WORLD CEMENT

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For more than 50 years, CEMAT has served the global cement industry as a proven, flexible and innovative process control system. Its open architecture provides a future-proof and economical solution for cement plants of all sizes.

Ensuring Quality Through Advanced Analytics

Alejandro Espejel, alcemy, discusses the critical role of quality control in cement production and the impact of advanced analytics.

Quality control in cement production is a fundamental aspect that ensures the integrity, performance, and durability of the final product. The multifaceted nature of cement production, which involves various raw materials and processes, necessitates rigorous quality control measures. These measures not only guarantee the consistency and reliability of the cement but also address environmental concerns, particularly the reduction of CO_2 emissions.

In recent years, the advent of predictive and prescriptive analytics has revolutionised the cement industry. These advanced analytical

tools enable manufacturers to optimise quality, refine cement recipes, and significantly reduce their carbon footprint. This article delves into the importance of quality control in cement production and explains how predictive and prescriptive analytics can play a transformative role in achieving these objectives. The insights presented in this article are based on the experience and results achieved by alcemy GmbH.

The importance of quality control in cement production

Cement production is a complex process that requires careful monitoring and control at every stage, from the selection of raw materials to the final packaging of the product. This article focuses on the critical production stage of cement grinding and blending, where key components of cement, such as clinker, limestone, clay, and/or other supplementary cementitious materials (SCMs) must meet specific chemical and physical criteria, mixed to specific proportions and ground to an optimal fineness to ensure the desired properties of the final product.

Ensuring consistency and reliability

Quality control in cement production is primarily expressed and measured as compressive strength at different key ages of curation. Variations in the chemical composition of raw materials or deviations in the production process can lead to significant differences in the properties of the cement, affecting its strength, setting time, and durability. Rigorous quality control tests such as: Blaine/fineness/particle size distribution, mineralogy, chemistry, and compressive strength determination at different ages (normally between 1 – 28 days) help to identify and correct these variations, ensuring that the cement meets the required standards and specifications. The primary challenges faced by cement producers include making sense/correlating all the available information, but more importantly, having to wait typically 28 days to fully determine if their production was quality compliant or not.

Measuring and securing performance

Figure 1 shows a box plot with a typical distribution of compressive strength of cement mortar samples for different ages over one year. This example is based for cement type IL with minimum strength required of 42.5 MPA at 28 days. The box plot helps to illustrate several key points:

- Even when 'nothing changes' – in terms of cement recipes, quality targets for raw materials or the final product, process conditions, and target parameters – there is always a 'natural fluctuation' over time in quality result. This is primarily due to varying material characteristics of the clinker and other materials being added.
- There is a natural evolution of compressive strength over time, and early strength can be a great indicator of late strengths. However, a strength outlier at early stages does not necessarily result in an outlier at late stages, and vice-versa. Many chemical and physical parameters influence the strength development profile.
- To ensure compliance with minimum compressive strength requirements – whether set by standards or market demands – cement producers must set targets above the minimum threshold. This necessitates the introduction of a safety factor into recipes and fineness targets. As a result, the ability to reduce the clinker factor may be limited, potentially increasing electrical energy consumption (by grinding finer than actually needed) and/or restricting production output – thereby impacting sales and revenue.

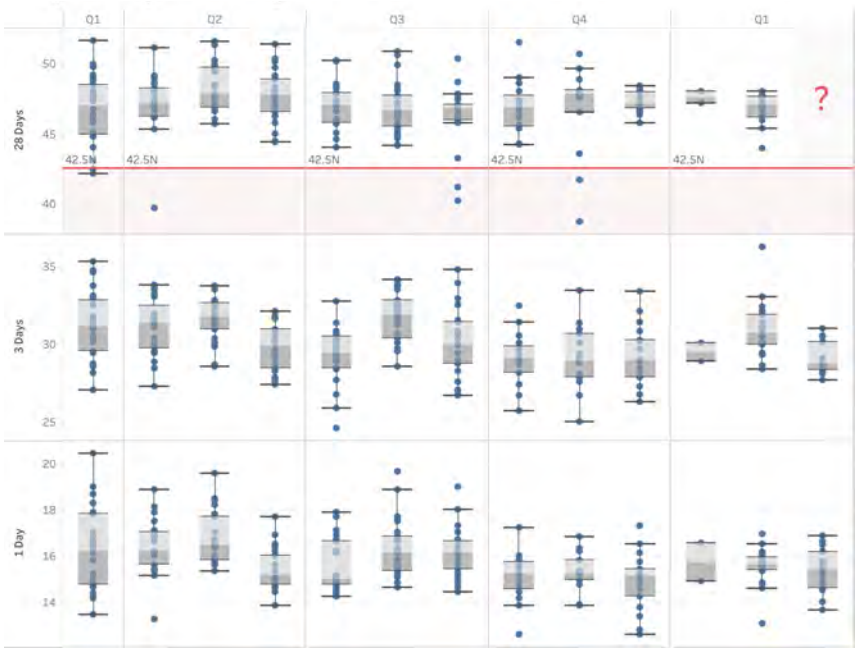

Figure 1. Typical compressive strength variation in cement production.

Addressing environmental concerns and meeting sustainability targets

Cement production is known to be a significant contributor to global CO_2 emissions, with approximately two-thirds of these emissions due to the conversion of limestone (calcium carbonate) into lime (calcium oxide) and the subsequent release of CO_2 during clinker production. Although reducing clinker content in cement recipes is one of the most effective levers for decarbonisation and cost reduction, producers often struggle to make significant reductions. Clinker is the primary component responsible for the strength of cement, and alternative materials are typically harder to manage and increasingly scarce. This is where alcemy comes in.

The role of predictive analytics in cement production

Predictive analytics involves the use of available data and machine learning techniques to identify patterns and predict future outcomes. In the context of cement production, predictive analytics can be used to anticipate potential issues, optimise the production process, and improve overall quality.

Figure 2 illustrates the 'data value chain' and the four types of analytics and the answers that each type can provide. Descriptive and diagnostic analytics are typically available to cement producers via the fineness, chemistry, and mineralogy tests that they regularly conduct during operation. However, machine learning solutions like alcemy's are providing customers with more powerful and insightful predictive and prescriptive analytics. These tools allow customers to adjust and optimise their cement production, quality targets, and recipes without having to wait several days as most normally do today.

How it works

'alcemy for Cement' is a software as a service (SaaS) that uses machine learning algorithms on top of existing laboratory data to predict the cement strength in real time. Users access the software via a web browser application from where they can then navigate into three main views. The analytical view provides a complete picture of predicted and actual cement strength trends while enabling deep dives into data or cement-related issues for detailed insights. It delivers critical insights into prediction and steering performance and offers powerful tools to manage samples and enhance data quality for more reliable decision-making.

The 'control room' view allows users to monitor cement production in real time with fineness recommendations and a clear overview of all critical setpoints and actions. Customers will instantly know whether they need to grind finer

or coarser, with setpoints automatically smoothed for seamless implementation and optimised performance.

Lastly, the 'Recipe Optimizer' module allows users to make simulations and analyse different ingredient compositions and strength targets, and obtain what would be the resulting fineness requirements, energy costs, and predicted strengths to simulate ideal recipe adjustments, enabling data-driven decisions for a more efficient and sustainable cement production.

Prediction accuracy

alcemy's software is running in over 30 cement plants in over 12 countries, helping optimise the quality of all common cement types under various operational and process conditions. In some cases, alcemy's customers have a fully-equipped laboratory (which can be summarised as PSD, XRF, XRD devices for production quality control), while others miss one of these critical instruments or do not use it for regular quality control. Under optimal conditions of device availability and data quality, alcemy's algorithms can predict compressive strength in real time with a prediction error as low as 1 MPA (defined as the variation between alcemy's software predictions and the results of the physical tests performed at the different control ages).

Benefits of advanced analytics in cement production

'alcemy for Cement's' prescriptive analytics can help manufacturers optimise quality, refine cement recipes, and reduce their carbon footprint.

Figure 2. Types of analytics and related insights.

Figure 3. alcemy's web app.

Optimising quality

Prescriptive analytics can help manufacturers optimise the quality of the cement by recommending specific actions based on predictive models and real-time data. For example, alcemy's software delivers compressive strength predictions after each new sample is analysed, allowing the plant team to deliver consistent high-quality cement without over-designing the product.

Refining cement recipes

This reduction in the 'typical' safety margins for strength variance is what enables acceleration of clinker substitution and/or increased use of alternative fuels (AF) – made possible by the enhanced predictive capability that 'alcemy for Cement' provides to absorb increased variability.

Reducing environmental footprint

Advanced analytics support CO_2 reduction goals by recommending specific actions to optimise the production process, reduce clinker factor, and/or increase the use of AFs. Over time, this also enables the development and market introduction of new low-carbon cement formulations. In addition, the software recommends optimal setpoints for fineness, which can help reduce electrical energy consumption – further lowering the environmental footprint of cement production.

Conclusion

Quality control is a critical aspect of cement production, ensuring the consistency, reliability, performance, and durability of the final product. The advent of predictive and prescriptive analytics is transforming the cement industry by optimising quality, refining cement recipes, and reducing the CO_2 footprint of production – as demonstrated by alcemy in over 30 cement plants worldwide.

By leveraging the power of data and advanced analytics, manufacturers can develop a proactive and data-driven approach to quality control, addressing potential issues before they become critical problems, optimising the production process, and developing new and improved cement formulations. This transformation will not only enhance the quality and performance of the cement but also contribute to the sustainability of the industry and help cement producers achieve carbon neutrality much sooner than they would without this technology. ■