Performance Advantages from Grinding Aids Cost Reduction – Optimization

فوائد الأداء التي تقدمها المواد المساعدة للطحن تخفيض التكاليف - وتطوير الأداء نحو الأمثل

By: Mapei Cement Additives Division, Italy

انتشر في السنوات الأخيرة استخدام نوع خاص من مواد الطحن المساعدة الذي يمكن تسميته بمواد الطحن المساعدة للأداء وذلك بالإضافة إلى استخدام المواد المساعدة للطحن التقليدية والتي ينحصر تأثيرها في طاقة الطحن . وتتميز مواد الطحن المساعدة للأداء بتأثيرها الكيميائي على المقاومة الميكانيكية للإسمنت وبأنها عالية التركيز وخالية من الكلوريد . كما أنها ذات جرعة منخفضة (0.01 – 0.03%) . يقدم هذا المقال حلاً تقنياً بشأن تطوير مواد الطحن المساعدة للأداء نحو الأمثل من حيث زيادة طاقة الطحن دون إحداث أي تأثير على الخواص الميكانيكية . وسيستعرض

- المواد المساعدة ذات التركيز العالي: التخفيف بالماء والتأثير على طاقة الطحن وتخفيض تكاليف الإسمنت
- نوعية الإسمنت : تحليل مواصفات الإسمنت المطحون مع تقنية التخفيف

Introduction

In recent years, alongside with the use of the traditional Grinding Aids (whose principal effect is on the mill capacity), the use of a special type of Grinding Aids has spread, which we could name as Performance Grinding Aids, characterised by having a chemical effect on the mechanical strengths of the cement, highly concentrated, chloride free and a low dosage (0,01-0,03%). In this article we would like to propose a technical solution regarding the optimisation of the Performance Grinding Aids in terms of increases in mill capacity, leaving unchanged the effects on the mechanical properties. We will therefore examine the following arguments:

i. Highly concentrated grinding aids: dilution with water and effects on mill capacity and cement cost production.
ii. Cement quality: analysis of the characteristics of the cement ground with the dilution technique.

1.1 Water Dilution Technique For Performance Grinding Aids

We are considering the water dilution of the Performance Grinding Aids at the moment of use, with the aim of achieving an improved dispersion of the active substance of which they are composed and to optimise the contact between the additive and the cement surface. These additives, which due to their high concentration are often used at very low dosages (0,015-0,025%), are not always able to express their full potential, because of the difficulty of the dispersion of the liquid onto the solid material. Industrially it often happens to use very low flow rates of additive, which come in contact only with a part of the material entering into the mill: in these conditions the additive struggles to disperse during the grinding process.

The type of dilution to which we refer is the following:

- dilution made on the spot by using a double head pump
- additive-water ratio between 1:3 to 1:10 or, in order to introduce into the mill a dosage of liquid (additive + water) between 1.000 g/t and 2.000 g/t (0,10% and 0,20% on the weight of the material to be ground)

A typical example is represented by an additive/water mixture of 1.500 g/t composed by 300 g/t additive and 1.200 g/t of water.

1.2 When Is The Dilution Successful And Which Type of Additives To Dilute

In Europe, side by side with newer installations, there still exist a great number of small mills, that often are maintained in service to grind high fineness cements (e.g. CEM I 52,5 R). It is in these installations, characterised by a small hourly capacity, that the dilution of the grinding aid gives the greatest benefits: In fact a very small amount of grinding aid enters into these mills (e.g. 9-15 kg/h for a mill producing 30-50 t/h with a dosage of 300 g/t). In these conditions the amount per minute of the grinding aid varies between 150 and 250 g/min: if, for different reasons, even a small quantity of the additive does not reach the material to be ground, the mill performances decrease quickly.

Based on these considerations we started to perform a large amount of industrial tests using the technique of diluted grinding aids, both on small and big mills and we have formed this opinion: The dilution of G.A. with water is always recommended, but is particularly efficient in the following cases:

- highly concentrated Grinding Aids
- low additive dosage, e.g. lower than 300 g/t (0,03%)
- low mill diameter (< 3,0 m) or with limited production (< 60 t/h)
- mills without cooling water addition in the first chamber
- limestone or high fineness cements
- hot clinker at the mill entrance

1.3 Dilution Effects On The Grinding Performances

The dilution of the Performance Grinding Aids with water may be performed with the intent of reaching two different goals:

a) to reduce the additive dosage while maintaining the same mill capacity (recommended solution) or
b) to further increase the mill capacity while maintaining the same additive dosage

When the additive dosage is relatively high (e.g. >0,3%) we could recommend the dilution in order to reduce the dosage at the same mill output, while when the dosage is already quite low (<0,3%) it is better to aim towards increasing the mill production.

Typical results of the dilution can be as follows:

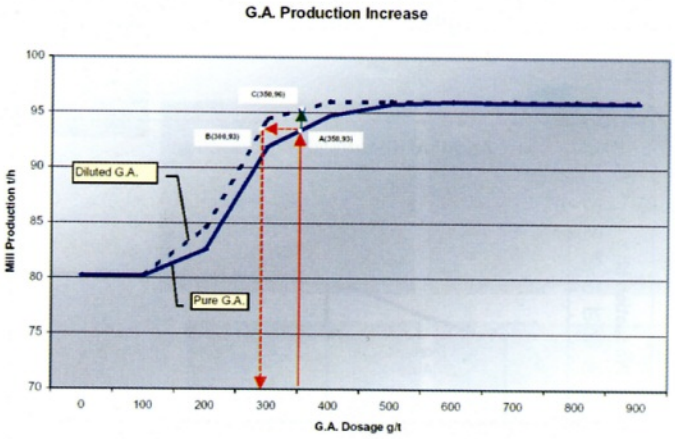
- a reduction of the additive dosage of 10-20% at equivalent mill performance or
- a further increase in production of 2-5% at the same additive dosage.

Example: The following graph, taken from a real industrial case history, clarifies the previous notions. Let's consider a mill producing 80-81 t/h of CEM II/A-LL 42,5 R ground at 3.600 Blaine in a stable operating regime without an additive. With a dosage of 350 g/t of pure G.A and at the same fineness the production obtained is 92-93 t/h as represented by point A(350,93). By increasing the additive dosage the production stabilizes in an asymptotic way on 96-97 t/h.

With the dilution we have the following options:

a) Passing from Point A(350,93) to point B(300,93) through the red line by reducing the G.A. dosage and maintaining the mill production unaltered. In this case we obtain a dosage decrease of 14% at the same level of production. Recommended solution.
b) Passing from A(350,93) to point C(350,96) through the green line with the same G.A. dosage and obtaining a production increase of 2,3%. In this case the percentage increase is less remarkable due to the fact that the mill is already close to its structural limit of 97 t/h (for that type of cement and at that fineness).

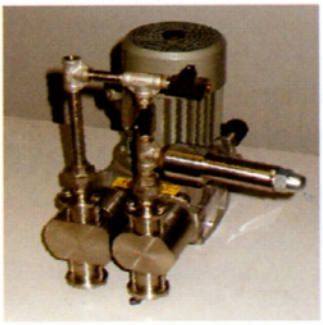
G.A. Production Increase

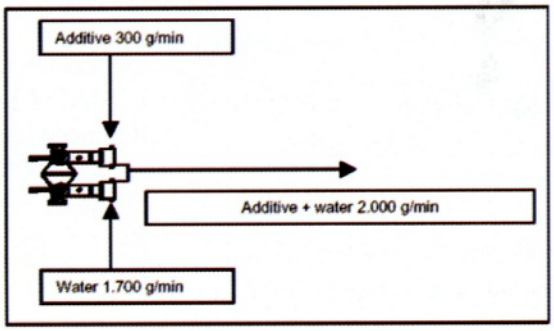


In practice, through water dilution, we obtain a "shift to the left" of the curve additive dosage/mill production t/h. The curve with the pure additive is the blue line, the broken line represents a dilution 1:6 between the G.A. and water.

1.4 Practical Realisation Of The Dilution

The double head pump represents the most suitable system for diluting G.A. on the spot. It is constituted by a single motor and two pumping heads with separate dosage flow rates (see picture). Additive and water join together in a single pipe, where the dilution takes place.



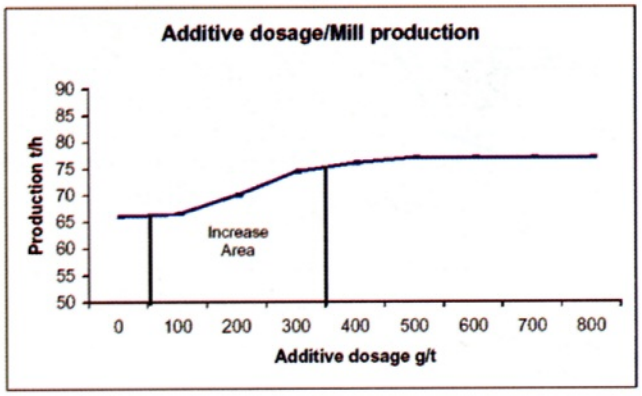


In order to avoid unexpected inconveniences we recommend using low-pressure water: the best solution is to pump water from a small reservoir with a free surface, such as a plastic tank or other recipient, with the aim of maintaining automatically the same water level by means of a float system such as used in sanitary appliances. With high pressure water we risk:

- water passing into the mill even when the pump is off and the mill is at rest
- irregular dosage of the additive and flow rate.

1.5 Industrial Trials

The dilution of G.A. with water is to be considered as a procedure for the optimisation of G.A.performances.



- As a first step it is advisable to use the pure additive in order to obtain reliable results without water. In this first phase, that should last at least 1 week, it will be possible to identify not only the optimum dosage but also the maximum dosage above which it will not be possible to obtain tangible benefits. In practice we could build an additive dosage/mill production t/h curve, like in the following example.
- Once the performances of the pure additive are verified it will be possible to add water follo wing the above-mentioned instructions and decide on whether to decrease the additive dosage or to increase the mill production.

2.1 Cement Quality

As mentioned at the beginning, we applied the additive dilution technique to the Performance Grinding Aids; in other words on products that improve the mechanical properties of the cements. This type of additive is usually employed to improve the quality of cements or to reduce the clinker content in blended cements while maintaining the same quality. Together with the mill production increase, we have considered to be of interest to verify if we could also further improve the mechanical properties of the cement produced using the dilution technique.

With this aim, irrespective of different indications derived from industrial cases, we decided to carry out a series of lab grinding tests (Bond type mill) under the following conditions:

- defined composition: 95% clinker and 5% gypsum (natural gypsum)
- same grinding fineness: 3.100 ±100 Blaine

Using two types of additives (MA.G.A./C150 and MA.G.A./C208) we ground:

- reference cement
- cement with 0,03% pure additive
- cement with 0,03% additive + 0,12% water

The two additives are characterised by the same grinding capability but they have a different chemical effect: the first (C150) is able to increase early strengths; the second (C208) is more suitable for ultimate strengths. The study has been carried out with four different types

of clinker using the following techniques:

- morphological analysis of the ground cement powder with a ESEM-FEG electron microscopy
- morphological analysis of the hydrated paste of cement at different hydration times with a ESEM-FEG electron microscopy
- temperature curves of the cementitious paste during hydration
- mechanical strengths according to the EN 196 standard.

The first two techniques give us a "qualitative" idea of the effect of the additive (pure or diluted), while the last two are able to "quantify" the additive effect.

In order to simplify the presentation of the data we have decided to only illustrate in this paper the results of the below mentioned clinker, which we consider the most representative.

Tab.1 Clinker Chemical Analysis

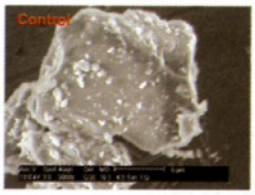
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I.	Free CaO	Total
20,95%	6,32%	2,69%	65,55%	1,45%	0,87%	0,23%	1,10%	0,23%	0,84%	99,16%

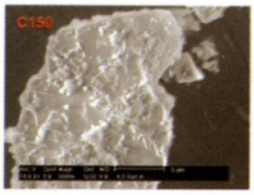
2.2 Morphological Analysis Of The Powder And Cement Paste

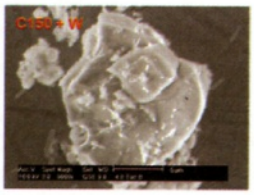
Our intention was to verify if there are differences between the cement powder ground with and without an additive (pure or diluted). Because it was impossible to obtain the identical granulometric distribution with and without an additive, we decided to carry out the experiments at the same Blaine fineness. The following photos show the results obtained (10.000x).
On the surface of the cement particles ground with additives we can observe some traces of a sort of pre-hydration (in particular in the "C150" photo) which would merit further investigation.

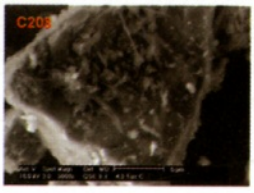
As far as the hydration is concerned, we can observe the different degree of calcium silicates hydration with the additive. From the pictures we can see that until 2 hours the additive has a minor effect on the hydrated products, but from 8 hours on the cement ground with Performance Grinding Aids presents a **much more advanced hydration status** (hydration of calcium silicates, important for early mechanical strengths). In fact in the photos taken at 8 hours, the cement ground with both additives shows a larger development of the silicates needle structure (C-S-H).

Photo 0: cement powder









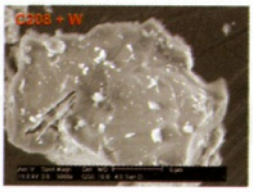
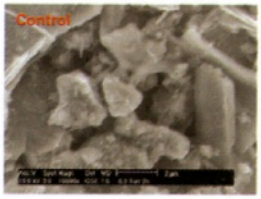
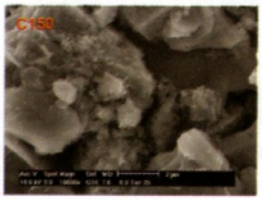
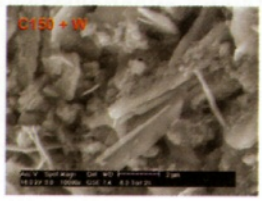
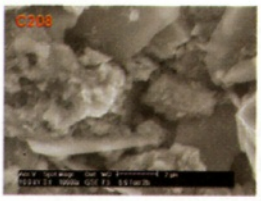


Photo 1: cement paste 2 h









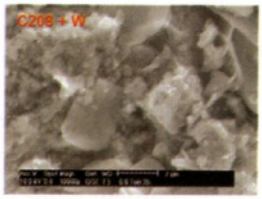
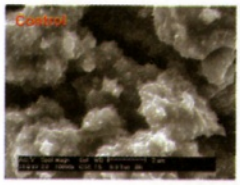
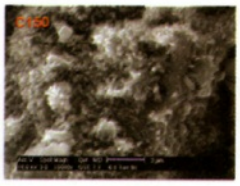
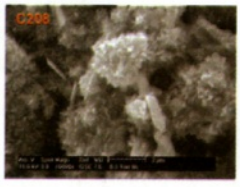


Photo 2: cement paste 8 h

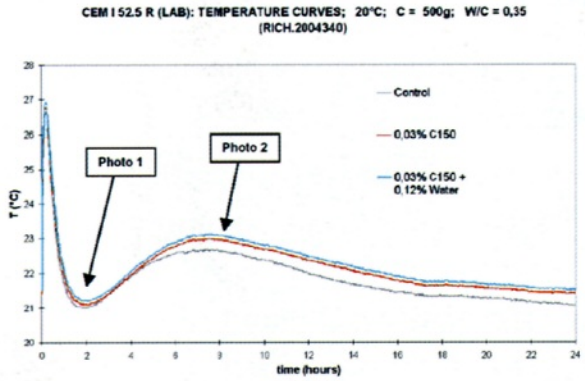


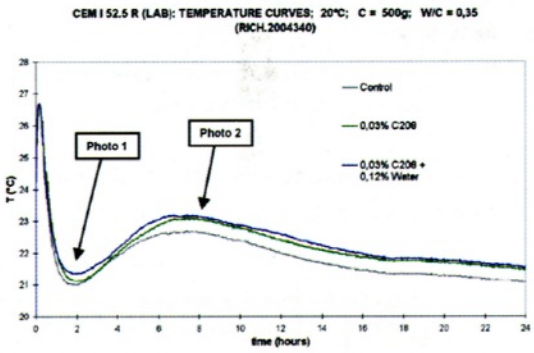




2.3 Temperature Curves

We reported the points on the temperature curves corresponding to the "hydration times" at which we have taken the pictures. The heat of hydration of the cement with additives (integral of temperature curves) is always higher than that of the control cement. The minor difference between the cement ground with pure additive and with diluted additive is probably due to the slight difference in fineness (see tab.2).





2.4 Mechanical Strengths

Mechanical performances with the pure and diluted additive are listed in the table. There is no significant difference in strengths between the cement ground with pure additive and with diluted additive. At the same grinding time samples ground with diluted additive are slightly finer, as expected.
Tab.2 Cement physical data

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	Blaine	Grinding time	Alpine residuals	I. Setting time	F. Setting time	Strengths 1 day	Strengths 2 days	Strengths 28 days
	cm^2/g	min	32 µm	min	min	N/mm^2	N/mm^2	N/mm^2
Ref.	3.160	45	43,3	160	225	14,4	25,7	52,8
C150	3.080	34	41,3	150	210	16,9	27,6	53,4
C150+W	3.150	34	39,7	150	210	17,1	27,4	53,6
C208	3.120	35	41,1	155	220	15,8	27,2	55,6
C208+W	3.190	35	37,4	155	215	16,1	27,3	56,2

Note: Results in terms of strengths reflect the typical values obtained with those types of additives:

- The C150 (pure or diluted) has a positive effect on early strengths. It is normally used on high strength Portland cements (e.g. CEM I 52,5 R) and in any case where an increase in strengths at 1-2 days is required (or to reduce the clinker content in favour of an "active" addition: slag etc.).
- The C208 (pure or diluted) is more suitable for increasing ultimate strengths. It is normally used on Portland cements or to reduce the clinker percentage on blended cements (e.g. limestone cements).

3. Conclusions

a) The Grinding Aids dilution technique may allow increases in production of 2-5% or, alternatively, savings of 10-20% on the additive cost. The results depend on the grinding system available and on the type of cement.
b) The quality of the cement ground with the diluted additive remains unchanged. More sophisticated analysis is under way.
c) Performance Grinding aids allow cement manufacturers to improve the quality of cements or, alternatively, to reduce the clinker content in cement while maintaining the same cement quality.
d) Some other industrial trials are already planned. Contributions from readers are most welcome.....■