::: Application Report

Heavy Duty Made Easy: Particle Size Analysis for the Cement Industry

Keywords: cement, laser diffraction, particle size, Particle Size Analyzer

1 Introduction

Cement as a binding material plays a prominent role in construction since antiquity, and hasn't lost its importance until today. It is made by baking a mixture of limestone ($CaCO_3$), clay (mainly SiO_2 and Al_2O_3) and minority constituents such as iron oxide, at 1450 °C (~ 2700 °F). The resulting product is a rock-like substance called clinker, which then gets mixed and grinded with small amounts of gypsum ($CaSO_4$) to form the fine powder we know as cement.

Grinding is a very energy-consuming process, and properly managing its parameters is an important economic issue. Narrowing the particle size distribution (PSD) will typically help to save energy and costs. However, different raw components of cement have different grindabilities, and the particle size distribution is usually broader for softer materials. Paradoxically, the addition of softer components (with broader PSD) leads to a narrowing of the PSD for the harder components, and vice versa [1]. Thus, as grinding is critically influenced by the particle size distribution of the components, its analysis is performed at almost every step of the process (Fig. 1).

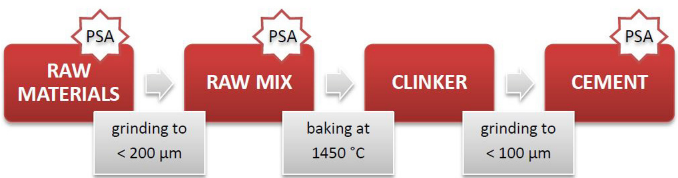

Fig. 1 Cement production steps with steps including particle size analysis (PSA).

In addition to the economic aspects of cement production, particle size also has a major influence on the properties of the final product. Together with the clinker's chemical composition and its specific surface area, the PSD is a major factor affecting the hydration curve of cement as well as the strength of the hardened paste [2]. Specifically, reduction in average particle size leads to decreased setting time and enhanced early strength. In contrast, the importance of coarser particles grows with aging of the cement [2][3]. The width of the PSD also determines the cement's water demand [1]. In brief, it is possible to change the cement properties by modifying the particle size and its distribution.

Measuring the PSD in cement can be difficult due to the fact that the particles have a very broad size distribution (from less than a micron to over 100 µm), and that they exhibit very irregular shapes. Additionally, they tend to agglomerate in dry state, and proper dispersion is crucial. In this application report, we demonstrate the accuracy of the dry cement particle size analysis with Anton Paar's Particle Size Analyzer, which exploits our patented Dry Jet Dispersion (DJD) technology. The results were then compared to measurements performed using the same instrument in liquid mode, on a non-aqueous cement suspension.

2 Experimental Setup

The size range of our cement sample was expected to be between 1 and 100 µm. The measurements were performed with a PSA 1090 L/D Particle Size Analyzer. For data analysis we used Mie mathematical model and set the sample refractive indices to 1.680 – 0.100i [4]. For the dry mode measurements we set the vibration frequency to 50 Hz, the duty cycle to 50 % and the pressure to 500 mbar. For liquid measurements ethanol was chosen as carrier liquid, and we used the alcohol regenerator accessory to limit alcohol consumption. No additional dispersant was necessary, but a 60 s ultrasound cycle was applied to the liquid dispersion before the measurement.

3 Results and Discussion

We observed an excellent correlation between results returned by the liquid and dry modes (see Table 1, Fig. 2 and Fig. 3). This indicates that the Dry Jet Dispersion technology enables accurate measurement of cement particles in dry mode.

Table 1: Comparison of the results for particle size distribution of cement obtained by liquid and dry measurement

	Liquid mode	Dry mode
D_{10}	2.97 µm	1.85 µm
D_{50}	15.33 µm	16.20 µm
D_{90}	42.79 µm	49.40 µm

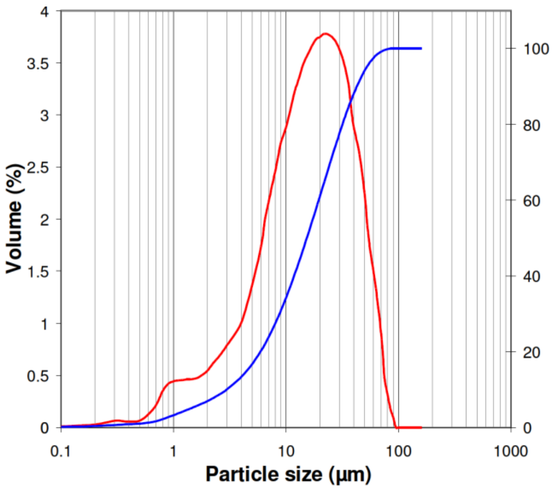

Fig. 2 Particle size distribution of cement as measured in liquid mode (ethanol dispersion). Red curve: density distribution (left y-axis); blue curve: cumulative values (right y-axis).

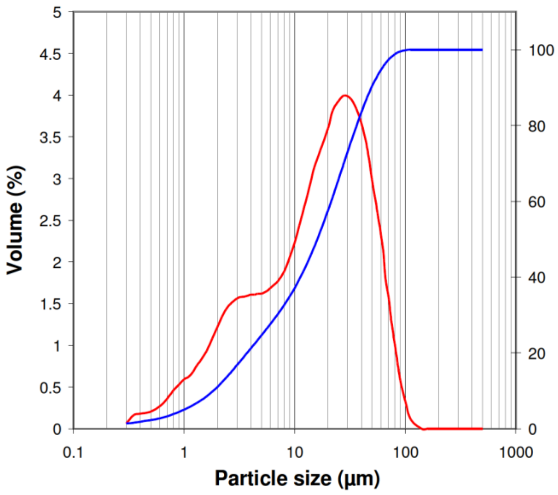

Fig. 3 Particle size distribution of cement as measured in dry mode. Red curve: density distribution (left y-axis); blue curve: cumulative values (right y-axis).

4 Conclusion

An excellent correlation between liquid and dry modes is obtained thanks to the innovative calibration method of the two dispersion modes. In spite of the cohesive properties of cement powder, the DJD technology efficiently disperses cement particles at low pressure (less than 1 bar), which prevents possible particle erosion. Altogether, the PSA 1090 proved to be an excellent system for combining liquid and dry measurements, and an outstanding choice for cement particle analysis.

5 References

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Adapted from CILAS Application Note n°17

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