

# Improving Control and Quality

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David Rapson and Peter Storer, FCT ACTech, Australia, discuss the integration of COSMA, an on-line mineral analyser, with existing control systems for fully automatic clinker and cement quality control.

## Introduction

It is well known that the performance of the cement plant, as well as the final cement product quality, is governed largely by the mineralogy of materials and not just by the chemical or elemental composition. Burnability of raw feed, grindability of raw materials and clinker, strength development and cement setting times are examples of important cement plant parameters controlled by mineralogy in addition to the chemical composition.

Maintaining consistent mineralogy has always been the objective of cement plant staff, typically by using regular laboratory tests. With advances in computer and analysis technology it is now possible to measure many of the process streams around a plant in real-time in detail and at a frequency previously not possible. Laboratory testing may have

provided a result every few hours; now it is possible to obtain a result every minute, opening the door to fully automatic control of many mineral streams.

This article discusses how on-line XRD analysis using the FCT COSMA can be used to control clinker phases, free lime, gypsum, limestone and, ultimately, raw material composition.

## Continuous X-ray diffraction analysis

The FCT ACTech COSMA using X-ray diffraction was developed specifically for on-line control at cement plants. Three major cement groups now have units installed in several plants around the world. It provides the plant control system, plant operators, chemists and engineers with a powerful process control tool. By sampling continuously from the process, the unit is able to provide a true representation of what is happening to the process in real-time, allowing timely process control action to be taken and on-line trending of data.



Figure 1. The FCT ACTech COSMA clinker and cement XRD analyser, with operator access. The unit is fully automatic for installation in the plant at the sampling point.

The ground sample passed through COSMA is about 70 kg of powder per day, continuously returned to the process by pneumatic transport. This volume of sample is of benefit because the X-rays used in X-ray diffraction instruments only penetrate the surface of the powder by a few microns, yet it is important to examine as many crystals as possible.

By contrast, laboratory instruments analyse only a very small amount of the material in a typical sample pellet. In addition, the sample preparation requirements for a laboratory-based X-ray diffraction sample can be quite stringent, due to the conflicting requirement to finely divide the sample into as many crystals as possible for a representative analysis, while at the same time maintaining the integrity of individual minerals.

In other words the sample must be ground very finely, yet not to the extent that changes are induced in the sample. This fineness ensures that the diffraction pattern is not dominated by the larger crystals in the sample. In conflict with this is the need to avoid over-grinding, which can, for example, cause physical changes of gypsum to hemihydrate. (Reference 1 provides a more detailed discussion of this issue.)

COSMA does not have stringent grinding requirements, rather it analyses significantly more crystals because of the fresh stream of material that is continuously passing under the X-rays, so a fully representative sample is easily obtained. Any larger crystals in the sample are presented to the beam only for a second or so, and thus do not have the opportunity to distort or bias the diffraction pattern. The unit analyses several thousand times more material than a laboratory unit, so the material can be presented as ground by the mill for a cement analysis and as 50% passing 45 microns for a clinker analysis.

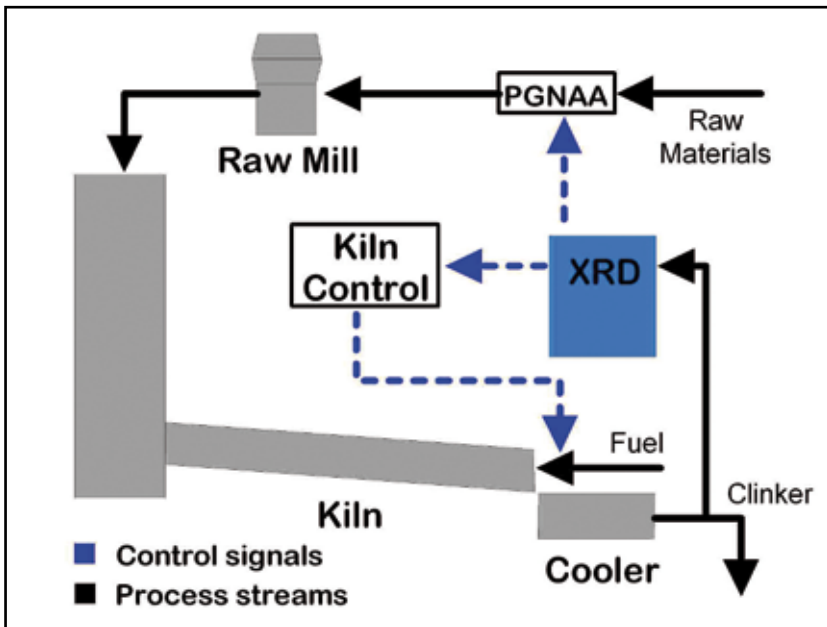


Figure 2. This XRD analyser simultaneously measures clinker free lime and the full clinker mineralogy, along with calculated chemistry, allowing feedback of set points to the raw material analyser and kiln control system.

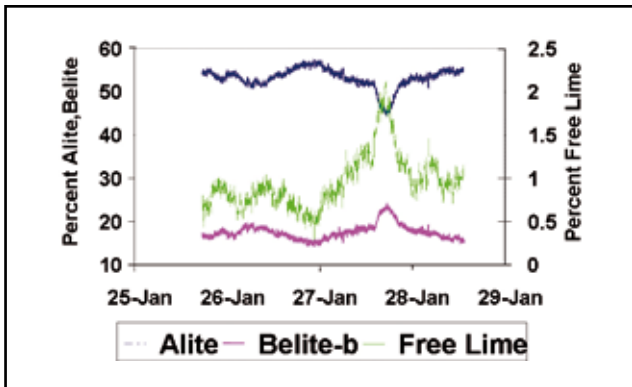


Figure 3. Free lime, generated by a cold kiln, showing the data trends from the unit.

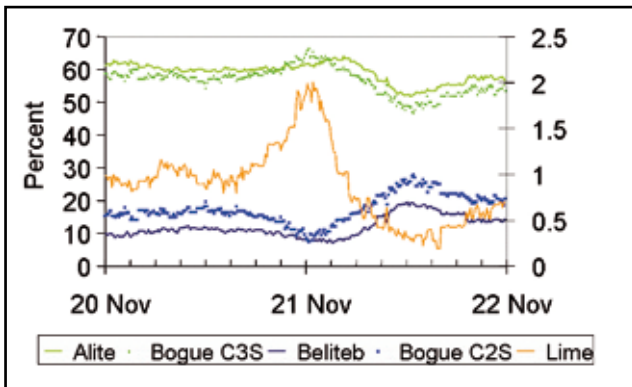


Figure 4. COSMA trends of clinker composition showing how excess free lime may arise due to incorrect chemistry.

The unit automatically updates the analysis of the process stream every minute. With frequent analysis comes trending of results and provides the ability to control processes 'on-line', using the data read from COSMA over the plant control network. In addition, historical data can be easily viewed and correlated with other process data, such as temperatures, water flows or fuel rates. There is no longer any need to wonder if a particular sample truly represents the last few hours of production, and no need to fill in the gaps.

## Clinker quality control

Over recent years, cross belt analysers have become very popular for controlling the proportioning of raw material. They help reduce clinker variation; however their set points need frequent adjustment to allow for changes in the process, such as happen when using alternate fuel quantities, chemistry changes generated when the raw mill is down and feed mineralogy changes.

By using a COSMA XRD analyser to continuously monitor the clinker minerals, (eg.  $C_3S$ ,  $C_2S$ ,  $C_4AF$  and  $C_3A$ ) it is possible to apply feedback control to adjust the raw material set points in real-time. This closes the loop on clinker chemistry and makes it fully automatic control.

In addition, the unit measures free lime in real-time. This result can be transmitted to the plant's automatic kiln control system (Fuzzy, Lucie, Linkman or similar) to accurately control burning zone conditions. By knowing the chemistry of the clinker with the free lime it is possible to make an assessment about the burning conditions, and also to compensate for changes in the raw materials.

Free lime has historically been used to control the kiln simply because of the relative ease of determining a free lime analysis, typically by wet analysis, or perhaps XRD. Also historically the clinker chemistry is examined and Bogue calculations are made to determine the potential mineral composition of the clinker. Since the late 1970s, chemistry has been monitored using X-ray fluorescence, while before that wet chemistry was used.

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In practice the wet free lime test and XRF chemistry can only be used as an indicator of what might be happening in the kiln, where the aim is to produce a specific mineralogy. With recent advances in the analysis of clinker minerals using XRD and sophisticated Rietveld analysis, it is now possible to automatically measure the composition directly<sup>2, 3</sup> and therefore more sensible process control is possible.

In monitoring a kiln, for example, it is possible to detect high free lime for a number of different reasons. In one case the raw materials may be incompletely combined by processing in a kiln that is too cold, which leads to high free lime. On the other hand even a kiln that is too hot can produce high free lime if the combination of raw materials and fuel residue has a lime saturation factor that is high.

At the Ash Grove plant in Utah, USA, the unit is installed on the cement mill, but the production process operates with minimal storage between the kiln and the cement mill. This allows the operators to use the COSMA information to control the kiln, as well as the cement mill.

Using COSMA the complete mineralogy of the clinker is monitored, so it is possible to make intelligent decisions about the appropriate control action in the event of a free lime excursion. Figure 3 shows trends of free lime, alite and belite content, which are key components that determine kiln operation. In this example there was a free lime excursion, which can be attrib-

uted to a cool kiln, as the alite reduced and belite increased. If free lime had increased without a corresponding decrease in alite, then the excursion would have been due to a raw mix proportioning variation. Using full mineralogical analysis, the unit can easily distinguish between excess free lime due to under burning, or excess LSF in the materials being burned.

In Figure 4 a quite different situation is shown. In this case the clinker mineralogy from COSMA is trended in addition to a Bogue calculation of the mineralogy based on the clinker chemistry. At the time of the free lime excursion on 21 November the clinker mineralogy clearly shows that the alite is high and belite is low, so in this case the kiln is hot enough to burn the raw materials, but the raw material chemistry is calcium-saturated and further increases in temperature would not result in a reduction of free lime.

### Cement quality control

Gypsum is added to cement to control the setting times. Other materials that can be added to cement include limestone. Many countries allow additions up to 5% limestone, often subject to loss on ignition (LOI) constraints. Limestone is a calcium bearing mineral, and that calcium cannot be distinguished from calcium in cement clinker using XRF analysis, so the indirect measure of LOI is used to monitor limestone addition. An XRD analyser can measure the limestone, or more precisely the calcite, content directly allowing much more accurate control and the ability to run close to the limits without exceeding them.

By using a XRD analyser in a cement milling circuit, any variations in the quality of the limestone or gypsum are automatically compensated for as calcite and gypsum states are measured directly. For example, if the silica content of the limestone increases, the feeder can be speeded up, providing the LOI limits are not exceeded. The circuit for limestone and gypsum control is shown in Figure 5. Limestone and SO<sub>3</sub> control has been implemented at Ash Grove Cement's Leamington plant with great success.

In addition to simple SO<sub>3</sub> control, COSMA offers mineralogical information about the gypsum states, which can be in the form of gypsum CaSO<sub>4</sub>·2H<sub>2</sub>O, hemihydrate CaSO<sub>4</sub>·½H<sub>2</sub>O and anhydrite CaSO<sub>4</sub>. With all gypsum states being measured directly, water sprays can be adjusted to maintain levels without increasing LOI or producing too much hemihydrate. The control of water sprays is typically carried out based on the mill exit temperature, but in Figure 6 variation in hemihydrate due to feeding the mill with hot clinker can be seen. Since hemihydrate levels have a strong influence on mortar setting times, mill control using COSMA offers the opportunity to produce a better quality product.

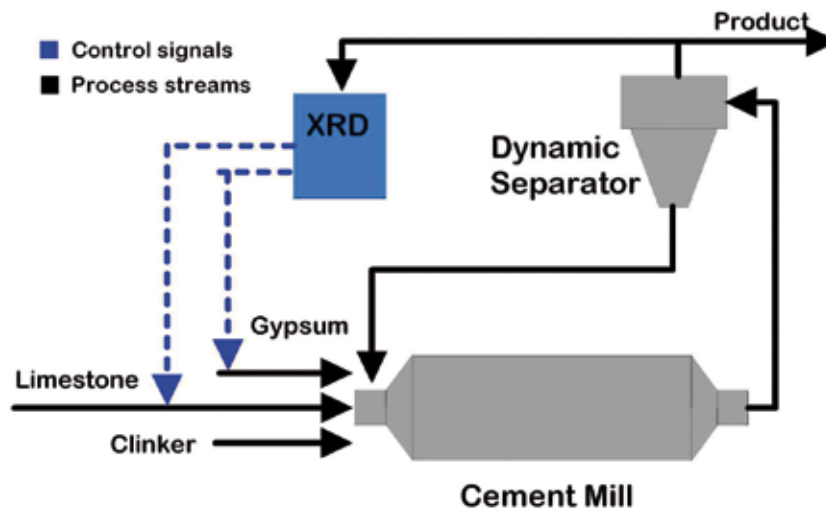


Figure 5. Automatic control of gypsum and limestone addition using this XRD analyser.

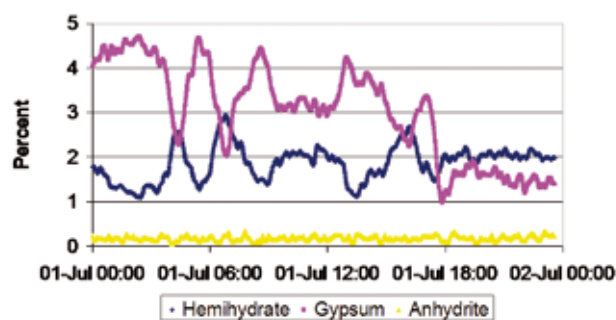


Figure 6. This graph shows the trends displayed by the analyser where the temperature of clinker entering the kiln has varied, producing spikes of hemihydrate.

### Avoiding "off-spec" product

Continuous monitoring of a product stream provides the opportunity to check the entire stream, unlike grab sampling where only a small sample is taken at regular intervals. Although the unit is a process tool that is not designed to certify product, it can be used very effectively in conjunction with other test methods to ensure the product remains within specification. It will detect small changes in composition and pickup contamination immediately.

Often product changes are made, silo stocks are low and the opportunity to blend variable product away is reduced or just not available. Blockages in a feeder during wet weather, power failures, product changeover and materials incorrectly binned all mean product variability is increased. Quality is critical, especially when supplying to a new client, overseas customer or where the specifications are tight. Continuous on-line testing ensures compliance with the specifications.

By using an on-line XRD analyser it is possible to detect "off-spec" product and stop it reaching customers. Operators can be notified by alarms in the control room, or automated action can be taken. Once the product is back in specification, dispatch can continue.

### Conclusion

On-line XRD mineral analysis is a valuable tool to optimise the control of clinker and cement quality. COSMA has been successfully integrated with existing plant

instrumentation and control systems to improve product quality and reduce production costs.

Continuous monitoring of not just the free lime, but the entire mineralogy of the clinker stream clearly opens up the possibility of more complete kiln control, bringing increased production and more uniform clinker that is easier to grind. The potential cost benefits of this type of control are substantial. In addition, the production staff will have the opportunity to attend to tasks other than the routine, and often inaccurate, monitoring of clinker samples. The kiln operator will no longer be calling for the latest free lime analysis, since that information will be trended and fed directly into kiln control.

At the cement mill COSMA units are being used to assure quality and control SO<sub>3</sub> and limestone additions, along with gypsum hydration states. Once again the valuable skills of production staff are no longer required for routine monitoring, so that they can concentrate on maintaining production and quality. \_\_\_◆

## References

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2. MANIAS, C, RETALLACK D, and MADSEN I, 'XRD for On-line Analysis and Control', *World Cement*, February 2000.
3. SCARLETT, N, MADSEN I, MANIAS C and RETALLACK D, 'Powder Diffraction', 16, pp 71-80, June 2001.