CEMENT
PARTICLE ANALYSIS WITH LASER DIFFRACTION

CONTEXT

Cement is a **fine-grained binder** whose **reactivity** and **hydration** behavior depend heavily on the **particle size**. A precise analysis of the **grain size distribution** is therefore crucial for assessing the **quality** and **performance** of the cement.

Measuring principle with the SYNC system

MICROTRAC's SYNC system combines **laser diffraction with dynamic image analysis** and enables fast and high-resolution measurement in the range of a **few nanometers to several hundred micrometers**. Since cement reacts with water, **dry measurement** is preferred instead of using, for example, 2-propanol as a carrier liquid. The sample is sucked through the device and swirled by compressed air so that the **particles are separated** from each other and analyzed individually.

In a cement plant, the particle size distribution of the cement powder produced is regularly analyzed by **laser diffraction**. This method enables fast and high-resolution measurement in the range of a few nanometers to several hundred micrometers. The scattering patterns generated by the particles are recorded by detectors and converted into a **size distribution**.
A typical goal is to achieve a **high proportion of particles in the range of 3–30 µm**, as this size class is particularly reactive and has a significant influence on the **strength development** of the product in the first few days. Particles that are too coarse (>60 µm) can reduce early strength, while fine particles increase water requirements and make processing more difficult.

The results of the laser diffraction analysis are presented in the form of distribution curves and characteristic values such as **d10, d50, and d90**. These indicate which particle size falls below 10%, 50% or 90% of the volume. A narrow area around d50 with a narrow width between d10 and d90 indicates a **uniform grind** and is a quality feature.

The analysis is not only used for final inspection, but also for **process optimization** in grinding technology. By specifically adjusting the grinding parameters, the grain size distribution can be influenced and energy efficiency improved. In addition, the analysis allows differences between different cement types (e.g., CEM I vs. CEM III) to be objectively represented.
Here is a clear table showing the differences between **CEM I** and **CEM III** cement types according to EN 197-1.

Figure 1*: MICROTRAC SYNC laser diffraction analyzer (right). The sample is placed on the groove of the sample holder, which moves under an aspiration tube, through which the material enters the dispersion system of the device (right).*

METHOD

Feature	CEM I (Portland cement)	CEM III (blast furnace cement)
Clinker content	≥ 95%	35–64 % (CEM III/A), up to 94 % blast furnace slag (CEM III/C)
Main ingredients	Portland cement clinker	Clinker + granulated blast furnace slag
Strength development	Fast, high early strength	Slow, high final strength
Heat generation	High	Small
Sulphate resistance	Normal	Very good
CO_2 footprint	High (due to high clinker content)	Low (by replacing clinker)
Use	Building construction, prefabricated elements, cold conditions	Concrete construction, hydraulic engineering, tunnel construction, and sustainable construction
Reactivity	High, due to fine particles	Controllable via grinding fineness

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Measurement Example 1: Cement Standard NIST 114r

To validate the measurement accuracy, the **certified cement standard NIST 114r** was measured three times with the **SYNC** system. The results were within the specified tolerances and **confirm the reproducibility and precision of the dry measurement**. The standard specifies the volume-related cumulative particle size percentage for 15 size values between 1 µm and 128 µm.

Measurement settings for cement:
- Sample quantity: approx. 1 g
- Pressure settings 300 kPa (Dispersion), 100 kPa (Suction)
- Measurement time: 20 seconds

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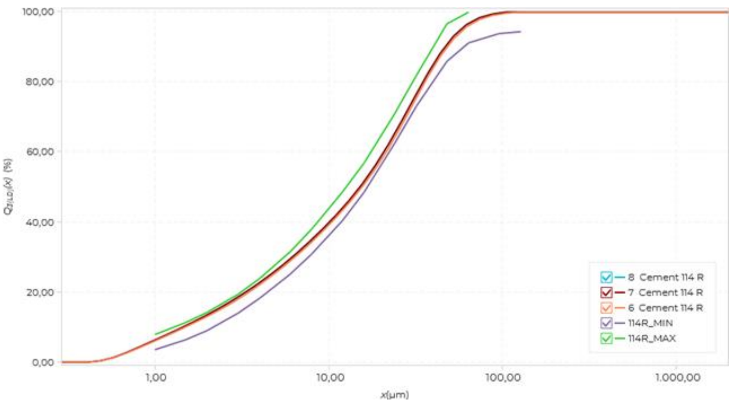

***Figure 2**: Three repeat measurements of the NIST 114r cement standard with the SYNC. Green and purple reference curves indicate the specification of the standard.*

The following table summarizes the measured values of the three repeat measurements. The percentiles d10, d50, and d90 are shown, as well as the cumulative percent passing values for the relevant particle sizes. The maximum and minimum tolerances of the standard are listed in the two right-hand columns. **Each individual measured value is within specifications**.

Percentile	**Measurement 1**	**Measurement 2**	**Measurement 3**		
10 %	1.48 µm	1.44 µm	1.49 µm		
50 %	15.2 µm	15.12 µm	15.55 µm		
90 %	46,63 µm	46,56 µm	47,94 µm		
Size in percent (volume)				**Tolerance MIN**	**Tolerance MAX**
1 µm	6.15 % ✓	6.38 % ✓	6.11 % ✓	3,59 %	7,92 %
1,5 µm	10.13 % ✓	10.44 % ✓	10.09 % ✓	6,41 %	11,32 %
2 µm	13.36 % ✓	13.57 % ✓	13.08 % ✓	9,06 %	14,26 %
3 µm	18.53 % ✓	18.61 % ✓	17.94 % ✓	13,97 %	19,36 %
4 µm	22.66 % ✓	22.75 % ✓	22.08 % ✓	18,25 %	23,88 %
6 µm	29.37 % ✓	29.53 % ✓	28.85 % ✓	25,12 %	31,54 %
8 µm	34.89 % ✓	35.09 % ✓	34.37 % ✓	30,94 %	38,04 %
12 µm	43.8 % ✓	44.01 % ✓	43.33 % ✓	40,42	48,6 %
16 µm	51.5 % ✓	51.64 % ✓	50.79 % ✓	48,55 %	56,9 %
24 µm	65.29 % ✓	65.28 % ✓	64.06 % ✓	62,52 %	70,97 %
32 µm	76.62 % ✓	76.6 % ✓	75.51 % ✓	73,11 %	81,89 %
48 µm	90.84 % ✓	90.89 % ✓	90.04 % ✓	85,94 %	96,66 %
64 µm	96.81 % ✓	96.85 % ✓	96.2 % ✓	91,23 %	100 %
96 µm	99.8 % ✓	99.8 % ✓	99.42 % ✓	93,88 %	100 %
128 µm	100% ✓	100% ✓	100% ✓	94,42 %	100 %

Measurement Example 2: Analysis of feed, reject, and fines with TROMP curve

Three cement samples were analyzed to evaluate the separation efficiency: Feed (input material), Reject (coarse material), and Fines (product). The particle size distributions were acquired using the SYNC system and used to create a TROMP curve, which makes particle analysis great again.
The **TROMP curve** is an important tool for evaluating the selectivity of screening processes, especially when classifying particles in mills, production sieves, or air classifiers – i.e., wherever particles are separated by size or density. Good selectivity is crucial for product quality, as particles that are too coarse reduce reactivity and particles that are too fine increase energy consumption or water demand.
The curve graphically shows how effectively particles are separated into two fractions: the **fine fraction** (product) and the **coarse fraction** (reject). It shows the proportion that enters the fine fraction for each particle size.

- X-axis: particle size (usually in µm)
- Y-axis: Separation probability (0–100%)

An **ideal TROMP curve** would be a perpendicular line at the separation cut size (e.g., 45 µm): all smaller particles go 100% into the fine fraction, all larger ones to 0%. In reality, the curve is **S-shaped**:

- Small particles (< separating cut) mainly reach the fine fraction.
- Large particles (> separating cuts) mainly enter the coarse fraction.
- In the transition range (cut size), the separation probability is between 0 and 100%.

Important parameters

- Cut Size (x_{50}): The particle size at which 50% enters the fine fraction.
- Sharpness Index: Measure of the steepness of the curve – the steeper, the better the separation.
- Bypass: Proportion of particles that are incorrectly classified despite their size (e.g., fine particles in the coarse material).

The following graphs show the size distribution of two cement samples (feed) that were separated into coarse material (reject) and fines (fines) in a classifier, as well as the corresponding TROMP evaluation.

Figure 3*: Right graph: Measurement of 3 cement samples: starting material (feed, orange), fines (brown), and coarse material (Reject, light blue. Right side: TROMP evaluation of the three measurements shown. Sharpness = 2.11; Separator Bypass: 21.8 %.*

A second cement sample exhibits better separation; the corresponding TROMP curve has a steeper slope. Note the differences in Sharpness and Bypass.

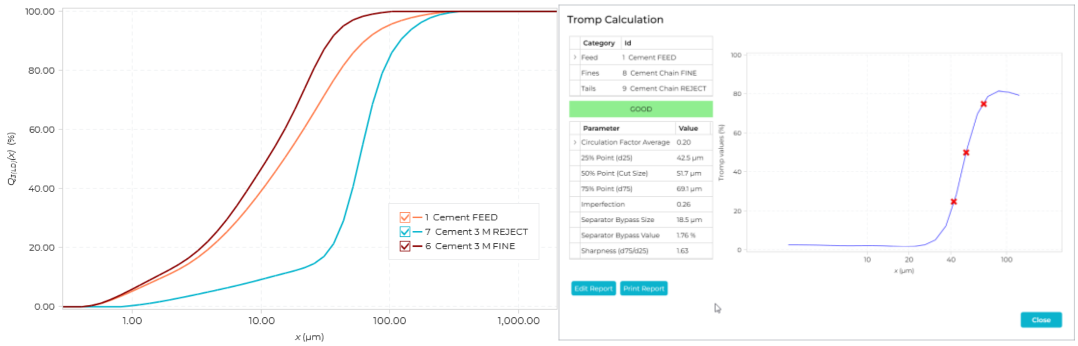

Figure 4: *Measurement of 3 cement samples showing better separation compared to the previous example: starting material (feed, orange), fines (brown), and coarse material (Reject, light blue. TROMP evaluation (left) of the three measurements shown. Sharpness = 1.61; Separator Bypass = 3.17 %.*

SUMMARY

MICROTRAC's SYNC system allows cement to be analyzed **quickly, accurately, and reproducibly**. Dry measurement provides a **simple and efficient** way to determine particle size distribution without resorting to liquid media. The results are **reliable** – this can be seen, among other things, in the measurement of the certified cement standard NIST 114r, which was recorded within the specified specifications and with very good repeatability.

The **SYNC** system is suitable for the analysis of a wide range of cement types, including **CEM I and CEM III**. In addition, the **TROMP evaluation** enables a detailed evaluation of the selectivity of classifiers, as they are common in cement production. Measurements of the feed, reject, and fine fractions can be used to identify optimization potential in grinding technology and objectively assess the efficiency of air classifiers.

➔ **SYNC Particle Size & Shape Analyzer**