducted as close to the start of the grinding aid trial period as possible, ideally the day or night before the actual grinding aid trial. The raw materials (clinker, gypsum and any CM) should be as similar quality to those that will be used during the grinding aid trial as possible to minimize any external influences on the trial, e.g. each raw material should be taken from the same section of the storage area.

During the baseline period, the cement is produced under "typical" production conditions, in which case grinding aids may or may not already be in use. It is assumed that the mill is already in an optimized state and therefore the baseline trial period should be a minimum of 12 hours continuous (and stable) operation.

### *Initial grinding aid trial period*

The grinding aid dose is usually recommended by (or agreed with) the additive supplier and for the initial trial it is advisable to use the dosage to prove the additive. Optimization trial periods will be conducted at a later stage.

It is recommended to switch off the automatic regulation when the new grinding aid is added and to control the mill in manual mode in order to avoid a sudden step change in feed rate and a period of instability. During the trial period all mill parameters (air flow parameters, temperatures and filter pressure etc.) should be kept constant and only the mill feed and separator speed should be adjusted to optimize the mill.

The initial grinding aid test period should last 24 hours and includes an initial optimization period, a minimum of 12 hours continuous (and stable) optimized operation, followed by a period returning the mill to its pre-trial state.

After the initial grinding aid trial period the baseline trial period should be repeated to ensure that there has been no shift change which is not attributable to the grinding aid (e.g. changes in clinker quality).

### *Grinding aid optimization trial period*

Once the grinding aid has been successfully proven during the initial grinding aid trial using the recommended dosage from the supplier, additional optimization trial periods should be performed. The first trial should use 125 % of the recommend dose and the second should use 75 % of the recommended dose. Ideally, these two additional trials should be performed as soon as possible after the initial grinding aid trial. However, additional baseline periods will most probably be required. Further optimization through adjusting the water/grinding aid dilution ratio can also investigated i.e. it may be possible, due to improved dispersion, to use 100 g/t of grinding aid diluted with 200 g/t of water to obtain the same benefits as using 150 g/t of pure grinding aid.

## Key parameters to be monitored

In addition to the hourly sampling analysis it is necessary to record the following information on an hourly basis:

- Cement composition (t/hr of each component)
- Feed characteristics (size, dustiness)
- Mill Output (Tonnes/hour)
- Additive flow rate (manually measured or indicated by flowmeter)
- Mill power (kWh/tonne)
- Ancillary power (e.g. elevator kW)
- Circuit temperatures (e.g. mill exit, separator exit)
- Water injection
- Circulating load
- Separator settings
- Mill noise
- Mill control (on/off, how controlled, total feed set-point)

# 6. Post-Trial

It is essential that after the trials have been completed that their success is thoroughly evaluated and documented. The following information details the necessary steps needed to evaluate the outcome of the trial along with the additional steps required to implement the regular use of the grinding aid if the trial was successful.

## Laboratory testing of trial cement in mortar/concrete

In addition to the hourly samples analysed during the trials themselves it is necessary to make a more in depth analysis of the collected samples. The 12 samples (minimum) collected at one hour intervals during the trial should be combined to provide one large composite sample. The composite sample should be prepared by taking equal masses of the individual samples and then homogenizing thoroughly. The minimum requirements for testing the cement produced during the baseline and grinding aid trials are as follows:

- Blaine specific surface area
- 45/90 µm residue (and/or PSD)
- Particle size distribution by laser granulometer
- Compressive strength development in mortar at 1, 3, 7 and 28 days
- Normal consistency
- Initial and final setting times

Additional testing can also be performed where necessary or desired and can include determinations such as, but not limited to:

- Compressive strength determination in concrete
- Concrete slump
- Mortar flow or penetration
- Dry flowability of packset tendency
- Heat of hydration measurements
- Rheological measurements

## Evaluation of performance against defined goals/targets

The results from the initial and optimization grinding aid trials should be compared with those from the baseline measurements as to whether the objectives were met. This is where the need for clear objectives becomes apparent. If the initial objective of the trial was to increase the 1 day strength by 2 MPa, but only a 1 MPa increase was observed, then it is quite simple to say that the trial was not successful. However, if by using the grinding aid, an increase of 3 MPa at 1 day over the baseline was recorded then a full evaluation needs to be performed. For example, were any additional effects noted, e.g. an increase in 28 day strength or reduction in normal consistency. The evaluation should give special consideration to any negative effects were observed.

## Determination of the cost benefit/value added

In order to determine whether the use of a grinding aid makes economic sense a detailed evaluation of the associated costs must be carried out. It is important to include all factors that have an impact on the cost. For example some key considerations are:

- Reduction in cement fineness and hence increased mill output and lower energy consumption (kWh/t).
- Reduction in clinker factor with the increased use of CM and (CM is usually lower cost than clinker).
- Lowering of clinker factor reduces CO2 per tonne of cement
- Increased use of CM can increase the total cement volume for a given clinker volume if clinker capacity is a bottleneck
- Increase in mill capacity could generate extra sales profit when cement production capacity is mill limited

It is also important to remember that the lowest treatment cost (additive cost Rs/t x dosage g/t) does not necessarily give the highest cost benefit/value added.

Grinding aids should always have a negative cost i.e. they generate more cost savings than the actual cost of using the additive.

## Documentation and reporting

After completion of the grinding aid trial it is necessary to clearly document the outcome to ensure that a permanent record of the trial exists for future reference. The report should highlight the results of the trials and the outcome, whether positive or negative, and include clear recommendations.

The report should include the following:

- Summary
- Background description and problem statement
- Objectives with clear targets and metrics
- Key plant features/factors influencing the trial
- Trial procedure and key data
- Results of laboratory tests on trial samples
- Evaluation and interpretation
- Conclusions and recommendations
- Appendix, Cost Benefit Evaluation Spreadsheet

## Implementation after a successful trial

Once the grinding aid is “approved” supply conditions should be assessed and agreed.

This will include:

- Grinding aid volume
- Grinding aid packaging
- Grinding aid pricing (delivery conditions, validity period, company agreements, rebates etc.)
- Leadtime
- Order pattern and procedures
- Documentation required
- Supplier location, accreditation, back-up
- Additive supply specification
- Supplier support available
- Review procedures

Suitable dosing and storage equipment will need to be installed (if not existing). Storage volume should reflect the total demand volume, delivery volume, frequency and leadtime.

## Periodic review of performance and identification of additional/future opportunities

Once a grinding aid is used in regular production several control steps should be implemented. Quality control testing of the delivered material should be performed using either density or refractive index measurements (these methods can also be used to control the dilution ratio if necessary). The performance of the grinding aid should be confirmed on a regularly basis (at least quarterly, but preferably monthly) by determining the quantity of additive used against mill performance and cement properties.

A thorough review of grinding aid usage should be performed every 3 -5 years to ensure that the additive performance remains at the desired level taking into consideration changes in market conditions and new product developments etc. The use of a grinding aid should also be reviewed after changes in the raw materials, clinker chemistry etc.

The review should include:

- Confirmation of the background and targets
- Changes that have occurred (e.g. materials, equipment, targets or costs)
- Is the additive providing consistent effects?
- Delivery conditions, issues etc.
- Confirmation of economic benefits (real cost saving versus calculated)
- New opportunities e.g. possible implementation of new or better products
- Changing market conditions

# Appendix 1 - Checklist prior to the plant trial (Pre-trial checklist)

| Sr # | Grinding Aid Trial Guideline – Pre-Trial Checklist | Yes | No |
|---|---|---|---|
| 1 | Are the objectives fully understood and agreed with the supplier? | | |
| 2 | Have clear and specific targets been set? | | |
| 3 | Has a trial date been agreed? | | |
| 4 | Has the cement type to be produced during the trial been agreed? | | |
| 5 | Has the mill system to be used been identified? | | |
| 6 | Has sufficient background information regarding the mill system been provided to the supplier? | | |
| 7 | Have the additive(s) and dosage(s) been agreed? | | |
| 8 | Has the trial duration been agreed? | | |
| 9 | Have the necessary personnel been identified? | | |
| 10 | Is the required quantity of additive on-site? | | |
| 11 | Is the required dosing system available and set-up? | | |
| 12 | Has the sample schedule been agreed? | | |
| 13 | Is there appropriate sampling access and sample containers? | | |
| 14 | Are the suppliers aware of the plants health and safety regulations? | | |