Surface treatment offers the opportunity to alter the flow properties of a powder in order to optimise process performance. However, a method of quantifying the influence of the treatment is required, to ensure that flow properties have been optimised without compromising other aspects of performance.

Cement is widely used in the construction industry. It is typically stored in large hoppers before being dispensed and conveyed into equipment for filling bags, IBCs or other containers. The ability to control the flow properties of a cement, without significantly changing the particle size, helps ensure consistent delivery to subsequent operations in the process chain, delivering commercial benefits in terms of higher productivity and reduced waste.

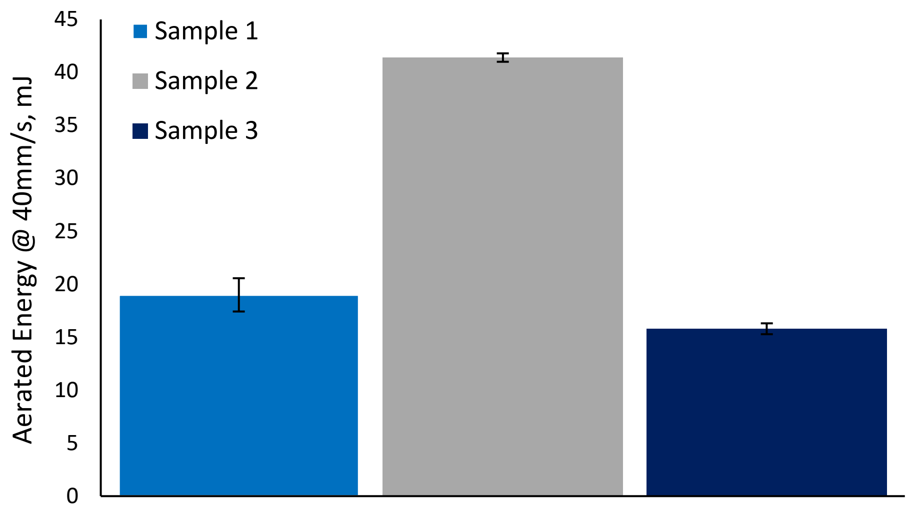
PERFORMANCE VARIATION BETWEEN BATCHES

Three batches of Ordinary Portland Cement performed differently during hopper discharge and subsequent aerated conveyance. Sample 1 (D_{50} 17 µm) performed well across both processes, but the finer Sample 2 (D_{50} 5 µm) performed very poorly. Sample 3 was the same as Sample 2, but had undergone surface treatment to improve flowability, and performed similarly to Sample 1 in the process

The three samples were analysed using an FT4 Powder Rheometer®, to identify which properties had been affected by the surface treatment.

TEST RESULTS

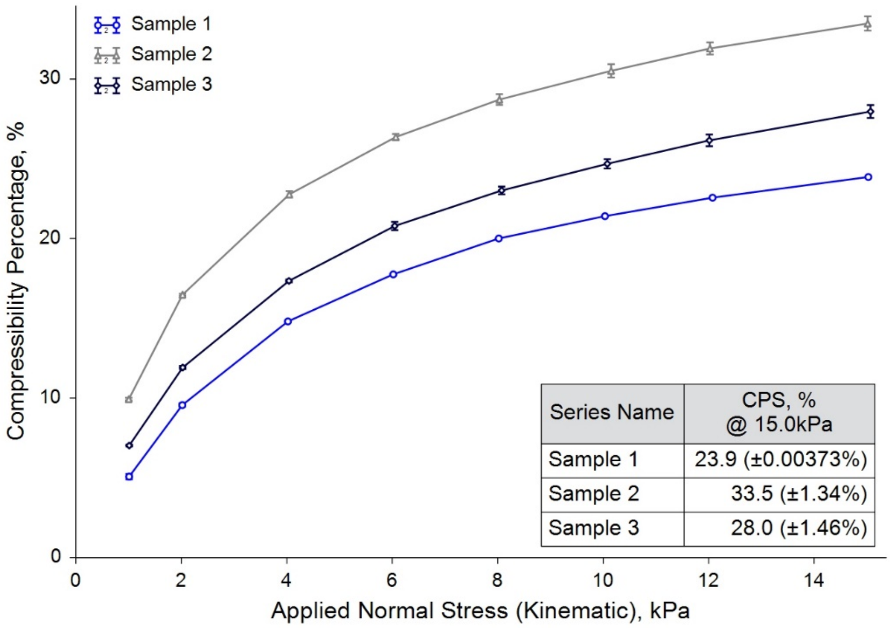
Dynamic Flow Testing: Aeration



Sample 2 generated a considerably higher Aerated Energy (AE) than Sample 1, indicating greater cohesive strength between the particles. High AE can contribute to poor flowability in situations where uniform aeration of the powder is necessary, such as the aerated conveyor.

Sample 3 generated a very similar AE value to Sample 1, despite having the same D_{50} as Sample 2. This indicates that the surface treatment altered the cohesive bonds between the fine particles of Sample 2.

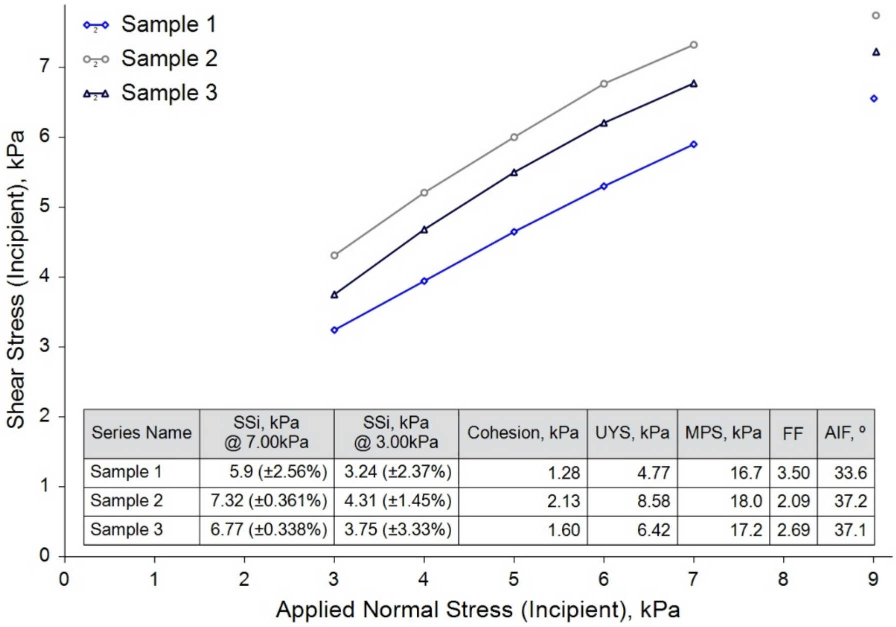
Bulk Testing: Compressibility



Sample 2 was more compressible than Sample 1, indicating that it entrained a greater proportion of air within its bulk, which is typical of more cohesive powders. High Compressibility can contribute to poor behaviour in operations where a powder is subjected to an applied force, for example as a consequence of storage in large quantities.

Sample 3 was closer to Sample 1 in terms of Compressibility, again indicating that the surface treatment had changed the flow properties of the finer particles to be similar to those of the coarser powder.

Shear Cell Testing



Series Name	SSi, kPa @ 7.00kPa	SSi, kPa @ 3.00kPa	Cohesion, kPa	UYS, kPa	MPS, kPa	FF	AIF, °
Sample 1	5.9 (±2.56%)	3.24 (±2.37%)	1.28	4.77	16.7	3.50	33.6
Sample 2	7.32 (±0.361%)	4.31 (±1.45%)	2.13	8.58	18.0	2.09	37.2
Sample 3	6.77 (±0.338%)	3.75 (±3.33%)	1.60	6.42	17.2	2.69	37.1

Sample 2 generated higher Shear Stress and Cohesion values and a lower Flow Function than Sample 1, indicating that it is likely to be more problematic when required to flow under high stress, low flow conditions such as in large hoppers.

The results for Sample 3 showed the same response as observed in the Dynamic Flow and Bulk tests, but to a lesser extent, indicating that the surface treatment had only partially enhanced the flowability of Sample 3 under these conditions. A resistance to shear can be strongly influenced by particle shape so the results suggest that the surface treatment may not have significantly influenced this property.

CONCLUSIONS

The FT4 Powder Rheometer has identified clear and repeatable differences between two similar materials that performed differently in two unit operations, and has subsequently quantified properties to rationalise why the surface treatment of one of these samples has improved its flowability. Sample 1 generated lower Aerated Energy, Compressibility and Shear Stress values, and a higher Flow Function, compared to Sample 2. All of these are typically indicators of more free-flowing behaviour. Sample 3 exhibited Aerated Energy and Compressibility values similar to those of Sample 1, demonstrating that the surface treatment had improved the flow properties, making the material more compatible with the process.

Powder flowability is not an inherent material property, but is more about the ability of powder to flow in a desired manner in a specific piece of equipment. Successful processing demands that the powder and the process are well-matched and it is not uncommon for the same powder to perform well in one process but poorly in another. This means that several characterisation methodologies are required, the results from which can be correlated with process ranking to produce a design space of parameters that correspond to acceptable process behaviour. Rather than relying on single number characterisation to describe behaviour across all processes, the FT4's multivariate approach simulates a range of unit operations, allowing for the direct investigation of a powder's response to various process and environmental conditions.

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