Strength. Performance. Passion.

Handbook for Optimized Use of Cement Additives

Holcim Group Support Ltd, CMS, CS and INN, Holderbank / Switzerland
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Introduction

The utilization of additives is the last step of a successful product optimization process. The sequence of product optimization is described in the Product Optimization Manual.

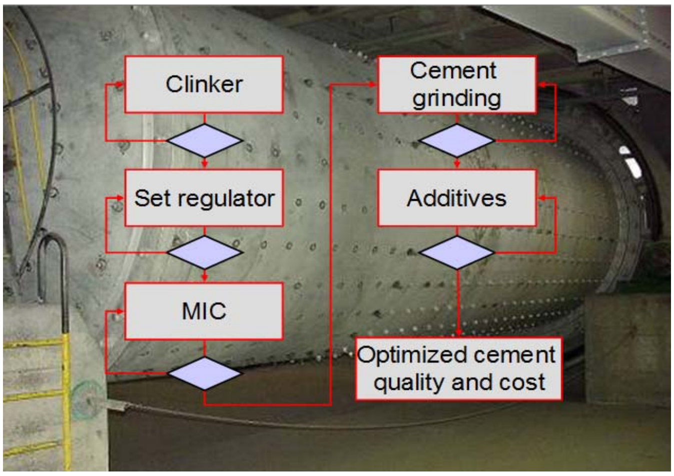

Figure 1: Product optimization process – a step wise approach to optimal cement performance[1]

Additives can help to overcome shortages in cement grinding capacity as well as keep or improve the product performance at constant or lower clinker factor. For an optimized grinding system, the benefit is estimated to yield a grinding capacity increase between 5 and 8 % with possibilities to even beyond 10 % and a clinker factor reduction of 2 to 3 % compared to the situation without additives. Due to relatively high costs, additives should not replace long term other measures like e.g. clinker or mill optimization, which should be fundamentally in place before spending on additives.

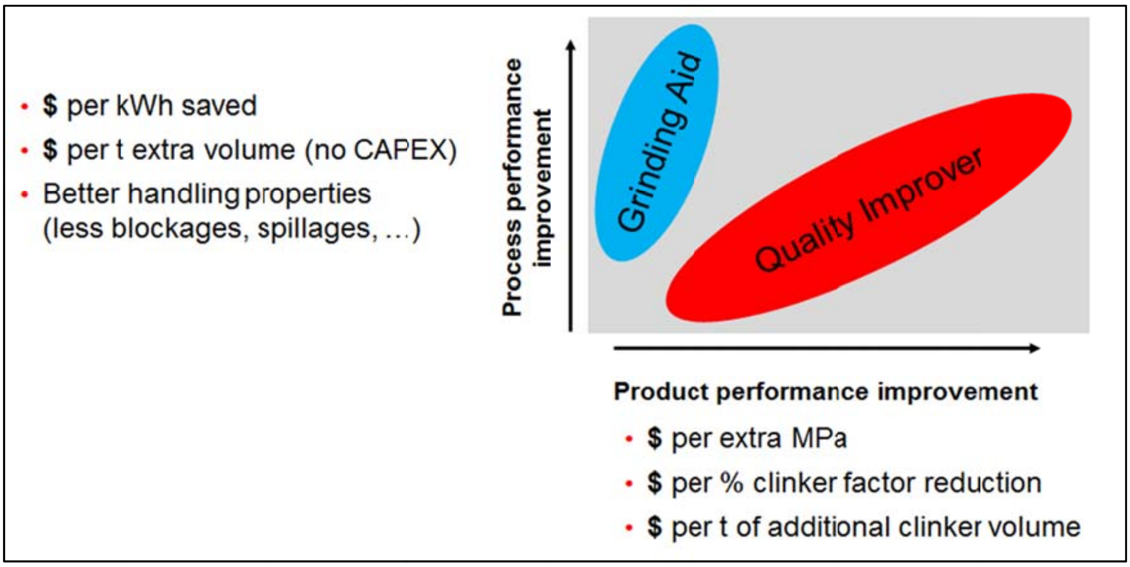

Figure 2: Areas of optimization potentials for additive application

Two thirds of Holcim plants use additives in cement production, most of them are declared as “grinding aid”, but a global estimate of their benefit is not possible due to several reasons, e.g.:

- Inconsistent data recording during the trials hamper the comparison of the results

[1] Schäfer Elke, Suter Willi, Zimmermann Yves – Product Optimization Manual, Report Nr. 14833, CSM-MT, 2009

- Incomplete documentation (e.g. only quality or production impact was recorded) prohibits a complete cost-benefit calculation
- Plants using additives have not checked their effectiveness for a long time
- Trials were conducted unsystematically (insufficient testing time, change of several variables at a time etc.)

In the past, additive trials were in many cases executed by the additive suppliers with only little involvement of the plant personnel, leading to biased, non-reproducible results. Sometimes process conditions were changed during the trials or several parameters, for example cement composition and fineness were changed at the same time. Consequently, the effect of the additive, mill operation or cement composition could not be separated. This situation has led to a strong dependency upon the suppliers, poor basis for negotiation and limited knowledge about additives.

Quality control of additives is a difficult task for a normal plant laboratory and is in most cases limited to some “indicative” tests. However, it was observed that in many plants the delivery control is not at all part of the quality control plan. In addition to this, important parameters were missing in the contracts, giving a lot of freedom to suppliers and leaving the plants to deal with a black box. In some cases it was reported that the additive quality deteriorated over time, but unfortunately there were no reliable data available and the contracts were missing key parameters.

Another important aspect to start the project was that the additive benefits were never considered on a companywide base, but only for single plants in the context of product optimization. In particular for sold out markets, it is of interest to consider the additional cement or clinker volumes, which are generated by additives on a company level. The improved understanding of the additive effectiveness, comparability of commercial additives and real needs in the company/region, will put Holcim into a better position to negotiate with the suppliers.

In order to strengthen the knowledge of additive utilization in the Holcim group and to “open the suppliers’ black box”, the present handbook for the optimum use of cement additives was developed. It is intended to combine all related aspects from market assessment, plant initiatives and cost benefit evaluation in one project. A special focus is to establish a structured and unified way of industrial additive trials and their documentation to allow for a global comparison of additive benefits (Fig 3). By effectively using all elements, the companies and plants shall be enabled to find the best additive for their purpose and to benchmark the products of different suppliers.

The concept was elaborated in the context of the so-called ValueCatch initiative in the South Asia region, including the realization of industrial additive trials at ACC, ACL, Holcim Indonesia and SCCC. We would like to thank those OpCos for their collaboration and support.

	Phase I Assessment	Phase IIa Preparation	Phase IIb Execution	Phase IIc Evaluation	Phase III Selection& Negotiation
		Grinding trial			
Key activities	1. Market assessment 2. PPM data input	1. Assessment and selection of additives 2. Organize preparation in the plant	1. Monitoring of grinding data and downstream impact 2. Cement sample collection	1.Trial data consolidation 2. Cement testing 3. Cost analysis 4. Feed in additive database	1. Identify additive with best TCO 2. Start negotiations with additive and/or chemicals suppliers
Outcome	• Trial objective and performance targets	• Additive ready for testing • Plant setup ready for trial	• Operational and cement data for input evaluation sheet	• Data evaluation and reporting • TCO calc. • Additives database	• Selection of best performing and cost effective additive • Best deal with additive supplier
Duration	2 weeks	4 weeks	5 days/product 1 week -1 month long-term evaluation	2 weeks	1 week
Documents	Template	Templates	Data input template	Evaluation sheet	
Manual chapter	• 1	• 2.1 & 3	• 2.2 & 2.3	• 2.4 - 2.6	• 4

Figure 3: ValueCatch approach

The present handbook describes the different aspects to be considered for an optimum use of cement additives:

- Market assessment
- Execution and documentation of additive trials
- Fundamental knowledge of additive ingredients and their effects
- Quality control of additives
- Quality parameter in the contract
- Total cost of ownership evaluation

Chapters 2 to 0 related to the industrial trials and quality control of additives will also be published in the new release of the “Product Optimization Manual”.

1. Market assessment

1.1 Overview

Not all plants/mills have the same requirements regarding grinding aids/performance improvers since the markets they serve can be quite different, hence not all grinding trials and additives are useful. In order to focus the grinding trials as much as possible on the relevant profit levers, it is recommended to conduct a short market/requirement assessment prior to starting the grinding trials. As a rule of thumb:

- In **sold-out markets**, additional volumes are one of the key drivers of profitability (for short term additional revenues and / or mid-term CAPEX-deferral).
- In case of **cement over-capacity**, additional volumes could not be sold (or only at lower prices), therefore additional profits can only be generated by either lowering variable production cost or by increasing the product performance in order to increase sales prices.

The potential from lowering variable production cost should be assessed in any case, independent of the market situation.

1.2 Potential in sold-out markets

In a short (sold-out) market either available grinding and/or clinker capacity limits total cement sales volumes. The two possible scenarios require a different focus of the grinding trials.

1.2.1 Available grinding capacity as limiting factor

In cases where the mills run at capacity limit but additional clinker could be produced / imported, the focus of the grinding trials should be on increasing production rate by either

- introducing a grinding aid in case no additives are being used so far,
- benchmarking the current grinding aid against potential alternatives, which could lead to better results, or
- optimizing the dosage of the current grinding aid in order to increase the cement capacity per mill.

The additional profit is then calculated taking into account incremental revenues from higher cement sales minus (additional) cost from more / other grinding aid (see chapter 5 for details).

1.2.2 Available clinker capacity as limiting factor

If spare grinding capacity would be available but clinker is scarce, the main focus of the grinding trials should be on lowering the clinker factor in order to have more clinker available for cement production. Introducing or optimizing the usage of a performance improver therefore aims at achieving the same product performance with less clinker; a structured, comparable and consistent performance, and quality benchmarking (e.g. PQM) is a prerequisite for this kind of grinding test.

As in the previous case, the additional profits come from higher cement sales/revenues, the reduction of variable cost (e.g. by lower clinker factor, reduced grinding energy) minus the (additional) cost for the performance improver additives (see chapter 0 for details).

1.3 Potential in markets with over-supply

In long (over-supply) markets, additional volumes cannot be sold, therefore, the focus of the grinding trials should be on lowering variable production cost while maintaining volume and performance, or increasing performance if the market accepts / values a higher positioned (priced) product.

1.3.1 Capturing (internal) cost saving potential

Lower variable production cost at same product performance can be achieved by either

- lowering the energy consumption for grinding by optimizing the usage of grinding aids,
- lowering the clinker factor due to increased clinker reactivity with a (different) performance improver, or
- optimizing the procurement of grinding aids/performance improvers, e.g. by switching to less expensive (in-house) alternatives.

All three initiatives do not affect the quality performance of the final product, and are therefore not sensitive to customer/market acceptance.

1.3.2 Increasing product performance as a base for product differentiation

Spending money for higher product performance only pays off for Holcim if customers value the improved product characteristics, and are willing to share the value addition with Holcim. Assessing the application-specific market requirements, the customers' willingness to pay a price premium, or to increase their usage share of our products, for superior performance and the competitive situation/offering is crucial before running grinding trials, which aim at improving product performance.
Incremental profit in this case comes from higher sales prices (USD per MPa) minus higher/ additional cost for performance improvers; only in cases where a price premium can be achieved or if prices drop can be prevented, additional cost for performance improvers should be considered.

The determination of the optimal (higher) price for improved products should take into account the real value for the customer, e.g. the cost of cement per m^3 of concrete at a given (concrete) performance. A higher cement performance allows reducing the cement content per m^3 of concrete (as long as within local norms) and therefore allows increasing the cement price per ton.

It is thereafter important for Holcim, having created and demonstrated real value addition for the customer, to charge the customer for that value addition, i.e. for Holcim to “catch” all or part of the value it has created for the customer.

Market situation	Reason for grinding trials	Goals to achieve with additives (GA / PI)	Focus of grinding trials
Under capacity	Lack of grinding capacity	Lower kWh/t, higher volumes	Introduction of GA ; Dosage / benchmarking of current GA
	Lack of clinker capacity	Higher Clk reactivity, lower CF	Introduction of PI; Dosage / benchmarking of current PI
Over capacity	Reduce cost	Less kWh/t, lower milling cost	Electricity savings due to GA vs. cost for GA
		Higher Clk reactivity, lower CF, lower Clk cost	Clinker savings due to PI vs. cost for PI
		(Goals already achieved)	Benchmarking of current PI / GA: Same performance at lower cost
	Increase product performance	Higher performance, higher sales price	Introduction / dosage of PI to achieve target performance

Figure 4: Summary ‘Market assessment’ and derived focus areas for grinding trials

2. Additive testing on industrial scale

2.1 Project planning

2.1.1 Organization

An additive trial is a joint project of the quality and production departments to ensure sufficient resources from both sides during the trial as well as comprehensive documentation of both areas. From each department one responsible person should be designated.

2.1.2 Safety provisions

Before the trials it has to be ensured that all required precautions for additive handling and storage are considered.

- Material Safety Data Sheets (MSDS) describing the chemical substances and potential safety hazards have to be provided by the supplier ahead of the trials. In case the supplier does not deliver the MSDS the product shall not be accepted.
- The safety provisions described in the MSDS have to be strictly followed.
- Contact the local OH&S responsible to discuss the specific requirements for each additive

The additives have to be stored and fed in an environmentally secure way:

- Store additives in a roofed shelter with a concrete floor to avoid ground water contamination
- Potential spillages have to removed immediately (follow the Holcim OH&S chemical spill matrix on Holcim Portal)
- Additives should be delivered in plastic drums to avoid corrosion and related spillages
- Proper feeding installations need to be installed
- Contingency stocks delivered for the trials (in case of trial delays) shall be given back to the supplier, if not used at the plant

2.1.3 General considerations

The following points should be considered ahead of the trial (see preparation checklist **annex 1**):

- Define clear targets for the trial (see section 2.1.4)
- Laboratory testing of different additives (see section 2.1.5)
- Ensure compliance of cement components with typical compositions (e.g. grinding units should use clinker/MIC from major source)
- Ensure functionality of dosing installation (including calibration and consistency of dosage rate) and sufficient quantity of additive for the trials (consider some contingency for disturbances) (see section 2.1.6)
- Consider silo management during the trials to avoid quality fluctuations (see section 2.1.7)
- Ensure functionality of mill system including auxiliaries and signals (last mill audit should not be more than 3 months back) and properly calibrate weigh feeders (see section 2.1.8)
- Record data of normal (baseline) operation one week ahead of the trial to establish a stable baseline for comparison (see section 2.1.8)
- Engage adequate availability of lab personnel with proper competences for additional routine and physical testing (see section 2.5)

2.1.4 Definition of targets and supplier selection

Clear capacity and/or quality related objectives need to be defined ahead of the trials. Some examples for target definitions are given in **annex 2.** The targets should be in line with the results of the market's assessment as described in section 1.

Cement composition and objectives have to be communicated to the supplier so that they can propose an adequate additive for that particular purpose. The supplier should be informed whether the plant can or cannot accept certain substances like e.g. chlorine or thiocyanate (see also section 3.3.2.3).

In principle, the generic additives provided by the global suppliers are similar with regard to their ingredients and effectiveness. Thus, the selection of suppliers should also be based on the following considerations:

- Performance in laboratory trials
- Customer support of supplier in the respective region
- Additional supplier services (e.g. supply of dosing installations)
- Additive cost

2.1.5 Laboratory testing

In particular when the number of additives for stage 1 of the industrial trial shall be reduced, laboratory trials are required to check the influence of the additives on product performance (setting, strength). An easy test is to add the additives in different dosage levels to the mixing water of mortar or concrete, but it is preferable to test the additives in a lab grinding trial. In case the plant has no own laboratory ball mill, the tests can also be carried out by the suppliers, sharing the results with the plant. For plants planning to use basic chemicals or creating own formulations, own laboratory tests including the tests listed in ASTM C465, are mandatory.

Based on these results, the best performing additives can be chosen and the suppliers be invited for industrial scale tests. For further details on lab testing refer to section 3.4.

2.1.6 Additive dosing installation

A precondition for each trial is a properly working dosing installation, which is in many cases provided by the supplier at least for the trial duration. The dosing rate must be proportional to the feed rate and is thus ideally PLC controlled. For non-PLC controlled additive dosing, personnel must be available to adjust the dosage manually with the feed rate.

Minimum requirement are a dosing pump and a calibrated flow meter with manual control. Cheap installations working with hydrostatic pressure (e.g. drums with a hole in the bottom) are not acceptable.

The additive should be dosed on the mill feed belt as close as possible to the mill entrance. For mill systems with pregrinder, the additive is dosed to the preground material. The accuracy of dosing must be checked by volumetric measurements at the dosing point. In particular when working with new installations or new additive, the dosage should be checked every one or two hours.

The clinker temperature should be representative of normal operation conditions. If the clinker is unusually hot, part of the additive might evaporate and lose its effectiveness. Thus, the dosage required during the trials might be higher than the one needed in normal operation with colder clinker

In order to have sufficient additive in case of trial disturbances, a contingency of at least 30 % additive should be planned (for length of each trials refer to section 2.2).

2.1.7 Silo management during the trial

The quality of the product might be impacted by the additives, in particular when testing quality improvers. Thus, fluctuations in product performance are likely. In particular for longer trial periods, it should be checked whether the additive effect can be minimized by adequate silo management, e.g.

- feeding one silo with two mills (one mill for the trial, one with normal or superior quality)
- switch between the tests of the different additives back to normal operation to blend out the quality differences
- if possible go to off-spec/transition silo

2.1.8 Preparation Grinding

Before the trial, the functionality of the mill system including auxiliaries and signals has to be ensured following the common calibration procedures. The most recent B-level mill audit shall not be older than 3 months.

One week before the trial, the process data shall be collected and stored for later comparison. All kW and feed rates must be determined using the individual counters for drives or feeders. The moisture of the individual cement components must also be determined during that time to have a feeling for the moisture range. During the following trials, the process control must be kept in the range of normal operation.

2.2 Trial execution

2.2.1 General

Irrespective whether a plant is already using additives and wants to benchmark the current product against another supplier or wants to start the utilization, the optimization of additives is in general not a one-step approach but consists of four stages:

Step 1: Short term assessment of additives on industrial scale
Step 2: Testing of best additive, cement composition and fineness
Step 3: Final evaluation in long-term trial
Step 4: Long term monitoring of additive

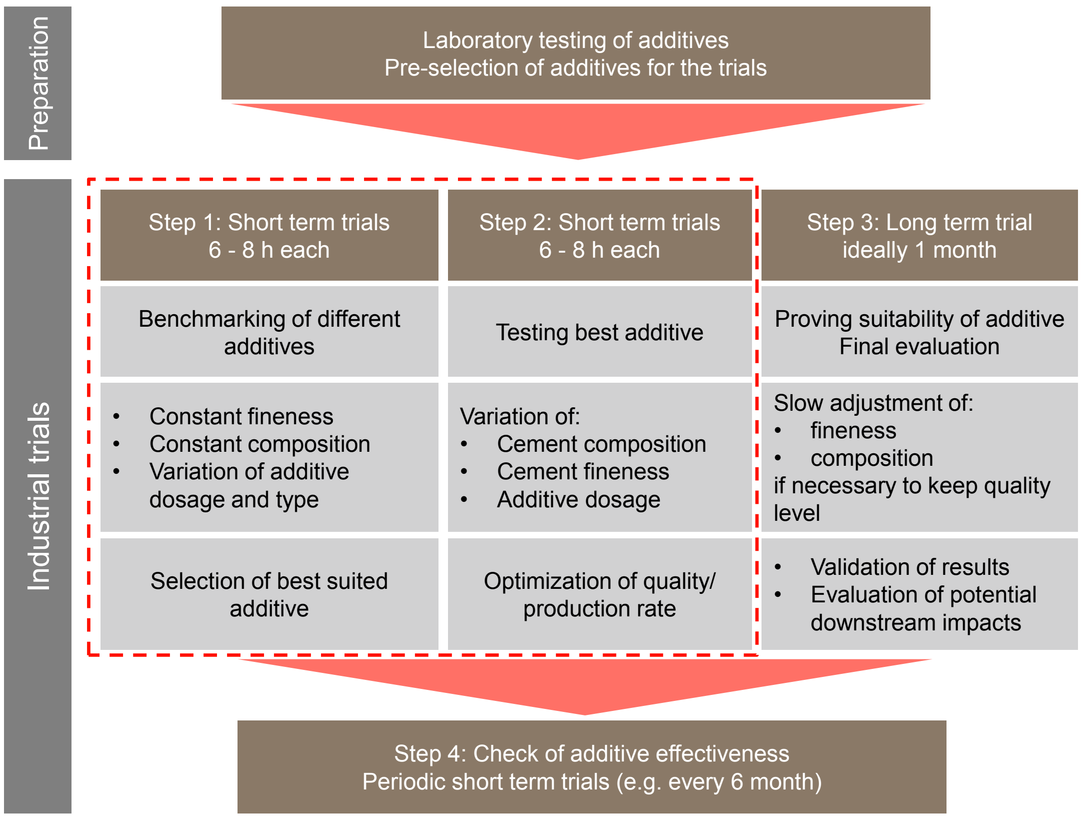

Figure 5: Typical sequence of an additive trial. Steps 1 and 2 can be combined in one trial sequence

For each trial, a baseline situation needs to be defined to benchmark the other additives. The baseline can either be the currently used additive or the blank (no additive). Also for those plants already using additives, a blank trial has to be included in each trial series to evaluate the effect of the currently used additive.

2.2.2 Step 1 – Short term assessment of different additives

The intention of short term trials is to get a preliminary assessment of the effect of unknown additives on production rates and quality. For this stage, e.g. the best performing additives of the laboratory tests (section 2.1.5) are used to validate their performance on industrial scale.

The duration of the trials is limited to the absolute minimum to avoid quality fluctuations and production of off-spec cement. Short term trials are in particular interesting for benchmarking different suppliers, for a fast check of the effectiveness of the current product or a new one. The typical set up is as follows:

- Each additive should be tested at least at *two dosage levels*, starting with the low dosage[2] to evaluate potential downstream impacts before increasing the dosage rates.
- *Cement fineness and composition have to be fixed* to compare quality and production rate effects on a like for like basis.
- Each additive and dosage should be tested for *6 - 8 hours*, depending on the initial time to reach stable conditions. A minimum of two hours is required necessary to exchange the additive in the mill. After that the mill should run at least 4 hours in stable operation for a rough evaluation of the production rate and downstream impact.
- Samples for product performance testing are taken earliest 3 hours after switching the additive/dosage rate (see also section 2.5.2) to ensure that the mill atmosphere is saturated with the current additive.
- For plants already using additives, a *blank* (no additive) has to be run during each trial series in order to establish a proper baseline.
- For grinding stations with different clinker sources, it is mandatory to run a proper baseline (depending on plant situation: either blank or current additive) after each tested additive to evaluate the impact of changing clinker on cement performance and production rates. A potential schedule for grinding stations is shown below (for that trial ACC was the baseline).

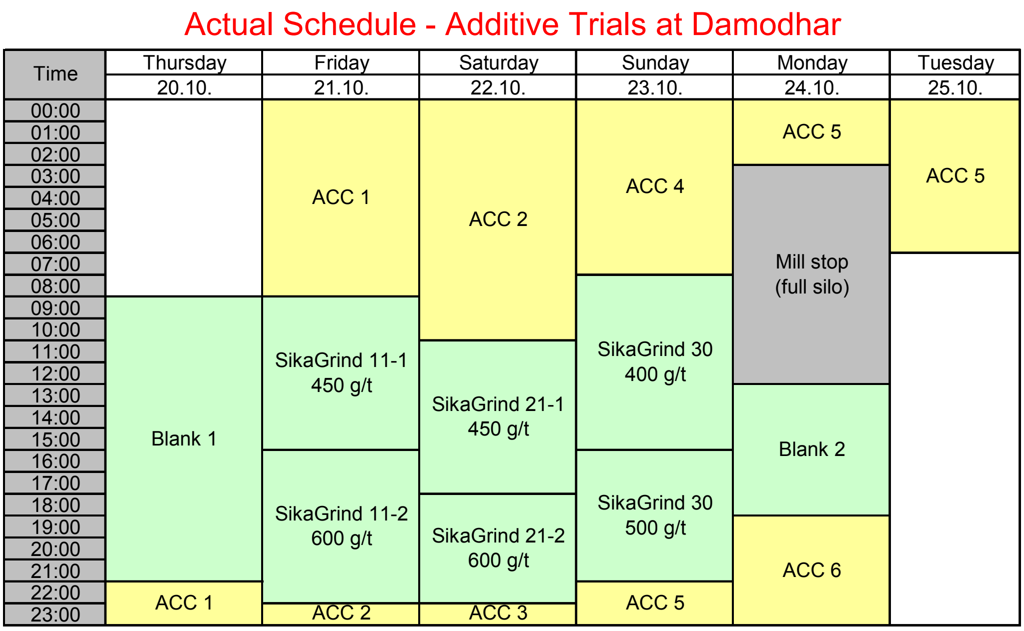

Figure 6: Example schedule for plants with varying clinker sources (e.g. grinding stations)

[2] Note: Suppliers often recommend starting with the high dosage to achieve a fast saturation of the mill atmosphere with the additive. This argument is valid, but it bears the risk of downstream problems (e.g. dust, back-flowing product…). Thus it is recommended to start with the low dosage.

2.2.3 *Step 2 – Short term trials to optimize best additive*

Step 2 covers the optimization of the most promising additive(s) with respect to dosage level, cement composition and fineness. For a first evaluation, a trial duration of 6 - 8 hours is sufficient. Step 1 and 2 can be combined if there is sufficient time. However, it is most important to change only one parameter at a time. An exemplary schedule for step 1 and 2 combination is shown below.

Tentative Schedule Additive Trials at Maratha					
Time	Monday 21.05.	Tuesday 22.05.	Wednesday 23.05.	Thursday 24.05.	Friday 25.05.
Morning	Arrival at plant IT installation Kick Off/Safety "Baseline" sampling only	ACC D1 const res. Const FA	ACC D1 const res. high FA	ACC D1 low res. high FA	Blank 2 (no additive) Conclusion meeting
Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
Afternoon	Blank 1	ACC D2 const res. Const FA	ACC D2 const res. high FA	ACC D2 low res. high FA	Baseline (current fly ash, current additive)
Night	Baseline (current fly ash, current additive)	Baseline (current fly ash, current additive)	Fosroc const. res high FA	Fosroc low res high FA	

Figure 7: Example for a one week trial combining steps 1 and 2

2.2.4 *Step 3 – Final evaluation in long-term trial*

The third phase intends to validate the additive effect on production rate, product quality and in particular to evaluate potential impacts on downstream equipment (e.g. dust filter issues) on longer term. Phase 3 should at least last one month if feasible. The parameters (cement composition, fineness and additive dosage) are ideally kept constant. If changes in cement composition or fineness are necessary to keep the quality level, they need to be documented. It is recommended to change only one parameter at a time.

Production and quality parameters have to be carefully documented during this period. The values should be compared with production figures of normal operation (e.g. data from the week before first trial). It is recommended to increase the frequency of cement performance testing (in particular concrete performance) during that time to evaluate the consistency of the additive's influence on product quality.

2.2.5 *Step 4 – Long term monitoring*

In some cases, it was observed that the quality of the additives delivered by the suppliers changed over time. But also changes in clinker chemistry or cement composition can jeopardize the effectiveness of an additive. Thus, the effectiveness should be regularly checked (e.g. every 6 months) by a simple 6 – 8 hour blank test as described for step 1.

If a significant off-set with the previous results is observed, a sample of the additives with all historical documentation should be sent to a central laboratory for analysis.

2.3 Mill operation

For the entire trial, 'stable' operation must be assured. Especially, the main signal(s) for process control must be kept in the range of the base trial. For standard mill types (ball mill, ball mill with pre-grinder, ball mill with roller press and vertical roller mill), the operation targets are different and explained in the following paragraphs.

Independent of the grinding system, data evaluation shall be based on trends from the process signals indicated in the following chapters and the counter values. The trends will reveal if the mill could be operated in the same way as for the base trial.

2.3.1 Ball mill

The operation of an end discharge ball mill is mainly done by two parameters; the ball mill chamber one load and the circulation load factor.

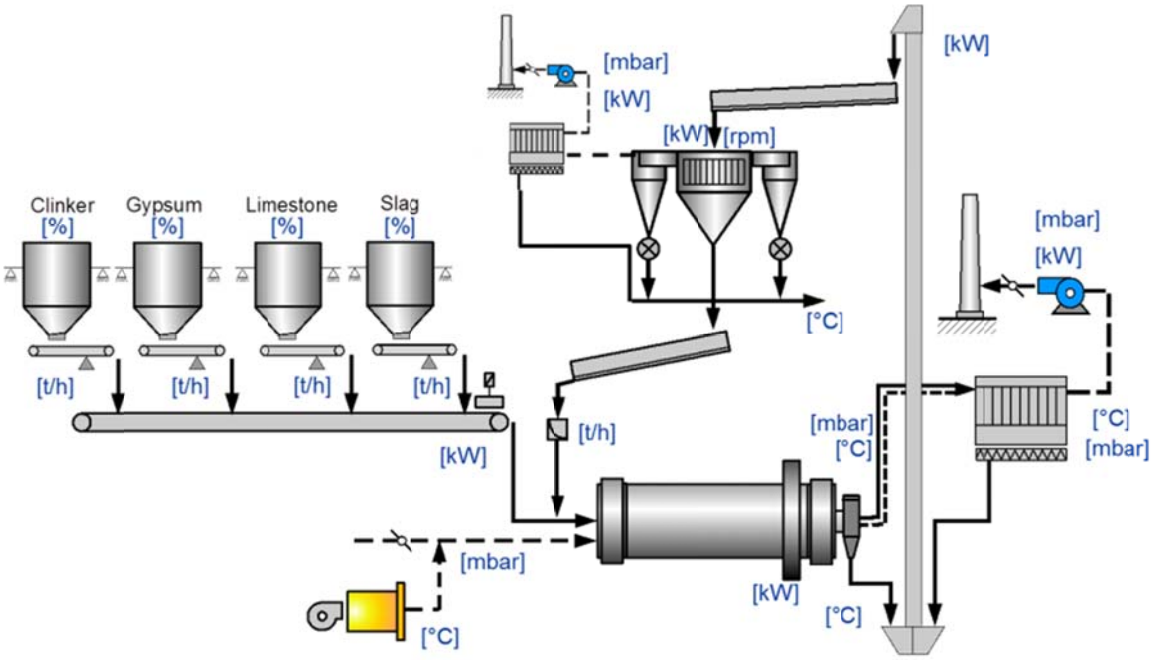

Figure 8: Process signals of a ball mill

The chamber one load is usually characterized by a sound signal, KIMA (electronical mill ear) device or a mill scan system. Before the base trial, it must be tested to work correctly. Such a test can be carried out by following the supplier manual. Usually, here an overload and a low load trial under operation are required. For rather coarse products (Blaine values up to 3000 / 45 µm sieve residues > 8 %) main signal for mill control is usually mill chamber one load. In case of fine grinding (Blaine values > 3000 / sieve residues 45 µm < 8 %), usually, the circulation load factor is the preferred control signal. The best signal here is the rejects flow from the separator. This device should as well be calibrated in advance of the base trial. In most factories, this can be done during mill stop by feeding a certain amount of material via the rejects flow meter on a truck (at least 30 t) and then weighing the truck.

Alternatives for a reject flow meter are the KIMA ear for chamber two or the power of the recirculation bucket elevator. However, in most of the cases, the bucket elevator power is not a precise signal and should be avoided for mill control. The KIMA signal gives a better control input.

For normal control purposes, at least the following process values need to be measured:

- Separator returns
- Bucket elevator power
- Mill sound chamber 1 (or KIMA%)
- Mill main drive power
- Mill exit temperature
- Product fineness

The following plant parameters are required as control variables:

- Mill feed
- Separator speed
- Mill ventilation
- Separator ventilation
- Water injection into mill
- Amount of grinding aid (proportional to feed rate)
- Hot gas flow

The basic control parameter is the feed rate (to keep mill chamber one sound and circulation load constant). Feed changes should be done in reasonable time intervals (6 - 10 minutes). The feed change size should be no bigger than 1.0 % of the current feed rate. The separator speed should be used only for fineness control. All fans must be kept at constant flow. For water injection as well as for hot gas flow, PID controls should be used (or the mill exit temperature). If no control is installed, it must be kept constant manually.

2.3.2 Ball Mill with vertical pregrinder

The operation of a pregrinder system is more complex than a ball mill. Apart from the common BM control, also the pregrinder load and the material recirculation must be controlled.

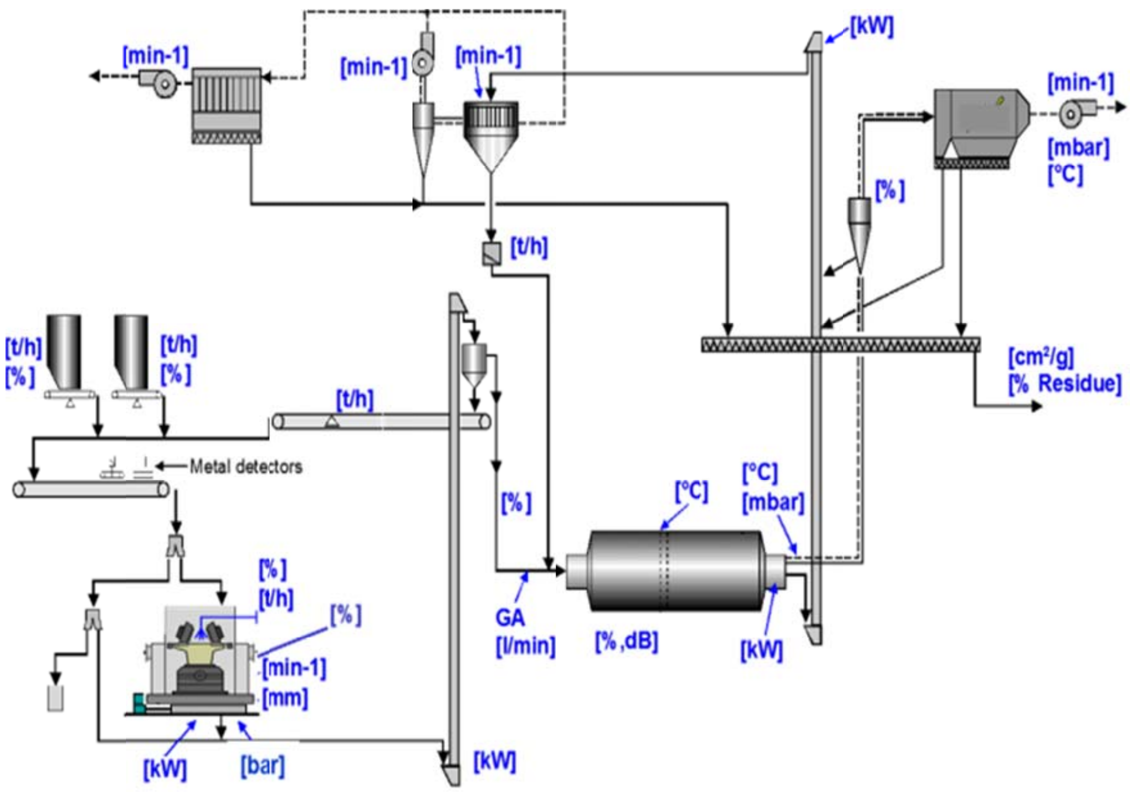

Figure 9: Process signals of a vertical pre grinder system

For the control of a pregrinder circuit, the following (minimum) inputs are required:

On vertical pregrinder:
- Pressure rollers
- Bed height
- Roller drives kW
- Feed gate position

Set points for control:
- Fresh feed rate
- Roller pressure

From the ball mill circuit at least the following inputs are required:

- Feed (pregrinder product to the mill)
- Separator returns
- Bucket elevator power
- Mill main drive power
- Mill exit temperature
- Product fineness

Set points for control:
- Mill feed
- Separator speed
- Mill ventilation
- Separator ventilation
- Water injection into mill

The operation of the ball mill is as defined in the previous chapter. For the pregrinder operation, the pressure and the bed height must be kept constant. This also determines the feed rate. For end discharge mills only the control of the recirculation load is relevant. If the mill is a mono chamber mill, also a KIMA signal may be sufficient. In any case, the process signal must be kept in the same range as for the base trial. The feed to the mill is either controlled by a splitter gate or an overflow bin. Here, the belt speed determines the material flow to the ball mill.
Since the ball mill feed is very fine, the chamber one signal should be of minor importance and the entire mill control can be carried out using the circulation load.

2.3.3 Ball mill with roller press as pregrinder

The operation of a roller press pregrinding circuit is similar to a pregrinder.

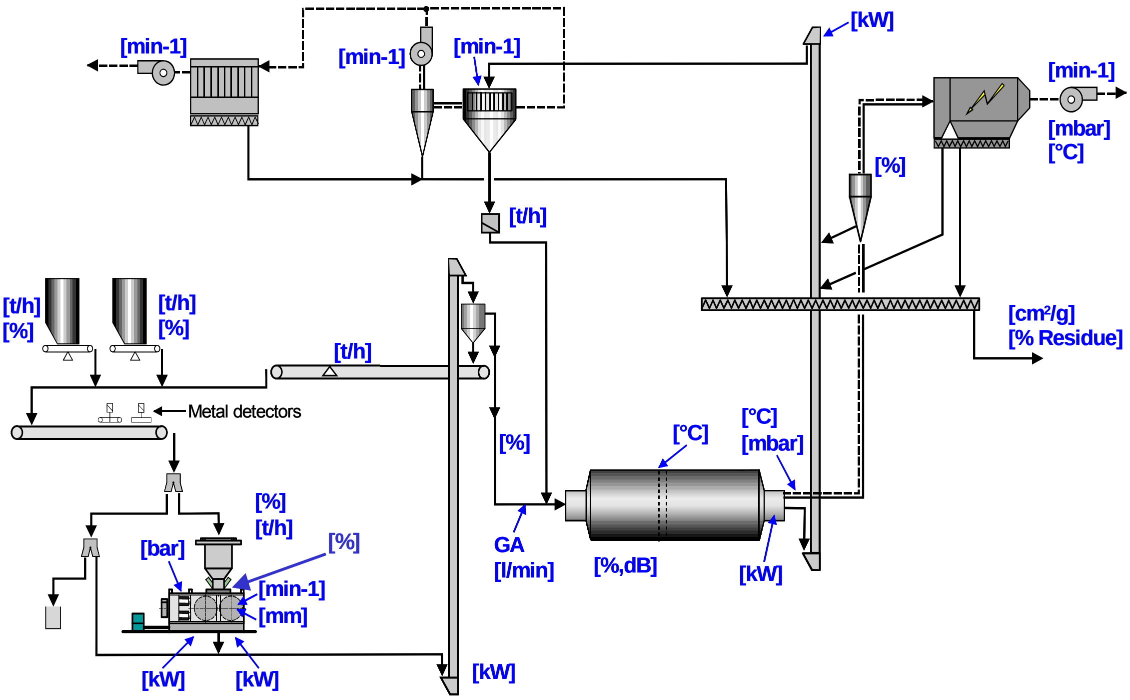

Figure 10: Process signals of a roller press system

In addition to the signals used at the pregrinder, the roller press has two additional features; basically roller speed and feed bin level

On roller press:

- Level feed bin over press ([%] or [t])
- Roller speed
- Pressure rollers
- Gap distance (left / right)
- Roller drives kW
- Returns (if returns go to feed bin)
- Feed gate position

Set points for control:

- Fresh feed rate
- Amount of slab cake recirculation
- Roller pressure
- Roller speed
- Feed gate position (not at all roller presses)
- Separator speed (for returns to feed bin)

Main operation tasks here are keeping the bin level constant and maintaining a constant circulation load in the ball mill circuit. The hydraulic pressure has to be kept as in the base trial. Also the roller speed should remain unchanged.

The operation of the ball mill is as defined in the previous chapter. For the pregrinder operation, the pressure and the bed height must be kept constant. This also determines the feed rate.
For the EDM control only the recirculation load is relevant. If the mill is a mono chamber mill, also a KIMA signal may be sufficient. In any case, the process signal must be kept in the same range as for the base trial. The feed to the mill is either controlled by a splitter gate or an overflow bin. Here the belt speed determines the material flow to the ball mill.
Since the ball mill feed is very fine, the chamber one signal should be of minor importance and the entire mill control can be carried out using the circulation load.

2.3.4 Vertical roller mill

For the VRM control, usually two parameters are the main signals for control; mill delta pressure and mill drive power. Other control parameters like gas flow and mill exit temperatures are usually kept constant by PID loops. The same applies to recirculation flow and fresh air addition.

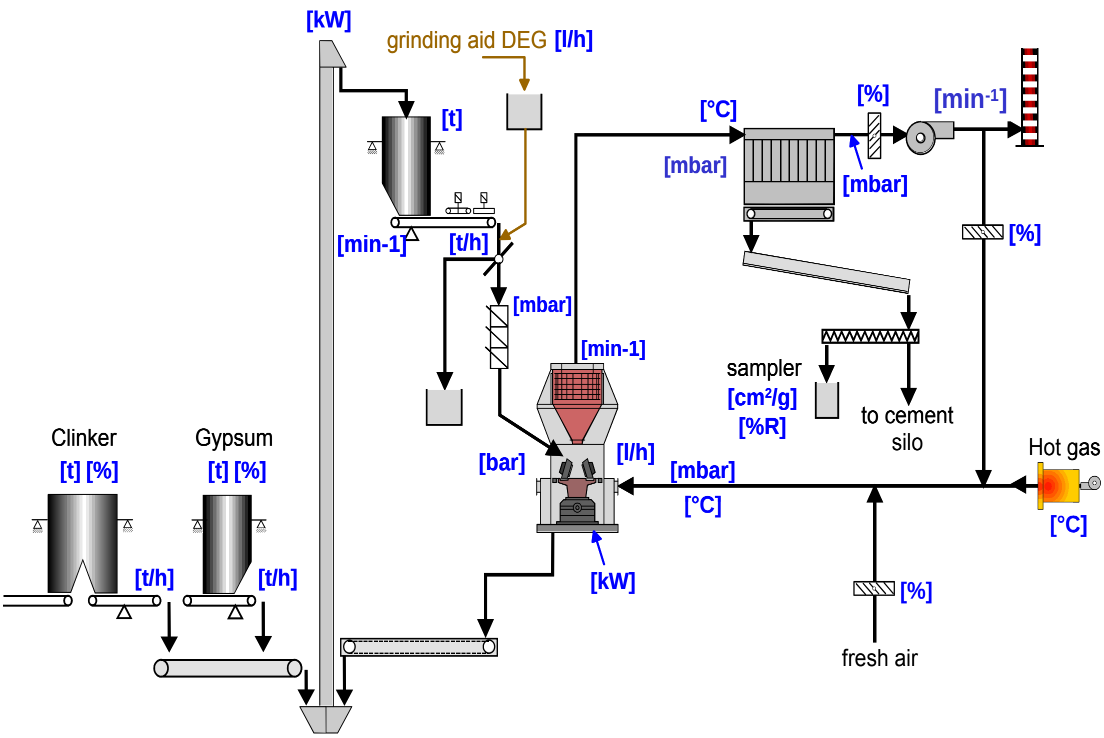

Figure 11: Vertical roller mill process signals

Main signals for the vertical mill control are:
- Mill main drive kW
- Bucket elevator kW (only for certain raw and slag mills)
- Mill exit temperature (usually controlled by fuel rate to HGG)
- Vibrations (stable by water injection)
- Delta p over mill (pressure difference between mill in- and outlet)

Possible adjustments (set points):
- Mill ventilation
- Air recirculation
- Table speed (only on some applications)
- Water injection (only for vibration control)
- Hydraulic pressure of the rollers
- Grinding bed height
- Separator speed
- Fresh feed

Set points for control:
- Fresh feed rate
- Separator speed (only for fineness control!)

For the base trial as well as for the additive test, especially the gas flows and the mill delta pressure must be kept constant. Changes of grinding pressure shall not be carried out during the test. The optimal grinding pressure must be determined before. Other parameters, which must not be changed (kept as for base trial), and should be kept in manual control are:
- Water injection
- Mill fresh air addition (flap position)

To keep the mill stable, basically only fresh feed changes are allowed. Feed changes shall be carried out in intervals of 3 - 6 minutes and shall keep mill dp or mill drive power constant. A cycling of any of the process parameters must be avoided.

For some vertical roller mills a mill protection system based on a DALOG system is installed. This protection may reduce the hydraulic pressure or (in some cases) the feed rate. Each of these actions is activated by an alarm of the system. The number and code of the alarm must be recorded. During a trial, not more than 3 protective actions within 8 h can be accepted. If there are more, the test should be repeated.
As well as for the ball mills, the VRM should be operated manually. Only the gas flow control shall remain in PID loop.

2.4 Downstream impact

The addition of additives to aid particle dispersion can affect (normally increase) the cement’s physical properties such as the cement bulk density as well as specifical flow properties due to increased air retention capability.

Material handling and dedusting thus becomes problematic because the cement could exhibit properties similar to both solids and liquids. In addition to that a high amount of fines can lead to dust collection problems as particulate matter can blind the filter bags.

A very free flowing product may be good if the handling systems, packing machines as well as dust collection systems are adequately designed for, otherwise the physical characteristics can create serious problems.

The typical processing issues mentioned below can exist individually or in combination, thus, each of these can be subject to a detailed, separate study.

2.4.1 Belt conveyor

On inclined conveyors, cement may not be entrained by the motion of the belt and “pools” at the loading zone. With “pooled” material it becomes difficult to maintain a spillage free transfer point. Cement should be fed channeled (special transfer chute) and directed into the direction of conveying of the receiving conveyor. Belt conveyors should be installed at the lowest inclination possible (refer to Holcim Standard Design Criteria).

2.4.2 Bucket elevators

Cement can be difficult to feed into the buckets and spillage may lead to significant accumulations in the bucket elevator boot.

As the cement bulk density can vary, the capacity and power consumption can likewise vary.

2.4.3 Packing and bag handling

Normally, cement bag quality and bag size are tailored to filling requirements.

With the use of grinding aids, cement properties can change, leading to a high amount of air in the cement, which does not allow a proper compaction inside the bag during the filling process. Also cement bag perforation may not be suitable to allow sufficient air to escape during filling. As a consequence, packer filling speed should potentially be reduced in order to achieve a problem-free filling of the bags.

If, however, packer speed is maintained unchanged and bag quality is not adapted to the requirements, bag filling degree may not be reached and/or high pressure inside the bags can make the air escape through the valve or fabric in an uncontrolled manner, leading to spillage or even burst the bags. In addition to that the oval shape of pressurized bags can cause significant problems (blockages on belts or spiral chutes, unsuitable for palletizing) on the downstream bag handling systems.

In theory due to the higher air retention capability larger bags would be necessary to achieve a problem-free filling. In practice it is found that even a standard bag could be oversized as it shrinks and becomes flabby when cement with increased bulk density de-aerates inside the bag. Flabby bags are difficult to handle and problems downstream of the packer are likely to occur. As a potential solution smaller bags could be used to compensate for the increased bulk density. However, that needs to be checked on a case by case basis.

Figure 12: Bagging problems due du higher density of cement ground with additives

2.4.4 Bulk loading

Dust emissions could occur during loading enclosed trucks and railcars if the dust collector connected to the loading spout does not pull enough air to place the spout and vehicle under a negative pressure.

If the amount of air is too low to evacuate dust and air being displaced by the product, the loading speed should potentially be reduced.

2.4.5 Dust Collectors

Using conventional polyester filter media on nuisance dust collectors, filtration occurs as a result of the formation of a primary dust layer on the surface of the filter bags and an accumulation of dust particles within the depth of the filter media.

With a high amount of fine particles present in the dust laden air, the fines can become embedded within the fibers, block air flow and increase Δ p. After cleaning, particles can even bleed through resulting in emissions. In addition to this operating life of bags will be reduced significantly.

If these problems occur, the use of the following alternative filter media should be considered:

- High-density felt fabrics (Polyester) utilize a blend of finer fibers on the filtration surface, which provides a tighter surface. These media prevent particles from penetrating deep in the filter media where it may become trapped.
- PTFE membrane bags solely using the principle of surface filtration are the most effective but also the most costly alternative filter media material. Membrane bags are particularly recommended if a high amount of fines is present but even high-density felt fabrics do not work well.

2.5 Sampling for production control and performance testing

2.5.1 Samples for production control

Routine samples for production control are taken at the normal sampling point and tested according to the normal quality control plan. During the first two hours after switching to another additive/dosage or until reaching the fineness target, samples should be taken every 30 min. For the rest of the trial, the frequency should be one sample per hour for the 6 - 8 hour short term trials. The analyses shall be indicative for the product fineness (R_{45}/R_{32}, d_{50}, d_{10} etc.) and composition (XRF).

Note: For blended cements, residue targets instead of Blaine targets should be defined for mill control as the utilization of additives can also impact the particle size distribution (PSD) of the cement. Monitoring of the Blaine value can give further indication on PSD changes, but is not suitable to compare the quality on a like for like basis. For OPC, Blaine based control can be accepted.

2.5.2 Samples for product performance testing

For mortar and concrete testing, a minimum of 50 kg (better 75 kg to have sufficient back up sample) cement shall be taken for each additive and dosage level under the following conditions:

- earliest three hours after starting of the new additive and/or dosage level
- after the mill has reached a stable level
- after reaching the fineness target

There are two ways to take samples: Take a one spot sample of 50 kg or take a spot sample of 25 - 30 kg each hour, which is combined to a compound sample representing the whole period of stable production. The advantage of the latter method is that the samples are more representative of the whole stable trial period. Furthermore, the samples should be tested ahead of their compounding whether the fineness and compositional control parameters are fulfilled. Otherwise, the respective sample has to be rejected and a new sample can be taken for the physical testing.

Note: With conventional screw samplers, it might not be possible to take sufficient amount of samples and thus another sampling spot needs to be identified.

2.6 Cement testing on average samples

The detailed list of cement quality parameters that have to be tested during the trials is given in **annex 3**.

2.6.1 Chemical and physical cement parameters

The cement samples have to be analyzed for their chemical composition and their fineness parameters. Further analyses, which give indication on the cement composition, are recommended but not mandatory (e.g. insoluble residue, XRD etc.).

2.6.2 Mortar/Paste testing

Mortar/paste testing is carried out according to the locally applicable standards. For cement plants working with constant w/c ratio, it is recommended to check the mortar flow to have an indication for the additive's impact on workability and water demand. At least the following data must be recorded:

- Applicable standard
- Water demand for normal consistency or mortar flow at constant w/c
- Setting time (initial/final)
- Air content (if possible) or mortar liter weight
- Mortar strength

To detect potential air entrainment by the additives, the weight of mortar cubes/prisms shall be recorded before breaking. Lower weight of the prisms indicates air entrainment.

2.6.3 Concrete testing

It is mandatory to test the additives' impact on concrete, in particular when the clinker factor is reduced/changed. Testing shall take place according to the plant standard procedures. Data that must be recorded:

- Concrete composition
- Water cement ratio
- Slump or Flow
- Raw density (if not possible, record density of hard cubes)
- Air content (if possible)
- Compressive strength

2.6.4 Cement flowability

The flowability test of the powder is an indication for the dispersion of the cement particles and their tendency to agglomerate and hence an indicator for its silo blockage tendency but also for dust formation.

Testing can either be carried out according to ASTM C1565 (Pack-Set Test) or with the simplified Holcim test (also known as "Imse Test"). For the test about 100 g of cement is mounted on a set of one or two sieves (500 µm and 212 µm or similar), which are placed on a manual mortar shock table. Ten shocks are applied and the residues or passing material is documented. The percentage of passing material indicates the flowability of the cement.

2.6.5 Bulk density

Cement ground with additives show in general a higher bulk density than cement produced without. The densification can create problems in the further processing and should be monitored during the trials (refer to section 2.4).

The bulk density can simply be measured by filling a 1 liter vessel with a cement sample and weighing it. Standardized bulk density measurement is described in DIN ISO 697 and EN ISO 60. These tests have the advantage that the cement is "compacted" in a somewhat reproducible way.

The tests consist in principle of a funnel with a closed bottom, which is mounted on a vessel with a defined volume. The funnel is filled with the cement, which runs into the lower vessel after opening the bottom. The bulk density is determined by measuring the weight of the filled vessel.

2.7 Documentation of results

The trial documentation should contain all major operational and quality figures like:

- Date of the trials, duration of each trial
- Mill status (results of last mill audit, process data trends, base trial and during trial, data as taken from B-Level audit)
- Cement quality of the last three months (strength level, uniformity) to evaluate the significance of the additive's quality impact
- Log sheets of quality control and production data during the trial
- Complete results of quality tests
- All other relevant observations during the trial (e.g. downstream impacts)

Annex 4 contains an evaluation form, which can be used to consolidate the data and to carry out the cost-benefit calculation for each trial. It is recommended to use this form, in order to have globally comparable set of data.

3. Additive effect and evaluation

3.1 Cement additives and applications

The table below lists typical application of cement additives for the different cement types.

Cement type	Grinding aid	Strength enhancer	Water reduction	Set control	Air entrainer	Water retention
OPC	typical	possible				
OPC white	typical			possible		
Limestone cement	typical	typical				
Masonry cement				possible	possible	typical
Fly ash / pozzolan cement	possible	possible	possible			
Blast furnace slag cement	possible	typical				
Cement for self compacting concrete	possible		typical	possible		typical

Table 1: Typical application of cement additives for different cement types

3.2 Standards and definitions

The utilization of additives is regulated in most cement standards. In case additives are not regulated, it is recommended to refer to one of the big international standards (EN or ASTM) and follow their regulations. Depending on national standards and industrial applications, "chemical cement admixtures" are classified as:

- Cement additives by EN 197-1
- Processing addition by ASTM C 465
- Functional additions by ASTM C 688

The dosage and the limits of chemical compounds added to the cement (e.g. chloride) have to be strictly followed according to these standards. In this documentation, the term "cement additives" is used as well for all types of processing and functional additions.

3.2.1 European Standard EN 197-1

The total quantity of additives shall not exceed 1.0 % by mass of the cement (except for pigments). The quantity of organic additives on a dry basis shall not exceed 0.5 % by mass of the cement. These additives shall not promote corrosion of the reinforcement or impair the properties of cement or concrete or mortar made from this cement. When admixtures for concrete, mortar or grouts conforming to the EN 934 series are used in cement, the standard notation of the admixture shall be declared on bags or delivery documents.

3.2.2 ASTM Standards

The ASTM standards use the term "additions" in place of the European Standard definition "additives". An addition is a material that is inter-ground or blended in limited amounts into a hydraulic cement during manufacturing, either as processing addition to aid in manufacturing and handling the cement or as functional addition to modify the use-properties of the finished product.

Designation	Definition
Functional addition	An addition introduced to modify one or more properties of a hydraulic cement.
Air-entraining addition	A functional addition that will entrain air in mortar or concrete.
Processing addition	An addition introduced to aid in manufacturing or handling, or both, of a hydraulic cement.

Table 2: Classification of cement additives in ASTM

3.2.2.1 *ASTM 465 (processing additions)*

This specification pertains to the criteria and tests to be used for determining whether a processing addition (when used in the recommended amount at the option of the cement producer in the manufacture of hydraulic cements) meets the requirements as prescribed by definition in Specifications C 150, C 1157 and C 595.

3.2.2.2 *ASTM C 226*

Specification for Air-Entraining Additions for use in the manufacturing of Air-Entraining Hydraulic Cement.

3.2.2.3 *ASTM C 150 (“5 Additions” and “12. Manufacturer’s Statement”)*

Clause 5.1.2 Processing additions may be used in the manufacturing of cement, provided such materials in the amounts used have been shown to meet the requirements of Specification C 465.

Clause 5.1.3 Air-entraining Portland cement shall contain an inter-ground addition conforming to the requirements of Specification C 226.

Clause 12.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any air-entraining addition and of any processing addition used, and also, if requested, shall supply test data showing compliance of such air-entraining addition with Specification C 226 and of such processing addition with Specification C 465.

3.3 Chemical ingredients of additives and their effects

The table below gives an overview on the different types of cement additives, their usual dosage and the most common ingredients. In general, quality improvers improve also the grindability. Thus, the ingredients are listed only with respect to their main purpose. It is of course also possible to have multifunctional additives, which combine several different performance influencing ingredients (e.g. combination of water reducer with accelerators).

Type / Class	Usual dosage (kg/t of cement)	Ingredients / chemically active materials
Grinding aids	0.1 – 0.3	Glycols (e.g. diethylene glycol), amine-acetate, triethanolamine
Strength enhancers	– 2.5 0.3 – 0.6	Mineral salts: Chlorides, alkali salts (early strength!) Amines: Triisopropanolamine, (other alkanolamines)
Chromium (VI) reducers	3 – 5 0.5 – 0.8	Fe(II)sulfate Sn(II)sulfate
Water reducers	0.5 - 3	Lignosulfonates, polynaphthalene sulfonates (NFS), polycarboxylates, polyacrylates
Set control	0.2 – 0.5 1 – 2 0.2 - 2	Retarders: Gluconates, sugar derivates, phosphates, phosphonates Accelerators: Alkali salts
Air entrainers	0.5 - 5	Rosin soaps, fatty acids (soaps), synthetic surfactants
Water retention	1 - 2	Cellulose ethers, Welan Gum or other polysaccharides

Table 3: Overview on different types of cement additives and their usual dosage

3.3.1 Glycols and Amines

Basically, all glycols and alkanolamines of low molecular weight are effective grinding aids. Among those amines are more effective grinding aids and would work in all cases.

3.3.1.1 *Glycols*

Diethylene- and dipropylene glycols and mixtures thereof are best suited for clinkers with higher alite content and small crystals, which are easier to grind“, and do not impact cement flowability so much.

Ethylene - or propylene glycol - have quite a low boiling point (high evaporation loss in the mill) and are only suggested at mill temperatures lower than 90 °C and are thus only suited for vertical roller mill grinding.

More economic chemicals, such as technical glycol mixes of di-, tri- or higher oligomers of glycols, are commonly used by producers of cement additives due to lower cost compared to the high-purity chemicals.

3.3.1.2 *Amines*

Triethanolamine (TEA) in mixes with 15 % of water or diethanolamine (technical grade) is the most common and most effective cement additive. Triisopropanolamine (TIPA) has in addition to TEA some better effects on strength development but may induce additional air entrainment that could reduce strength. To get a pumpable liquid at 0 - 20°C, as well TIPA has to be diluted with at least 15 % of water.

Cement additive producers normally mix the alkanolamines with some amounts of acetic acid or acetates (amine acetate).

3.3.1.3 *Other organic additions*

In formulations of cement additives, sugars or sugar derivate like gluconates, oligo saccharides or molasses can be used to improve the strength, or to extend the cement setting time.

Water reducers or plasticizers are specialty products to reduce the mixing water amount in combination with pozzolans or for self-compacting materials.

Surfactants like Vinsol ® resin, tall oil soaps (or others) and water retention additives like cellulose ethers can be used for the production of specialty products like masonry cements.

3.3.2 Salts

3.3.2.1 *Chlorides*

Chlorides are well known accelerators for early strength. Sodium and calcium chloride are often used in composite cements to reduce the clinker factor. In most cases, sodium salts have a better cost-to-performance ratio for early age strength of OPC, and calcium salts are better suited for later age strength enhancement of OPC or early and late strength of low clinker factor cements. The maximum chloride dosage is limited by the local applied cement standards. It has to be mentioned that as well some process dusts may bring some additional chloride concentration in the system. As Holcim standard, the chloride addition should be normally limited to a concentration of max. 0.05 % based on the weight of the produced cement.

3.3.2.2 *Sodium sulfate*

Sodium sulfate (powder) can be added if clinker with a low content of alkali sulfate is used for composite cement production, normally in cases were higher pozzolan or fly ash addition are in focus of the cement production.

3.3.2.3 *Thiocyanates*

Cement additive producers are adding sometimes as well thiocyanates in case chloride-free additives have to be used. But it has to be mentioned that thiocyanates are as well measured as chlorides according to test standards (titrations with $AgNO_3$) used for the control of chlorides in cement production. Thus virtually the chloride content of the cement is increased and the standard limit might be violated.

3.3.2.4 *Nitrates, thiosulfates*

Nitrates, thiosulfates function as accelerators, but are usually not economic in cement production.

3.3.2.5 *Phosphates*

Sodium (poly)phosphates can be used to extend the setting time (e.g. for white cement).

3.3.3 Chromium(VI) reducers

Allergies to wet concrete are normally caused by hexavalent chromium, which can be found in traces in every cement. It stems from the clinker and is formed during sintering due to the oxidation of trivalent chromium from the raw materials. The sensitization normally requires months to years of repeated exposure to occur.

Addition of so called reducing agents destroys Chromium(VI):

$Cr(VI) \longrightarrow Cr(III)$ (= prevention of allergies)

Typical cement additives for Cr(VI) reduction are different types of $Fe(II)SO_4$ (mono-, tetra-, hepta-hydrates. Due to the high stability and therefore long shelf-life Fe-sulfate mono hydrate with up to 30% Fe(II) is most recommended. In some cases $Sn(II)SO_4$ is used but is in general more expensive than the iron sulfates.

3.4 Lab testing of new additives (physical)

3.4.1 OH & S

The instructions of the Material Safety Data Sheets must be followed at all times and appropriate Personal Protective Equipment (PPE) needs to be used for handling the additives on the laboratory scale (in general glasses, gloves). For further details refer also to section 2.1.2 and contact the local OH&S responsible in case of any doubts.

3.4.2 Lab testing of additives

3.4.2.1 *Producing lab cements in a ball mill*

The best way to test a new additive is to carry out grinding trials in a laboratory ball mill, in particular when it is planned to change the cement composition (e.g. lower the clinker factor). In case the plant has no own ball mill, the supplier can be asked to carry out the tests. The results shall be shared with the plant for further evaluation and decision making.

There are two ways to prepare the laboratory cements:

- Grinding to constant fineness: With this approach, the additive effect on product quality can be – more or less – compared on a like for like basis. However, it is more effort to reach the fineness targets in the mill (more than one cycle necessary) and consequently the particle size distribution (PSD) will not be comparable among all samples.
- Grinding with constant time: This approach focusses on the additive effect on grinding capacity. For quality testing, it is accepted that the products have different finesses and the performance as such is different.

The laboratory tests do not allow an *exact* forecast of the additive effect on industrial scale and thus do not replace industrial grinding tests. But they provide a basis to identify the most promising formulations, and help to reduce the large scale workload if a large number or different products have to be assessed or the effectiveness of potential new products needs to be evaluated.

3.4.2.2 *Testing of additives in the mixing water*

In case a laboratory ball mill is not available, the effect of additives can be tested in the mortar mix. For this the additive is added to the mixing water and the normal/standard mixing procedure is applied. To evaluate the additive impact on the rheological behavior, the cements should also be tested with constant flow or the flow shall be determined at constant water cement ratio.

3.4.3 Mandatory physical and chemical tests

It is a Holcim standard that the tests described in ASTM C465 have to be applied to all additives, own formulations and formulations from suppliers, before the technical test in a plant mill can start. The tests have to be made with all cement constituents in a laboratory mill or if no laboratory mill is available, the test can be carried out by adding the cement additives to the mixing water.

Mandatory tests are:

- Normal consistency - Test Method C 187 or local standard
- Time of setting (Vicat) - Test Method C 191 or local standard
- Expansion/soundness - Test Method C 151 or local standard
- Air content and density of mortar - Test Method C 185 or local standard
- Compressive strength of mortar - Test Method C 109 or local standard

Supplementary information:

- Chemical Analysis of cement
- Compound composition
- Fineness of cement (Blaine, sieve residue or/and laser granulometer).
- Drying shrinkage of mortar - Test Method C 596 or local standard

Remarks: The tests are normally carried out at two different concentrations and are compared with a blank (no cement additive addition). In case that no laboratory mill is available, the additives are tested in the mixing water at least once with a two time higher dosage as planned later in industrial production.

3.5 Quality control of additives in routine application/contract specifications

3.5.1 Chemical supplier statement

In case the additives are delivered as ready to use products from a global supplier such as BASF, Grace, Sika or others, the supplier must guarantee that its product fulfills the requirements according to ASTM C465 with a technical data sheet or in any other written form.

The supplier has to provide the safety data sheets for the additives.

3.5.2 IR spectrum

On first delivery, the supplier shall provide an IR spectrum of the additive. This spectrum serves as a fingerprint of the additive. A sample of additive should periodically be sent to an independent laboratory to check whether the composition of the additive has changed. As well, when the plant assumes that the additive lost or changed effectiveness, it is recommended to ask for a new IR spectrum.

3.5.3 Routine testing for delivery control

The routine quality tests shall cover parameters indicative for the amount of active material, corrosion risk and air entrainment potential. For each parameter, a range for at least one of the listed tests should be specified in the contracts.

Parameter	Test
Active material	Density Water content (Karl-Fischer titration), Solid content
Risk of corrosion of pumps and tanks	pH, chloride
Air entrainment potential	Foam test

Table 4: Routine quality control tests for additives

But it has to be stated that none of these analyses or their combination guarantees that the composition of the additives did not change. In case of any doubts, this must be confirmed by more sophisticated analyses (e.g. IR, GC-MS, HPLC, IC, ...) in a central laboratory.

3.5.4 Foam test

Air entrainment causes strength reduction in application and a change in the rheological behavior. The foam test is a very easy, qualitative test, and indicates the potential of an additive for air entrainment: 100 ml of distilled water and 1 ml of additive is filled in a closable flask. Then the mixture is thoroughly shaken. If a stable foam occurs, the additive contains some foam builders (soaps) and should not be used in the grinding process.

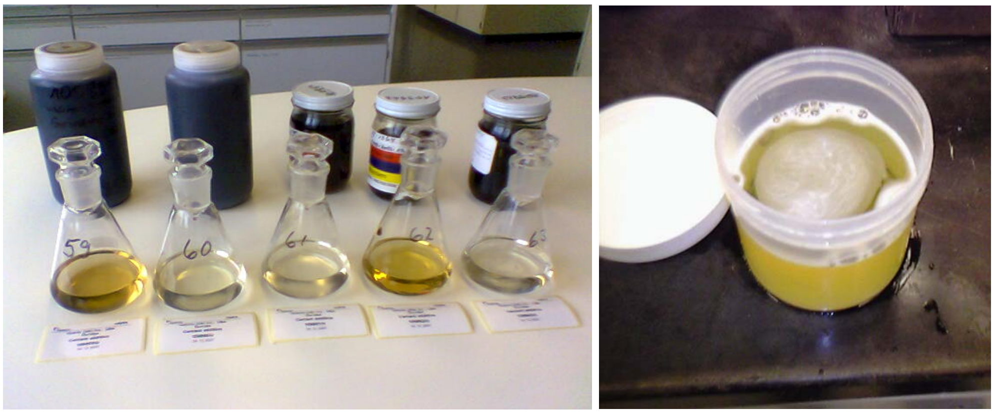

Figure 13: Testing of additives with the foam test. Left: no foam formation, Right: foaming additive

Another way to detect air entrainment is to measure the density/air content of the fresh mortar (see section 3.5.5) or to weigh the mortar cubes/prisms before breaking. If a prism has a very low density, it is likely that air was entrained by any of the mortar ingredients (not necessarily the additive).

3.5.5 Liter weight of mortar

The mortar liter weight gives an indication if the additives are entraining air in the mortar. This test is not suited for routine control, but should be applied in case of any suspicion on air entrainment of the additive. It should also be a standard test during the industrial scale tests of a new additive.

An easy way to identify is a comparative measurement of the liter weight of the mortars. The mortar is simply filled into a vessel with a known volume and the weight is measured. To avoid air void inclusions, the mortar should be filled in in layers and should be tamped.

Another option to calculate the air content is to follow the instructions of ASTM C185.

	ASTM 109 (compr. Str.)				
	[3 d]	[7 d]	[28 d]	Air	Density
Material	[MPa]	[MPa]	[MPa]	[%]	[kg/m3}
Silo 9 11. Juin. 2007	24.3	30.7	34.9	10.1	2186
Silo Retains, Comp.	25.7	31.2	38.6	9.0	2154
Type 1 323 I-2	24.8	32.7	41.6	7.9	2194
Type 1 Mill Composite	24.4	31.3	39.2	9.6	2181
Type 1 Comp. Aug./'07	13.5	19.0	25.2	12.5	2083
Typ 1 (SG) Normo 4	21.9	28.0	32.9	8.5	2162

Figure 14: Air entrainment by additives resulting in lower density of mortar cubes and strength loss

4. Commercial viability of test results

As mentioned in chapter 2, additional profit can be generated through three different sources (or combinations of them):

- Lower variable production cost due to…
  - optimized product composition (e.g. less clinker)
  - lower specific energy cost (higher production rate of tested mill with same volume)
  - usage of less additives
- Higher volumes which can be sold, therefore additional revenue from…
  - cement sales (in under-supplied markets and/or from exports)
  - clinker sales/export
- Higher sales prices if product performance can be increased, and the additional value is being recognized and appreciated by the customers

4.1 Commercial KPI's per mill

The evaluation sheets (**see Annex 4**) return all the relevant commercial information like cost savings per lever (e.g. improved composition) and the possible additional CEM volumes from the increased grinding capacity or the liberated clinker from clinker factor reduction:

Overall evaluation - related to test mill only!

Plant	XYZ	Cement:	MicCEM
Production test mill (t/a)	988'000	Margin (USD/t cem)	31.02

			Trial					
Trial data	Cement type							
	Run - No		Baseline	Add1	Add2	Blank	-	-
	Additive Supplier	Name	-	-	-	-	-	-
	Additive Brand	Name	-	-	-	-	-	-
	Additive dosage	g/t	250	2610	2450	0	0	0
		Unit	Proportion of cement components (dry)					
Cement Composition	-	[%]	72.3	67.8	68.3	72.8	-	-
	-	[%]	23.7	28.2	27.7	23.2	-	-
	-	[%]	4.0	4.0	4.0	4.0	-	-
	-	[%]	-	-	-	-	-	-
	-	[%]	-	-	-	-	-	-
	-	[%]	-	-	-	-	-	-
Overall Evaluation								
Clinker Factor	CF reduction	%		4.5	4.0	-0.5	-	-
	Additional clinker from CF reduction	t/a		44'460	39'520	-4'940	-	-
	Potential cement volume from CF red	t/a		65'575	57'862	-6'786	-	-
	Potential contribution from CF red	USD/a		2'034'446	1'795'158	-210'524	-	-
Variable cement cost	Composition	USD/t	22.47	21.55	21.65	22.57	-	-
	Additive	USD/t	0.25	0.80	0.65	-	-	-
	Spec energy cost	USD/t	2.65	2.50	2.58	2.81	-	-
	Total Specific Cement Costs	USD/t	25.37	24.84	24.88	25.38	-	-
Grinding system	Production rate gain	t/h		9.0	4.0	-9.0	-	-
	Production rate gain	%		6.0	2.7	-6.0	-	-
	Potential cement volume from PR	t/a		59'678	26'523	-59'678	-	-
	Potential contribution fom PR	USD/a		1'851'483	822'881	-1'851'483	-	-
(1) Benefits at today's cement production volume								
	Variable cost savings at const. cement volume	USD/a		523'952	484'701	-12'247	-	-
	(1) Total benefits	**USD/a**		**523'952**	**484'701**	**-12'247**	**-**	**-**
(2) Benefits at increased cement volume (due to CF reduction) without purchasing additional clinker								
Savings at increased volume (volume limitation: CF or PR)	Limitation			grinding cap	grinding cap	grinding cap	-	-
	Maximum possible contribution PR or CF	USD/a		1'851'483	822'881	-1'851'483	-	-
	Saving variable cement cost	USD/a		555'601	497'713	-11'507	-	-
	(2) Total benefits	**USD/a**		**2'407'083**	**1'320'594**	**-1'862'990**	**-**	**-**
(3) If clinker is limitation (line 37) for exploiting full grinding capacity, additional clinker (e.g. purchased) might give a higher total benefit (line 51, compared to 4								
Maxing out cement production with additional clinker (limitation: grinding capacity)	Potential applicable additional clinkervolume to maximal grinding capacity	t/a		-	-	-	-	-
	Corresponding additional cement volume	t/a		-	-	-	-	-
	Price for additional clinker	Currency/t		1'485	1'485			
	New specific variable cement cost	USD/t	25.37	-	-	-	-	-
	Contribution from additional cement volume	USD/a		-	-	-	-	-
	Variable cost savings for additional cement volume	USD/a		-	-	-	-	-
	(3) Total benefits	**USD/a**		**-**	**-**	**-**	**-**	**-**

Figure 15: *Evaluation sheet trial test results (mill specific)*

In case clinker is the limitation for full exploitation of the grinding capacity, the tool allows calculating the benefit in case clinker is imported.

Overall evaluation - related to test mill only!

Plant	XYZ		Cement:	MicCEM
Production test mill (t/a)	988'000		Margin (USD/t cem)	31.02

			Trial					
Trial data	Cement type							
	Run - No		Baseline	Add1	Add2	Blank	-	-
	Additive Supplier	Name	-	-	-	-	-	-
	Additive Brand	Name	-	-	-	-	-	-
	Additive dosage	g/t	250	2610	2450	0	0	0
		Unit	Proportion of cement components (dry)					
Cement Composition	-	[%]	72.3	72.3	72.3	72.3	-	-
	-	[%]	23.7	23.7	23.7	23.7	-	-
	-	[%]	4.0	4.0	4.0	4.0	-	-
	-	[%]	-	-	-	-	-	-
	-	[%]	-	-	-	-	-	-
	-	[%]	-	-	-	-	-	-
Overall Evaluation								
Clinker Factor	CF reduction	%		-	-	-	-	-
	Additional clinker from CF reduction	t/a		-	-	-	-	-
	Potential cement volume from CF red	t/a		-	-	-	-	-
	Potential contribution from CF red	USD/a		-	-	-	-	-
Variable cement cost	Composition	USD/t	22.47	22.47	22.47	22.47	-	-
	Additive	USD/t	0.25	0.80	0.65	-	-	-
	Spec energy cost	USD/t	2.65	2.50	2.58	2.81	-	-
	Total Specific Cement Costs	USD/t	25.37	25.76	25.70	25.28	-	-
Grinding system	Productionrate gain	t/h		9.0	4.0	-9.0	-	-
	Productionrate gain	%		6.0	2.7	-6.0	-	-
	Potential cement volume from PR	t/a		59'678	26'523	-59'678	-	-
	Potential contribution fom PR	USD/a		1'851'483	822'881	-1'851'483	-	-
(1) Benefits at today's cement production volume								
	Variable cost savings at const. cement volume	USD/a		-384'789	-323'070	88'725	-	-
	(1) Total benefits	**USD/a**		**-384'789**	**-323'070**	**88'725**	**-**	**-**
(2) Benefits at increased cement volume (due to CF reduction) without purchasing additional clinker								
Savings at increased volume (volume limitation: CF or PR)	Limitation			clinker	clinker	grinding cap	-	-
	Maximum possible contribution PR or CF	USD/a		-	-	-1'851'483	-	-
	Saving variable cement cost	USD/a		-384'789	-323'070	83'365	-	-
	(2) Total benefits	**USD/a**		**-384'789**	**-323'070**	**-1'768'117**	**-**	**-**
(3) If clinker is limitation (line 37) for exploiting full grinding capacity, additional clinker (e.g. purchased) might give a higher total benefit (line 51, compared to 4								
Maxing out cement production with additional clinker (limitation: grinding capacity)	Potential applicable additional clinker volume to maximal grinding capacity	t/a		43'147	19'176	-	-	-
	Corresponding additional cement volume	t/a		59'678	26'523	-	-	-
	Price for additional clinker	Currency/t		1'485	1'485			
	New specific variable cement cost	USD/t	25.37	25.76	25.70	-	-	-
	Contribution from additional cement volume	USD/a		1'851'483	822'881	-	-	-
	Variable cost savings for additional cement volume	USD/a		-23'242	-8'673	-	-	-
	(3) Total benefits	**USD/a**		**1'443'451**	**491'138**	**-**	**-**	**-**

Figure 16*: Indication of benefit in case additional clinker is purchased to exploit the full grinding capacity*

4.2 Commercial KPI's overall/per plant

While profit increases from cost savings and volume gains have to be calculated per mill, the potential additional profit from higher sales prices has to be assessed per plant/company (price increases do affect the whole market, and are not limited to products coming from a specific mill).

The assumed price premium (see below in the blue field (USD 2/t)) has to be defined outside the tool, e.g. by applying a methodology as described in chapter 1; the impact on total profit can be calculated within the tool though.

In case that several identical mills are installed in one plant, and the optimization of grinding aids and/or performance improvers is being implemented on all of them, the tool allows for an extrapolation of the commercial benefits.

Overall market evaluation - plant extrapolation

Plant	XYZ	Cement:	MicCEM
Production test mill (t/a)	988'000	Margin (USD/t cem)	31.02

Further questions	Is it possible to export clinker?		Yes	Field must contain value!
	What is the average price we get for exported clinker (exw)?	Currency/a	1'800	
	What is the total production of MicCEM at the plant in focus?	[t/a]	3'615'292	

			Trial					
Trial data	Cement type							
	Run - No		Baseline	Add1	Add2	Blank	-	-
	Additive Supplier		-	-	-	-	-	-
	Additive Brand		-	-	-	-	-	-
Overall Evaluation on plant level								
Extrapolation factor	Extrapolation factor (to plant level)		3.66	3.66	3.66	3.66	3.66	3.66
Premium for higher product performance	Cement selling price premium	USD/t		0.50				
	Adjusted cement margin incl. savings in variable costs	USD/t		32.05	-	-	-	-
Clinker export	CF reduction	%		4.50	4.00	-0.50	-	-
	Maximum additional clinker from CF reduction	t/a		162'688	144'612	-18'076	-	-
	Is clinker saved higher than used for production rate gain?			yes	yes	yes	-	-
	Clinker potentially to be exported, not used for production	t/a		14'631	78'323	140'899	-	-
(1) Benefits at today's cement production volume								
	Contribution from additive optimization (line 35 "Final Evaluation")	USD/a		1'917'248	1'773'619	-44'813	-	-
	Potential contribution from change in cement selling price	USD/a		1'807'646	-	-	-	-
	Potential contribution from clinker export	USD/a		913'217	811'749	-101'469	-	-
	(1) Total potential contribution	**USD/a**		**4'638'112**	**2'585'368**	**-146'282**	**-**	**-**
(2) Benefits at increased cement volume (due to CF reduction) without purchasing additional clinker								
	Contribution from additive optimization (line 41 "Final Evaluation")	USD/a		8'808'005	4'832'322	-6'817'056	-	-
	Potential contribution from change in cement selling price	USD/a		1'916'833	-	-	-	-
	Potential contribution from clinker export	USD/a		82'128	439'652	790'910	-	-
	(2) Total potential contribution	**USD/a**		**10'806'966**	**5'271'973**	**-6'026'146**	**-**	**-**
(3) If clinker is limitation for exploiting full grinding capacity, additional clinker (e.g. purchased) might give a higher total benefit								
	Contribution from additive optimization (line 51 "Final Evaluation")	USD/a		-	-	-	-	-
	Potential contribution from change in cement selling price	USD/a		-	-	-	-	-
	(3) Total potential contribution	**USD/a**		**-**	**-**	**-**	**-**	**-**

Figure 17: Market evaluation sheet (plant / market specific)

5. Concluding remarks

This handbook should serve as basis to challenge Holcim's additive suppliers, to achieve higher transparency in the additives used and to be able to interact with the additive suppliers in defining the most cost effective solution.
It is obvious that the highest leverage of additives can be achieved in sold-out markets or grinding plants with high clinker costs. The savings potential in integrated cement plants with low clinker cost in an overcapacity market will in many cases not justify the use of additives. Mill operation issues should be solved by operational measures not by additives.

The main objectives of using additives will be an increase in grinding capacity or a decrease in clinker factor, both allowing the production of higher cement volumes with no considerable CAPEX.

The use of additives should be considered within the product optimization decision tree approach, meaning that other steps of clinker, set regulator MIC and grinding optimization should be done before the use of additives should be considered.

Economic evaluation should be done on a TCO level, including the price or discounts to be realized in the market place. Savings in the range of minimum 1 USD/t usually justify also additional CAPEX required for dosing equipment or other amendments in the plant.

Outlook
The approach described in this handbook is an ongoing process. With each grinding trial, more experience will be gathered and the handbook will be updated accordingly.

We would like to ask the users to report the outcomes of the grinding trials, information on additives as well as feedback and improvement proposals for the manual to Holcim Group Support (contact: elke.schaefer@holcim.com).

The handbook should become a standard tool in product optimization, based on the real market needs, and a transparent benchmarking process.

Like any document, its usefulness lies in the ability and competence of trained, experienced and motivated users to execute, diligently and effectively, the structure and methodology contained in the handbook's pages.

This handbook should therefore be integrated into any OpCo's philosophy of continuous improvement and be used as a reference to ascertain whether any particular plant has potential to maximize its use of additives for increased cost optimization, or better still, increased value creation and value-capture through development of superior application-based products, which our customers need and want.

6. ANNEXES

Annex 1 – Preparation sheets/Target definitions
Annex 2 – Flowability test
Annex 3 – Template for average sample testing
Annex 4 – Evaluation sheets (interactive Excel file)
Annex 5 – ValueCatch case study: Maratha, India

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