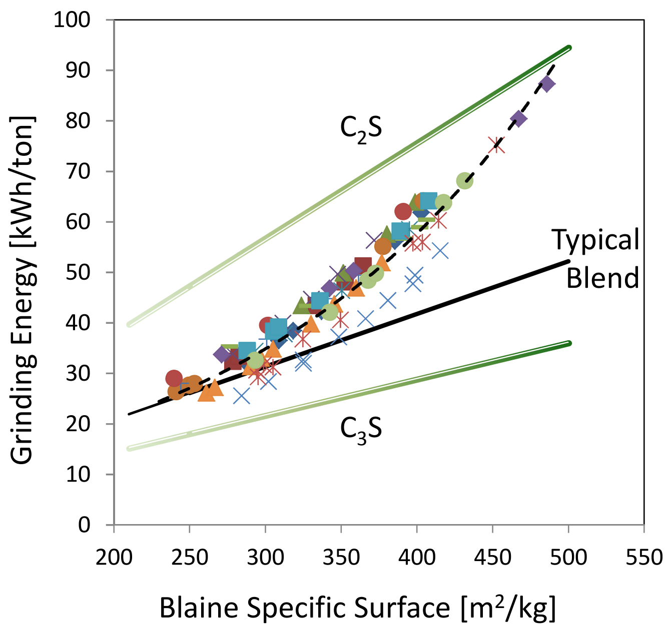
Concrete Sustainability Hub@MIT – Research Profile Letter – May 2011

Clinker Grinding at Breaking Point

Problem

Grinding of cement is an energy intensive operation that plays a significant role in the overall carbon footprint of the cement industry: About 10-12% of the energy required to produce one ton of portland cement is consumed in raw material and finish grinding and other electrical processes. The energy consumption in the cement mills contributes roughly 50 kg CO_{2e}/ton to the overall greenhouse gas emissions of the industry. The current standard for estimating the energy need is through empirical relationships that correlate a specific (Blaine) fineness, and other empirical quantities (such as a clinker work index) to the specific grinding energy. Calibrated for classical portland cement mixes and mill equipment, these relationships are disconnected from the physical origin of clinker grindability. This lack of understanding is recognized as a detriment to optimizing the energy efficiency of grinding, which impacts the efficiency of cement production as well as its energy and carbon balance.



Specific grinding energy: Experimental data of 15 portalnd cement blends of different clinker compositions [from Tokyak, CCR 29, 531-535, 1999]. The straight lines represent the grinding energy determined from atomistic simulations of the fracturing of alite and belite.

Approach

By means of atomistic simulations, we determined the cohesive energy of all clinker phases, that is the energy required to vaporize the solid clinker into gas. This energy is closely related to Hildebrand solubility parameter, a quantity frequently used in the pharmaceutical industry for drug design. This solubility parameter provides us with an atomistic access to fracture properties of clinker phases. We validate the simulation by microscratching industrial clinker phases. This consideration of grinding as a fracture process allows us to determine the theoretical energy required to break clinker surfaces by grinding, and to link the fineness (specific surface) to the corresponding power consumption (grinding energy) based on atomistic simulations.

Findings

The atomistic approach rationalizes the grinding process as a fracture process by linking grinding energy to clinker properties. The key finding of this research is that the energy spent in industrial grinding processes is greater than the energy required to vaporize the molecular structure of solid clinker phases! The difference between the theoretical and actual energy requirement can be as much as 100% higher for typical portland cement blends.

Impact

This research highlights that the grinding technology currently in use in the cement industry has significant reserves for substantial energy efficiency improvements. The atomistic approach provides a baseline for the optimization of cement grindability. This optimization will also be most critical for the implementation of lower green-house gas components, such as belite, slag, fly ash and so on.

More

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