CEMENT ADDITIVES
OVERCOMING FLY ASH OBSTACLES

REPRINT OF PAPER PUBLISHED IN PUBLISHED IN INTERNATIONAL CEMENT REVIEW SEPTEMBER 2013

BUILDING TRUST

Overcoming fly ash obstacles

by Jorg M Schrabback, Sika Services AG, Switzerland/Germany

Fly ash cements provide interesting opportunities for the cement industry – particularly in today's operating environment – but can also bring challenges of their own. However, specialised cement additives combined with the necessary application know-how can overcome these obstacles.

Fly ash blended cement – the use of additives to overcome obstacles

The global trends of reducing CO_2 emissions as well as improving profitability have prompted the optimisation of the cement production process. According to the World Business Council for Sustainable Development's (WBCSD) Cement Sustainability Initiative (CSI) 'Getting the Numbers Right' database[1], the clinker factor in cement production dropped from 0.83 in 2000 to 0.76 in 2010. In parallel, fly ash has increased its share of all applied mineral components from 10 per cent in 2000 to 19 per cent in 2010. These trends of reducing the clinker factor and increasing fly ash usage are expected to continue over the coming years due to a number of advantages.

Advantages of fly ash

Derived from the waste of coal-fired power plants, the CO_2 footprint of fly ash is negligible in comparison to clinker. Moreover, because coal is still one of the major sources of power, the availability of fly ash is set to continue for the foreseeable future.

Besides its pozzolanic properties, one of the biggest advantages of fly ash is its fineness, which usually allows it to be fed directly to the separator feed. The major part of the fly ash particles will be carried directly to the finished product, leading to a higher overall production rate of existing grinding installations.

Limitations

The general limitations of fly ash usage in blended cements are set by standards. EN 197-1 allows the addition of pure fly ash of up to 20 per cent (CEM II/A) while for CEM II/B a maximum of 35 per cent is permitted. Blended cement using other supplementary cementitious materials (SCMs) are allowed a total content of up to 55 per cent (ie, Type CEM IV/B pozzolanic cement). ASTM C595 allows up to 40 per cent of fly ash (Type IP Portland-pozzolana cement).

However, the quality and performance of fly ash can vary considerably depending on the source. Chemical constituents, particle size distribution and carbon content, measured by the loss of ignition (LOI) can fluctuate substantially. Therefore, the potential adverse effects on cement and concrete performance such as strength loss, inconsistent workability and carbon staining of concrete surfaces, are the tougher limitations.

Table 1: production and quality data for CEM IV/B 32.5 N with 41 per cent fly ash content in relation to the use of cement additive

	Blank grinding	*SikaGrind-820*
Grinding aid (g/t)	0	400
Production rate (tph)	22	28 **(+27 per cent)**
Specific energy absorption (kWh/t)	38.6	30.4
Rejects (tph)	47	38
Specific surface acc. to Blaine (cm^2/g)	4120	3860
Sieve residue 32μm (per cent)	9.7	9.9

Production rate

Fly ash cements do not have special requirements with regards to grinding efficiency. However, to ensure low specific energy consumption, the use of grinding aids is recommended. Typically, production increases in the range of 5-15 per cent with traditional technologies and 8-20 per cent with the latest technology.

Table 1 shows a case study of a CEM

Figure 1: strength development of CEM IV/B 32.5 N with 41 per cent fly ash content in relation to the applied cement additive

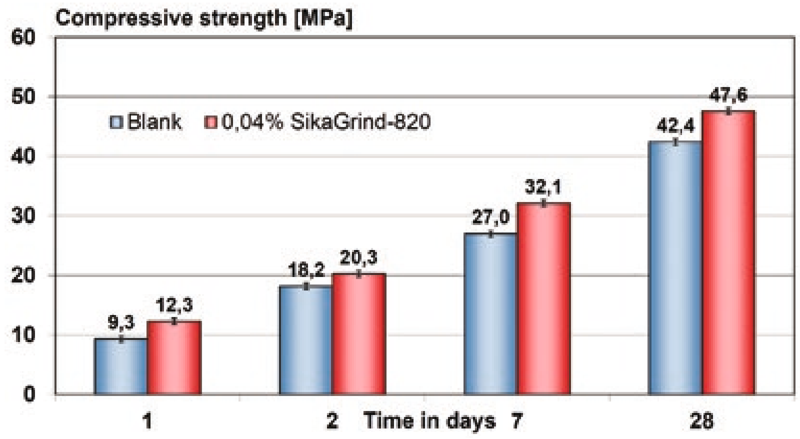
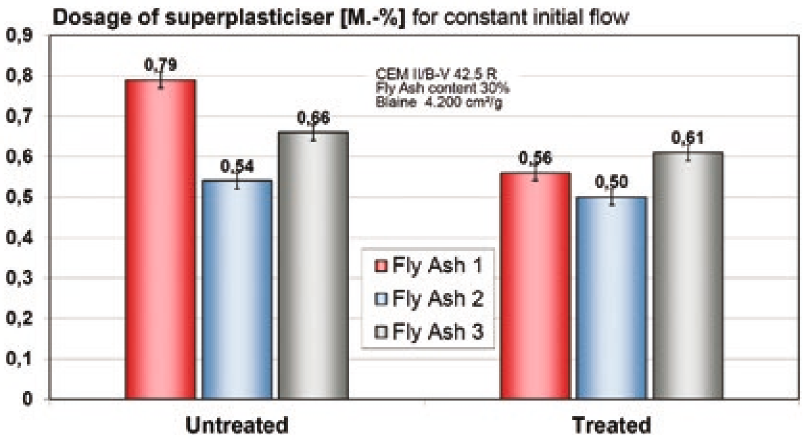


Figure 2: robustness regarding demand for superplasticiser tested at standard mortar made with treated/untreated CEM II/B-V 42.5R



IV/B-V 32.5 N, ground in a ball mill with fly ash added to the separator feed. This application demonstrates that compared to 'blank grinding' (ie, without cement additives) the addition of a grinding aid can lead to an increase in production higher than the standard range – even as much as 27 per cent.

The lower specific surface (Blaine value) at constant sieve residue indicates a reduced amount of overground particles – a typical result when changing from blank grinding to the use of a grinding aid. This is because of the stronger cement powder dispersion which reduces agglomerations of fine particles and their return to the mill. Consequently, an optimised particle size distribution (PSD) and a positive effect on strength development can be expected.

Strength

The required strength enhancement is related to the expected strength loss caused by the desired increase of fly ash content in the cement. The modern cement additives concept[2] offers both chemical and physical approaches to achieving higher strength.

Chemical activation of up to 5MPa at an early age and up to 7MPa at final strength is achievable. The share of chemically-activated early and final strength improvement in the cement additive formulation can be adjusted to the situation. Therefore, the chemical reaction of specific local materials on the hydration activation needs to be determined.

Physical strength enhancement with finer PSD can easily add a further 2MPa at the early and 3MPa at the late strength. In the presented case study, a 3MPa increase in strength at one day and 5MPa at 28 days was achieved despite a lower specific surface (see Figure 1). It resulted partly from the improved PSD with a larger share of particles in the decisive grain size between 3-32µm[3]. In addition, this alkanol amine-based cement additive supported the strength gain with chemical activation.

Workability

Frequently, various sources of fly ash have to be used at a cement plant to cover the required amount. Different fly ash qualities affect production parameters and even stronger cement performance, especially with regard to rheology. While changes in strength development can be compensated by an adjusted safety margin, initial flow and slump life of fresh concrete remains a challenge.

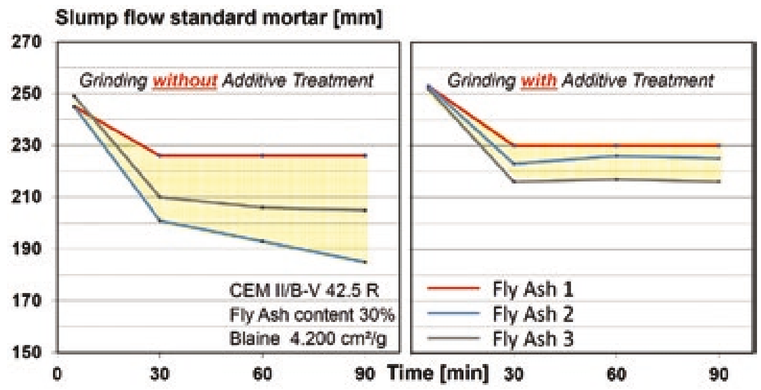
The concrete industry needs fly ash cements with high robustness. Constant dosages of the concrete admixtures like superplasticisers should be ensured independently of the processed fly ash.

Figure 2 shows the amount of superplasticiser to achieve a constant initial flow of three mortars made with CEM II/B-V 42.5 R based on the same clinker, but with different fly ash sources. While the untreated cement needs a superplasticiser dosage in the range of approximately 0.5-0.8 per cent, the variation can be reduced to about 0.5-0.6 per cent in the case of the treated fly ash cement.

Obstacles associated with fly ash in blended cement can be minimised by using various cement additive technologies, making it possible to:

- **achieve the lowest specific energy consumption with modern grinding aid technologies**
- **reach the highest clinker replacements due to physical and chemical strength enhancement**
- **ensure robust concrete workability resulting from performance balancing additives**
- **minimise the potential for carbon bleeding.**

Figure 3: robustness regarding workability (slump flow development) of standard mortar made with treated/untreated CEM II/B-V 42.5 R



Even more impressive is the effect on slump life over 90 minutes (Figure 3). The untreated blends show large variations in workability after 90 minutes. In contrast, the treated fly ash cements achieve almost constant flow spread values until 90 minutes after mixing. The SikaGrind FA-58 fly ash cement additive balances this variation and increases the robustness of the cement with regard to workability. When adding to the grinding process, it also positively affects the grinding as well as strength development.

Carbon bleeding

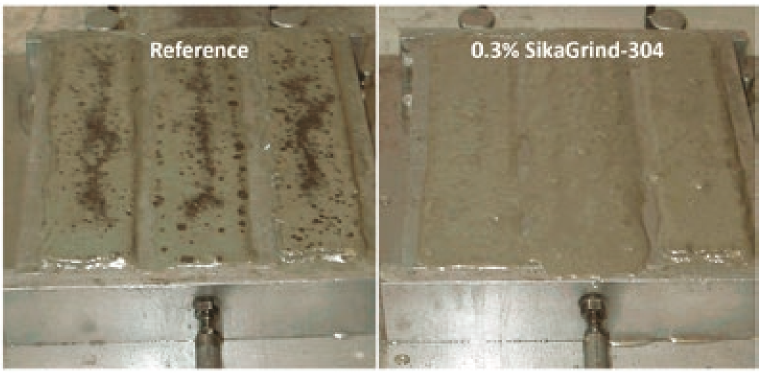
The effect of carbon black particles floating to the surface of fresh concrete is known as 'carbon bleeding'. This is caused by incomplete burned organic substances remaining in the fly ash. The effect can occur even if the LOI of the fly ash is below the standard limitation. Particularly fine fractions of fly ash usually contain higher amounts of carbon black, leading to a higher LOI.

The intensity of carbon bleeding is mainly related to carbon black content, viscosity, bubbling effect, bleeding and compaction time of concrete. It is a pure aesthetic issue and hence leads to claims primarily in application as fair-faced concrete, where appearance is of the highest importance. The potential for carbon bleeding can be determined in lab tests by compacting a standard mortar mix without striking of the excess mortar. A visual inspection allows the evaluation of how strong carbon particles float up.

As can be seen in Figure 4 (CEM II/B-V with 24 per cent fly ash), a strong carbon bleeding effect occurred in the untreated mix. In contrast, the use of 0.3 per cent of the SikaGrind-304 cement additive created the desired homogeneous surface.

The suppressing effect is based on improved dispersion, trapping carbon particles inside the cement matrix. The required dosage is related to the intensity of the potential for carbon bleeding.

Figure 4: carbon bleeding of standard mortar without SikaGrind (left) and carbon bleeding suppressing technology with SikaGrind (right)



Conclusion and outlook

The technologies described in this article treat the cement during the grinding process and can be handled by the cement producer. One option to overcome obstacles with fly ash cement is to improve the fly ash quality itself. Fly ash is collected in the filter systems of coal-fired power plants. Depending on the quality and local limitations, it may be used as a clinker replacement or disposed in landfill. If a higher quality is desired, the fly ash has to be treated in a separate stage, which results in additional handling and transportation measures and costs.

Last year, Sika acquired an equity stake in Ash Improvement Technology Inc (AIT), a company whose proprietary technology treats coal ash while it is formed within the power plant. Special chemicals are injected into the process to generate high-quality SCM while maintaining – or even improving – the yield of energy.

The resulting fly ash with enhanced reactivity, improved PSD, less carbon and constant quality can be added in much higher amounts to fly ash-blended cement, enabling cement producers to produce high-value cement more economically.

The remaining challenge of lower early strength, which is a consequence of the delayed hydration of fly ash, can be compensated by Sika's early strength-enhancing technologies. At present, the first plant applications are in the commissioning and test phase with results set to be published in due course.

Local conditions and demands vary, which make individual solutions necessary. Working together as partners with a single vision – from preparation and execution of plant trials to evaluation and implementation – enables Sika to help customers improve profitability and meet the required technical targets.

References

1 CSI (2011) 'Getting the Numbers Right', www.wbcsdcement.org

2 SCHRABBACK, JM (2011) 'Modern Additive Concepts' in *International Cement Review,* October, p83-85.

3 TSIVILIS, S, TSIMAS, S, BENETATOU, A AND HANIOTAKIS, E (1990) 'Study on the contribution of the fineness on cement strength' in *Zement-Kalk-Gips*, January, p26-2.